Fisheries Management of Floodplain Wetlands in India

Edited by
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(Indian Council of Agricultural Research)
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INTRODUCING WETLANDS

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INTRODUCTION

Wetlands are one of the precious aquatic systems intimately associated with mankind and have been used extensively and exploited recklessly throughout the globe. The problem is more acute and intense in thickly populated countries like India. They are the excellent repository of aquatic biodiversity besides many other functions, such as irrigation, potable water, recharger and decharger of ground water, flood protector and trappers of nutrients and toxicants. It is in this backdrop that the conservation of wetland has assumed a serious dimension in recent times, especially after the Ramsar Convention adopted at the Earth Summit·in Rhio de Janeroa, 1992. Ramsar convention defines wetland as:

- *Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt including areas of marine waters, the depth of which at low tide does not exceed six meters.*

It is evidenced that pin-pointed or precise definition of wetland is a difficult proposition, as it includes whole range of water bodies, from very shallow water bodies to coastal tidal waters up to six meters including the mangrove wetlands. In general, however, natural lakes available in the floodplains are referred to as wetlands, especially from fisheries perspectives.

In India the distribution of wetlands is wide spread from the cold arid zone of Ladakh to wet Manipur, from warm and arid zone of Rajasthan to tropical monsoonic central India and humid Southern peninsula. Most of the wetlands in India are directly or indirectly associated with river systems, such as Ganga, Brahmaputra, Tapti, Narmada, godavari, Krishna and Cauveri. However, largest congregation of wetlands is under Indo-Gangetic and Brahmaputra plains. The area under wetlands in India has been estimated at 4.1 lakh ha (MoEF, Govt. of India, 1992) comprising natural (1.5 lakh ha) as well as manmade (2.6 lakh ha).

In recent years most of the wetlands in India are under threatened category as encroachment, siltation, weed infestation and pollution are rampant. Accordingly, these water bodies need effective conservation measures to protect their utility functions both physical as well as biological.

HYDROLOGY AND GEOMORPHOLOGY OF FLOODPLAINS

Floodplains are the low lying alluvial lands bordering rivers and are created by sedimentation from the movements of the river and its meanders. The topography of floodplains varies with the pattern of currents and abandoned natural levees providing higher areas, ox-bow lakes and other meander cutoffs. Floodplains generally fringe the main river channel (Hollis, 1995). The river and floodplain system are the part of one basin system, which is linked to the upland catchment areas with small tributaries, where from water, sediment and nutrients are drained. The river and floodplain are also intimately associated with downstream reaches of river enriching the coastal zone with freshwater, sediment and nutrients.

FLOODPLAIN WETLANDS AND THEIR FUNCTIONS

The natural aquatic ecosystems available in a floodplain are referred to as floodplain wetlands, such as ox-bow lakes and tectonic depression. In India they are known by different names viz. *beel* (West Bengal, Assam) *maun* and *chaur* (Bihar), *pat* (Manipur) and *tal* (Uttar Pradesh). These water bodies are generally shallow but perform a number of vital functions, such as:

- Recharging of groundwater
- De-charging of groundwater
- Attenuation and de-synchronization of floods
- Trapping of sediments
- Anchoring of shoreline
- Removal and detention of nutrients
- Improvement of water quality
- Supporting food chain

- Habitat for fish, bird and wildlife
- Recreation and navigation

In addition to the above the floodplain wetlands are also used extensively for irrigation, potable water and other day-to-day household activities in rural sector. The functions performed by wetlands are linked to economic value and other social benefits like health and sanitation, either directly or indirectly. It is imperative, therefore, that the utility functions of these wetlands got to be preserved at all cost so as to ensure the well being of humanity. It is in this backdrop that the economic valuation of wetland functions has received attention in recent times and is being developed rapidly.

ISSUES AND THREATS TO WETLANDS

Wetlands in general and floodplain wetlands in particular are highly threatened ecosystems owing to various omission and commissions. Reclamation and modifications of wetlands have become the order of the day leading to colossal loss of biological as well as other utility functions. The conservation of these precious ecosystems has been recognized as one of the priority area among the researchers, planners and policy makers throughout the world. There are many issues, which need immediate attention such as:

- *Effective conservation of physical entity of wetlands*
- *Conservation and sustainable utilization of biological resources*
- *Maintenance of ecological balance essential for life support system*
- *Restoration of biological damage caused by human interventions*
- *Developing suitable and effective management packages*
- *Creation of awareness among the people to educate them on the far-reaching implications of ecological degradation*
- *Increasing human participation in resource management in eco-friendly manner*

The wetlands are reeling under a number of threat perceptions leading to increased aberrations and even to total loss of resources. The important threats affecting the wetlands adversely are:

- *Rampant encroachment for arable lands and human settlement*
- *High rate of siltation in the face irrational catchment modifications*
- *Increasing incidences of eutrophication and pollution*

- *Increasing stands of unwanted biotic communities like aquatic macrophytes*
- *Over exploitation of resources for short-term gains*

RESEARCH PRIORITIES ON WETLANDS

In view of increasing threats confronting the wetlands in India, research on following priority areas is the need of the hour.

- *Survey and mapping of wetland resources of the country using remote sensing technology*
- *Application of GIS and mathematical modeling in important wetlands areas Evolving quick evaluation techniques on environmental impact assessment and other human activities*
- *Assessment and effective conservation of biodiversity, especially species related to human welfare and maintaining ecological elasticity*
- *Developing effective control measures for prolific growth of unwanted biota and exotic species*
- *Developing strategies for the control of siltation*
- *Developing eco-friendly and rational package of practices for fisheries development.*

STATUS OF FLOODPLAIN FISHERIES IN INDIA

India is bestowed with tremendous prospect for fisheries development as most of the lakes under Ganga and Brahmaputra river basins have indicated productivity potential in the range of 1000-2000 kg/ha. The present yield, however, ranges between 160 kg/ha (Assam) and 350 kg/ha (West Bengal). There are many reasons for low fish yield from these productive systems. Increasing level of eutrophication, blockade of auto-stocking of riverine fish seeds and massive stands of aquatic weeds are some of the important factors contributing to the low production and productivity of fish. Besides, the fish catch structure has also changed from carp dominance fishery of earlier years to forage and predator dominance fishery.

Data generated at CIFRI suggest that presently the fish catch of floodplain wetlands indicated the dominance of smaller and forage fishes to the tune of more than 50%, while the contribution of IMC ranges from 5-10% only (Jha, 1997, Sugunan, 2000).

MANAGEMENT OF FLOODPLAIN WETLANDS-FISHERIES PERSPECTIVES

Floodplain wetlands are one of the finest inland fishery resources from centuries. In recent years, however, most of the floodplain lakes worldwide, but more intensely in developing countries, are passing through a critical phase of ecological transition owing to increased human intervention. The fisher folk depending on these water bodies for their bread and butter are in a state of quandary as getting very little catch in spite of efforts. The fact remains that auto-stocking of riverine fish seeds in these lakes was the onus of natural fishery, which has gone wrong as the connecting channels between lakes and rivers have become defunct. Evidently, these lakes need rational stocking.

Various forms of enhancement, therefore, hold the key for the sustainable fisheries development in these ecosystems. Based on the research conducted at CIFRI, the following forms of enhancement are suggested for the effective management of floodplain wetlands:

- Stock enhancement
- Species enhancement
- Environment enhancement
- Management enhancement

CONCLUSION

Ecologically the floodplain wetlands are highly productive ecosystems, but reeling under various kind of stress factor. The production functions and the biodiversity, necessary for human welfare, have developed aberrations. The utility functions of these ecosystems need immediate restoration through eco-friendly and scientific management practices, developed by CIFRI. Public awareness and their active participation is necessary to conserve the dwindling resources, both physical as well as biological. India can not afford to lose these ecosystems, as they are vital for the survival of mankind.

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FISHERIES MANAGEMENT NORMS FOR FLOODPLAIN-WETLANDS IN INDIA

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Wetlands are amongst the most valuable natural ecosystems as they are vital to the very existence of man and human civilization on earth. Nonetheless, wetlands continue to be a nebulous concept, evading a universally acceptable definition. Ramsar convention defined *"wetlands as areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters"*, not a precise definition indeed. It is generally understood that the wetlands occupy the transitional zone between permanently wet and generally dry environments. They share characterstics of both the environments, yet can not be classified exclusively as either aquatic or terrestrial.

THE RESOURCE

Floodplain wetlands, locally known as *jheels, beels, chaur, mauns, diyara* and *pats*, in different parts of the country, represent lucrative location for fisheries in the states of Eastern Uttar Pradesh, Northern Bihar, West Bengal, valley districts of Assam, Manipur, Tripura and foot hills of Arunachal Pradesh and Meghalaya (Table 1).

They owe their origin to the often changing course of rivers or their meanderings. Some of these (more so in the north-eastern region of the country) originated as a result of seismic activity, caused due to crustal instability, resulting in depressions in which flood water from upland/ river flowed in. Accordingly, there are floodplain wetlands of varied types:

- Oxbow lakes or channels left by the former course of the rivers.
- Shallow depressions caused by seismic activities.
- Swamps or wetlands, which are lakes at higher successional level.

However, majority of this resource is constituted by oxbow lakes which, physiographically, can be grouped into two categories:

- Those retaining continuity with the river/ tributary through some channel either throughout the year or atleast during rainy season are termed as **"open or live lakes."** Such lakes represent a combination of lotic and lentic habitats, becoming at times nearly a natural lake ecosystem.
- Those which are completely cut off and remain isolated from the river course throughout the year are known as **"closed or dead lakes".**

The water balance in these floodplain wetlands, affected by the incursion of river water, varying degrees of precipitation and the nature of catchment, are highly complex and present contrasting pictures of their area and depth within a year.

PRESENT STATUS OF FISHERY

The fishery of ox-bow lakes, in general, is passing through a critical phase owing to their utter neglect in the past and large scale river valley modifications in the present. Fish harvest from these lakes was generally considered in the past as a renewable natural resource, available for unlimited exploitation to provide revenue to the concerned department.

In the changed hydrological regimes, due to river valley modifications, majority of these lakes have lost their riverine connections and, thus, the auto-stocking of the prized fish species of commercial importance. The impact has also been in the considerable acceleration in eutrophication rate due to near stagnant water regime and absence of any eco-management practice. The situation has worsened further with multiple breeding forage fish species attaining dominance due to greater colonization of macrophytes and decreased abundance of commercially important carp species.

The present trend of fishery of certain ox-bow lakes of North Bihar, as an example, are presented in Table 2. The same holds good, more or less, for similar water bodies in other states too. The trends have, however, changed in certain ox-bow lakes of North Bihar, where fishery management norms, such as clearance of unwanted weeds and stocking with quality fish seeds in desired quantity, were employed.

PROSPECTS FOR DEVELOPMENT & REQUIRED INPUTS

The high productivity potential and very low level of its present realization, has left enough scope for improvement through scientific management of these precious ecosystems. However for its sustainable fisheries development, the conservation norms have to be adopted in right earnest to achieve the goal of sustainability. In order to do that a balanced approach has to be made through 'macro' and 'micro' level planning.

The **macro-level planning** has greater and long term role to play and as such it requires serious attention. The following aspects have to be taken care of at the macro-level for sustainable development of fish and fisheries:

- The mechanism for transfer of scientific technologies need be strengthened.
- Environmental education/ awareness must be made mandatory, specially amongst the target group, *i.e.* fishermen community.
- Fishermen Cooperative Societies must be strengthened and made accountable.
- The credit and subsidy schemes should be strengthened with certain degree of rationality.
- Fishermen should be trained properly for better understanding of production functions.
- Priortisation of wetlands based on economic, cultural, aesthetic and socio-economic considerations need be done.

The **micro-level planning** needs take care of the following aspects:

- Holistic approach of development of floodplain wetlands is a must with proper identification of activities to be implemented.

- Required and timely arrangement of finance for effective execution of project or projects concerned.

- Proper monitoring of the activities in the framework of environmental variables.

AVAILABLE TECHNOLOGIES

The National Commission on Flood Control in its recommendations submitted in March, 1980 emphatically stressed the need to utilize the floodplain wetlands as fishery resource. Concerted research efforts during last two decades have resulted in the formulation of suitable scientifically based guidelines for the development of floodplain fisheries.

The scientifically based available management norms for development of fishery of these wetlands are as under:

- Development of culture based fishery (closed lakes)
- Management of capture fishery exclusively (open lakes)
- Fish husbandry based fishery development (pen and cage culture)

There are systems which combine all the above three technologies for development of fisheries, especially in the large open type floodplain wetlands. In this the marginal shallow areas are cardoned off, by construction of suitable dykes, for culture system and the deeper central portion left for capture fisheries.

Development of culture based fishery

In the face of increased human interventions, especially in relation to taming of rivers, the floodplain wetlands are being converted into closed systems at a very rapid pace. Accordingly, culture based fishery development in such floodplain wetlands may be the right answer. The basic objective behind this is to stock these water bodies rationally and recapture the stock. In culture based fishery management, the stocking holds the key to good performance. It is well known that in such management practice the growth is dependent on stocking density, while the survival depends on the size of the fish seed stocked. Evidently right species stocked of right size and in right numbers, in tune with the environmental status, is essential to get good yield. The size of fish caught is market dependent and as such the stocked species must be captured at their right size to have better market acceptability and better economic return.

The basic tenets of culture based fishery management of floodplain wetlands , therefore, would be:

- selection of species in tune with the biogenic capacity,
- stocking of appropriate size,
- stocking in appropriate density,
- stocking species in correct ratio, and
- capture of stocked species at right size..

Management of capture fishery

The floodplain wetlands which have retained their riverine connectivity (open type) can be ideal sites for their capture fishery management. These water bodies being the typical example of river continuum possess the characterstics of riverine ecosystem in relation to fish and fishery. The basic approach of management in such waters should be to allow the autostocking to play its role by conserving the incoming fish brooders and subsequently preventing the wanton killing of juveniles. It is essential, therefore, to follow the following steps for better success:

- proper identification and protection of breeding grounds,
- ensuring free and smooth migration of brooders and juveniles from the rivers and back,
- stringent steps to protect the brood stock and juveniles, especially of economically important species, through effective conservation norms, and
- keeping a strict vigil on overfishing as well as reckless fishing practices through destructive gears.

Fish husbandry in floodplain wetlands

In recent years, after the trials and perfection of pen culture technology by CIFRI, the extension of fish husbandry in relation to fish and prawns has become an effective option for the fishery development of floodplain wetlands. Pen culture has big potential in water bodies like floodplain wetlands due to their high nutrient status and as such very high productivity potential. The pen culture technology has an added advantage of utilizing the lake periphery only without disturbing the fishery of the lake proper. It has been established through various experiments and trials by CIFRI that viability and utility of this management option in optimizing fish yield from floodplain wetlands is beyond doubt, if practised with precision and proper understanding. The steps involved in pen culture are:

- selection of right site,
- proper design of the pen structure,
- suitable preparation of the enclosed pen area,
- proper selection of species to be cultured,
- rational stocking of proper size fish/ prawn seed, and
- rational supplementary feeding.

CONCLUSION

Floodplain wetlands are one of the prime and traditional fishery resources in the country with tremendous scope for their fishery development, following scientifically based norms. The view that fishery has a negative impact on such ecosystem is not true. Rather it has been experienced those floodplain wetlands where fishery activity is being practised regularly have better environment as compared to those lying virgin from fisheries point of view. Thick stands of macrophytes creating hostile aquatic regimes for many organisms, with rapid process of swampification already set in, has been seen to be the hall mark of such virgin wetlands.

It is imperative, therefore, that we should seriously aim at conserving this physical resource rather being bogged down on conflicting issues. The question of conserving biodiversity becomes irrelevant if the wetlands are lost. **Sustainable development implies rational utilization of resources, both physical and biological, without compromising the ability of the future generation to garner their needs.** In the light of this it becomes our prime duty to conserve the floodplain wetlands resource. Its fishery development, following scientifically based norms may play a pivotal role in conserving the wetlands, increased fish production and gainful employment to thousands of people.

Table 1. Distribution of Floodplain Wetlands in India

State	Distribution (district-wise)	River Basins	Local Names	Area (ha)
Arunachal Pradesh	East Kameng, Lower Subansiri, East Siang, Dibang & Tirap valley, Lohit, Chhanglang, Tirap	Kameng, Subansiri *beel* Dibang, Dihang, Lohit		2,500
Assam	Brahmaputra & Barak valley districts	Brahmaputra & Barak	*beel*	100,000
Manipur	Imphal, Thoubal & Bishnupur	Iral, Imphal, Thoubal	*pat*	16,500
Meghalaya	West Khasi Hills, East & West Garo Hills	Someshwari & Jinjiram	*beel*	213
Tripura	North, South & West Tripura	Gumti	*beel*	500
Bihar	Saran, Champaran, Saharsa, Muzaffarpur, Darbhanga, Monghyr, Purnea, Motihari, Samastipur, Begusarai	Gandak & Kosi	*mans* & *chaurs*	40,000
West Bengal	24 Parganas, Hooghly, Nadia	Ganga (Hooghly), Matlah	*beel*	42,500

Table 2. Trend of fishery in certain ox-bow lakes of North Bihar

Ox-bow lakes (with management status)	% of abundance in the total catch			
	IMC	Catfish	Forage fish	Small prawns
Wild				
Kanti. Muzaffarpur	5.25 - 12.85	53.81- 62.16	18.48 - 22.99	7.11 – 10.35
Matwali. Motihari	4.98 - 9.14	25.89 - 33.65	48.67 - 54.83	3.54 – 7.10
Partially managed				
Manika. Muzaffarpur	3.09 - 14.67	23.24 - 43.50	39.08 - 50.00	3.00 – 19.40
Brahmapura. Muzaffarpur	3.88 - 22.00	18.90 - 24.00	53.71 - 55.75	3.25 – 8.57
Managed (under World Bank Scheme)				
Muktapur. Samastipur	9.98# - 76.15$	4.58$ - 26.95#	11.25$ - 63.50#	3.21 – 4.05
Motijheel. Motihari	2.41# - 65.47$	10.23$ - 46.23#	15.14$ - 54.98#	2.56 – 3.65
Kararia. Motihari	15.60# - 74.21$	8.45$ - 39.12#	11.56$ - 51.36#	3.49 – 5.45
Motipur. Muzaffarpur	12.30# - 64.32$	13.56$ - 23.00#	16.57$ - 49.31#	2.98 – 4.38
Manjhaul. Begusarai	17.24# - 80.31$	8.20$ - 18.42#	9.25$ - 38.30#	1.65 – 3.24

 # Prior to management
$ After management

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FLOODPLAIN FISHERIES RESOURCES OF BIHAR AND WEST BENGAL

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BACKGROUND

The alluvial plain of Ganga basin represents many *synclines* (regional depressions) produced by slow crustily down-warp of the earth. It has a large tract of depressed landmass dotted with floodplain lakes of various shapes, sizes and origins. The intensity of depressions is more intense in the northeastern region of North Bihar extending to West Bengal and Assam. These natural shallow lakes are locally known as *Maun, Chaurs, Tal* (Bihar) or *Beels* (West Bengal). Biologically, they are highly sensitive as well as fragile supporting unmatched biological wealth being the excellent repository of biodiversity. In recent times, however, most of the lakes have lost their pristine characteristics in the face of indiscriminate exploitations and have largely been converted into *weed-bowls*. During the last few decades the trend of destruction has been accelerated to manifold owing to phenomenal increase in conflicting interests among various user groups (irrigation, potable water, industries, recreation, fisheries and so on). Accordingly, the intensity of resource loss, both physical as well as biological, is so alarming that the very existence of such lakes is at stake.

The total area under floodplain lakes has been estimated at 0.21 million ha spreading to the states of Bihar, West Bengal, Assam, Eastern Uttar Pradesh, Manipur and other NE states. The floodplain lakes have shown tremendous scope for fisheries development yielding more than 2 lakh tonnes of fish per annum provided management on scientific principles. The present fish yield, however, is at staggering low in the range of 165 kg/ha (Bihar) to 350 kg/ha (West Bengal). The fact remains that the production potential of these water bodies ranges between 1000 and 2000 kg/ha (Jha, 1995, Sinha and Jha, 1997, Sugunan *et al.*, 2000 a, Sugunan and Bhattacharya, 2000 b, Yadava, 1989). The technologies related to fisheries management, developed at CIFRI, assure an annual fish productivity of over 1,000 kg/ha.

An insight to the available ecological data including of fish and fisheries not only indicate aberrations in water quality, but also suggest decline in carp fishery, the mainstay of rural economy, owing to massive proliferation of unwanted biota. Certain common trends affecting the fish and fisheries of floodplain lakes can be summarized as under:

- *Massive and thick stands of aquatic macrophytes (submerged, floating, emergent and marginal).*
- *Lopsided and inadequate proliferation of pelagic communities, plankton in particular.*
- *Greater colonization of molluscan fauna at the benthic niche.*
- *Increasing presence of forage and smaller fish species with less economic value and relatively poor market acceptability (more than 70% at times).*
- *Increasing incidences of alien fish species putting extra pressure on native fishery.*
- *Increasing instances of irrational and reckless fishing practices, such as use of fine meshed mosquito clothing dragnets.*
- *Rampant encroachment of wetlands for getting additional arable land or human habitation.*

FLOODPLAIN WETLAND RESOURCE IN BIHAR AND WEST BENGAL

The total area under floodplain wetlands in Bihar and West Bengal has been estimated at 40,000 ha and 42,000 ha, respectively (Table-1)

Table 1: Floodplain wetlands in Bihar and West Bengal

States	**Area (ha)**
BIHAR	**Total Area = 40,000** • ***Ox-bow lakes(Maun) = 5200*** • ***Tectonic lakes(Chaurs) = 34,800***
WEST BENGAL	**42,000**

STATUS OF FISH AND FISHERIES IN FLOODPLAIN LAKES OF BIHAR AND WEST BENGAL

The production and productivity of floodplain lakes in Bihar and West Bengal are in total mess in the face of many existing as well as emerging threat perceptions centered around the 'Man", who happens to be the prime beneficiary since time immemorial. Presently, the rate of fish yield has been much lower then the desired level (165-350 kg/ha), especially when these ecosystems are highly productive in nature.

Ox-bow lake (maun) fisheries of Bihar

Perusal of time series data on the abundance and structure of fish catch from various ox-bow lakes indicates greater dominance of forage and predators with poor market acceptability and relatively lower remunerative value. The abundance of prized fishes, such as IMC, has gone down to the non-remunerative level (3-5%). This singular factor has paved ways for irrational fishing practices like rampant use of fine meshed mosquito clothing nets, making the ecosystem an ecological desert. The fish catch structures of certain ox-bow lakes including the annual yield under Gandak basin, Bihar are given in Table 1. Most of the lakes although stocked with IMC, the concentration of forage fish was on the rise indicating non-adherence to proper stocking schedule, such as proper ratio of various species or size of stocking materials or density of stocking. It is well known that growth and mortality of culture candidates depend on their size and density of stocking. More the density poor the growth and smaller the size of stocking material more the mortality.

Table 2: Fish catch structure (%) in ox-bow lakes of Bihar (Sinha & Jha, 1997)

Lake	*IMC**	*Predators*	*Forage & other small fish*	*Shrimp*	*Average yield kg/ha*
Manika, Muzaffarpur	3.09-14.67	23.24-43.50	39.08-50.00	3.0-19.40	182
Brahampura Muzaffarpur	3.88-22.00	18.90-24.00	53.71-55.75	3.25-8.57	200
Kanti, Muzaffarpur	12.25-12.85	53.81-62.16	18.48-22.99	7.11-10.35	106
Muktapur, Samastipur	9.03-21.00	14.99-24.67	52.77-60.08	3.93-12.53	157
Motijheel, Motihari	2.41-6.22	20.39-31.12	51.0-55.32	2.70-6.12	180

* *Partially stocked*

__Chaur (tectonic lakes) fisheries of Bihar__

Bihar is bestowed with huge area under chaur (34,800 ha) with four major chaur regions *viz.* Kabartal, Kusheshwarsthan, Simri-Baktiarpur and Goga. These shallow but highly productive aquatic systems have been the victim of utter neglect in the past and over exploitations for the present. These water bodies receive water from a network of rivers and rivulets during the monsoon flooding. They support very high biodiversity as well as productivity potentials. Most of the chaurs under Gandak basin Bihar are in advanced stage of eutrophication with thick to very thick stands of macrophytes, especially water hyacinth. Air-breathing fish species like *Clarias batrachus, Hetropneustus fossilis, Anabas testudenius* and *Channa* spp are abundantly prevalent in these water bodies. Besides this, a large number of smaller fish species of potential ornamental value as well as predatory species have also occupied the system with vengeance being the ideal habitat for their survival and growth. Other important fish species prevalent in these water bodies are *Notopterus notopterus, N. Chitala* and *Mastocembelus armatus,* minor carp, minnows and forage fishes.

Multi-species commercial fishery, a mixture of many species from very small forage fish to large catfish, remains the hallmark of *chaur* fishery. The contribution of major carp has been found to be a meagre 5% or even less depending upon the ingress of riverine spawn during floods (Table 3). In absence of organized fisheries and marketing channels authentic data on the trend of fish yield remains elusive till date. However, the information generated from certain specific *chaurs* at CIFRI indicates low yield in the range of 60-150 kg/ha in spite of high production potential ranging from 1000 to1500 kg/ha.

Table 3: General trends of fish catch structure in chaurs

Group	**Dominant species(in order of abundance)**	**% contribution**
IMC	*Catla catla, Labeo rohita Cirrhinus mrigala, Labeo calbasu*	3-5
Minor carp	*Cirrhinus reba, Labeo gonius, puntius sarana*	5-10
Feather-backs	*Notopterus notopterus, N. chitala*	8-12
Catfish	*Wallago attu, Mystus seenghala, M. vittatus, Ompak pabda, Clupisoma garua*	35-45
Murrels	*Chana marulius, C. striatus, C. gachua*	10-15
Airbreathig	*H. fossilis, C. batrachus*	7-14
Minnows/ Perches	*Nandus nandus,·Puntius* spp. *Chela* spp., *Chanda* spp.	30-60

Beel fisheries of West bengal

West Bengal Beels portray a relatively better picture of fish and fisheries as compared to Bihar. The fishery is though mainly dominated by miscellaneous species, the major carps have indicated sizeable contribution, which may be attributed to more pragmatic stocking schedule. Catfish and live-fishes are also common in total fish landings. The main commercially important species encountered were *Catla catla, Labeo rohita, Cirrhinus mrigala, Cyprinus carpio, Hypophthalmicthys molitrix, Ctenopharyngodon idella* and *Labeo calbasu*. The catfish had the greater dominance of *Wallago attu* and *Mystus aor*. Murrels, Feather-backs and air-breathing species were the other dominant groups of commercial importance. The catch structures of West Bengal beels are given in Table 4.

Table 4: Percentage composition of fish catch in West Bengal beels

Groups	*% composition*
IMC	33-55
Catfish	5-8
Murrels	6-7
Featherbacks	2-3
Air-breathings	15-16
Miscellaneous	22-37

CHALLENGES TO FLOODPLAIN FISHERIES

The prevailing ecological conditions of floodplain lakes in Bihar and West Bengal have a definit bearing on the current yield pattern. Accordingly, in order to enhance conserve the endemic fish germplams and to increase the productivity, effective management norms have to be in place. Challenges are many, as such it requires immediate prioritization of objectivity. In view of enhancing the production and productivity of floodplain wetlands it is necessary to look into the following:

- Selection of suitable scientific management norms with adequate attention on various forms of enhancements, such as environment, stock, species and technological.
- Careful thinking, adequate feedback and intense monitoring of the systems are necessary before the introduction of exotic species in floodplain lakes. Introduction of new and exotic species should be based on scientific principles so as to get sustainable production on long term basis.

FISHERIES ENHANCEMENT IN FLOODPLAIN LAKES

Fisheries enhancement as defined by FAO infers that it is a technical intervention in existing aquatic systems, which can substantially alter the environment, institutional and economic attributes.

In the backdrop of tremendous scope for fisheries development in floodplain lakes of Bihar and West Bengal immediate introduction of scientific management practices, as under, is necessary.

- *Stock enhancement*
- *Species enhancement*
- *Environment enhancement*
- *Management enhancement*
- *Introduction of new culture systems*

Information generated at CIFRI suggests that in view of depleted stock and species of prized fishes, the onus of sustainable fisheries from floodplain wetlands depends on the success of culture based fishery development, in the states of Bihar as well as West Bengal. This is more relevant when the process of autostocking of prized fish seeds from riverine source has developed snag owing to large-scale river valley modifications. Most of the lakes have now been converted into separate and isolated entity due to non-functioning connecting channels between the rivers and floodplain lakes. However, these systems should not be treated as culture ponds where density of stocking is invariably high. Culture based fishery development of floodplain lakes can be explained as extensive form of *aquaculture and intensive form of capture fishery*. The optimum production from a system is a function of proper growth and less mortality of stocking candidates thereby it can also be expressed as *density dependent growth and size dependent mortality*. The fact remains that for getting sustainable production from these systems a stocking density of 2000/ha of larger fingerlings in the size range of 100-150 mm is recommended.

CONSTRAINTS IN FISHERIES DEVELOPMENT OF FLOODPLAIN LAKES

- *Lack of adequate knowledge on modern fishery management among target groups*
- *Inadequate Training support to farming community*
- *Weak extension network from laboratory to land*
- *High rate of illiteracy among the target group*
- *Paucity of quality fish seed, feed and related items*

- *Inadequate financial support in time, especially from financial Institutions*
- *Irrational leasing policy, especially short term leasing*
- *Poor functioning of cooperative societies*
- *Conflicts among various user groups*
- *Social tensions*

THRUST AREAS FOR FISHERIE DEVELOPMENT IN FLOODPLAIN LAKES

- *Increasing fish production and productivity by bringing more lakes under scientific management*
- *Conservation of physical as well as biological properties of floodplain lakes*
- *Strict vigil on the introduction of alien fish species*
- *Diversification of activities, such as introduction of shrimp farming in pens and assessment of potential and developing culture systems for ornamental fishes available in these systems*
- *Integrating the fisheries development of wetlands with other facets of agriculture, such as fish-makhana, poultry, duckery and so on.*

SALIENT RECOMMENDATIONS

- *All-out efforts to put suitable mode of enhancements in place, such as stock, species, technological, environment and new culture systems.*
- *Steps to strengthen the extension services for making it more user friendly*
- *Streamlining the cooperative societies with adequate teeth to address various risk factors*
- *Ensuring need based financial support to fisher at their doorstep*
- *Immediate review of existing leasing policy for making it long term, 5-7 years.*
- *Developing one fish seed hatchery and one model lake development package in each district*
- *Managing lakes adopting cluster mode thereby grouping similar lakes under one category for better management and better extension of technologies*
- *Immediate ban on irrational fishing practices like rampant use of fined meshed mosquito clothing as dragnets*
- *Immediate steps to streamline the marketing channels to avoid middlemen*
- *Developing meaningful linkage among Institutions, developmental agencies and fish farmers*
- *Upgrading the knowledge of farmers on regular basis through training*

* *Diversifying activities by introducing penculture for seed raising as well as table fish, freshwater Prawn farming; collection and culture of ornamental fish species etc.*

CONCLUDING REMARKS

Bihar and West Bengal are very rich in terms of floodplain fisheries resources with high productivity potential. Effective utilization of these resources for fisheries development can lead to sizeable contribution of fish to national basket. However, most of the lakes are in advanced stage of eutrophication owing to increased man-induced interventions. The fish and fisheries are reeling under various existing as well as emerging threat perception, which need immediate attention of all concerned.

Effective and efficient management of resources, both physical as well as biological holds the key for sustainable and environmental friendly fisheries enhancement.

In precise, it is more a management crisis than resource crisis in both these states.

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STATUS OF FISHERIES OF FLOODPLAIN WETLANDS OF ASSAM

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INTRODUCTION

India has extensive wetlands (low-lying areas) mainly associated with the Ganga and Brahmaputra river basins, which are collectively termed as floodplain wetlands. These include typical ox-bow lakes, sloughs, meander scroll depressions, back swamps, residual channels or tectonic depressions. These water bodies vary widely in area, shape, depth, extent of riverine connection, etc. and have tremendous potential for development of capture, culture and culture-based fisheries in them. These water bodies together cover an area of 2.02 lakh hectares and constitute important fishery resources in the states of Assam, W.B., Bihar, Manipur, A.P., Tripura and Meghalaya. Among these states, Assam has the largest area (one lakh ha or 49.45% of total area) under floodplain wetlands. The beels of Assam are either created by or are associated with the Brahmaputra and Barak river systems. These are also known as *haor* (lake-like wetlands) and *anoa* (ox-bow lakes) in the Barak valley and as *mora nadi/ mornai* (meaning dead river), *era suti* (abandoned river cource), and *jan* (connecting channel) in the Brahmaputra valley.

DISTRIBUTION OF *BEELS* IN ASSAM

Assam has 1,392 enlisted *beels* covering a total area of *c* 100,000 ha, of which 423 are registered and the remaining 969 are unregistered ones. The unregistered beels are under the control of both Government (505) and semi-government/ public bodies like *Mahkuma Parishads/ Gaon Panchayats*, etc. (464 no.).

Physiographically, the state can be divided into three regions – (i) the Northern Brahmaputra valley, (ii) the Southern Barak valley and (iii) the central hilly region. As per the existing record, the central hilly region comprising Karbi Anglong and North Cachar Hills districts does not have any enlisted beel. The Barak valley comprising Cachar, Hailakandi and Karimganj districts has enlisted 322 beels covering 8,000 ha. The Brahmaputra valley, which comprises 18 out of total 23 districts of the state, contain an overwhelming 1,070 beels covering 92,000 ha water area. Since this valley spans the entire length of the state in the east-west direction with different agro-climatic conditions, it can be further subdivided into upper Assam (7 districts containing 376 beels covering 31,000 ha), central Assam (4 districts containing 342 beels covering 31,080 ha) and lower Assam (7 districts containing 352 *beels* covering 29,920 ha). Thus, the central Assam region comprising Nagaon, Morigaon, Darrang and Sonitpur district contain the largest area under beels (Table 1).

Table 1. Distribution of *beels* in Assam.

Zone/ District	River basins	Number of beels				Area (ha)
		Reg.	Unregistered		Total	
			GS	SG/PS		
I. Brahmaputra valley					**1070**	**92,000**
1.1 Upper Assam					**376**	**31,000**
Tinsukia (SB)	Lohit, Buhridihing, Nadihing, Dibru, Dumduma				17	8000
Dibrugarh (SB)	Buhridihing, Dibru, Sensa		-		21	
Sibsagar (SB)	Dichang, Dikhow, Jhanji, Dimow, Darika, Teok, Namdamg	16	10	28	54	12,000
Jorhat (SB)	Bhogdai, Jhanji, Teok, Dichai, Kakodonga.	22	19	22	63	
Golaghat (SB)	Dhanshiri, Kakodonga, Difalu, Daiyang, Rengma, Digholi	21	1	47	68	
Lakhimpur (NB)	Subanshiri, Dibang, Dikrong, Ranganadi, Kada, Ghagra	13	36	25	74	11,000
Dhemaji (NB)	Jiadhal, Kumatia, Champara, Dikbai, Simen	9	21	49	79	
1.2 Central Assam					**342**	**31,080**
Sonitpur (NB)	Jiabharoli, Borgang, Gabharu, Belshiri, Buroi, Kharoi, Sipai	3	10	9	22	13,000
Darrang (NB)	Dhanasri, Nanai, Pachnai, Mangaldai, Barnadi	17	13	1	31	
Nagaon (SB)	Kollong, Kapili, Sonai, Haria, Diju	38	120	14	172	18,080
Morigaon (SB)	Kollong-Kapili, Sonai	44	62	11	117	
1.3 Lower Assam					**352**	**29,920**
Kamrup (NSB)	Puthimari, Kalahi, Barnadi, Digaru, Bharalu, Barapani, Shingra, Kalajol	23	9	14	46	10,000
Nalbari (NB)	Pagladia, Baralia, Tihu, Nona/Ghogra	26	8	14	48	

Barpeta (NB)	Chaulkhowa, Buhradia, Kaldiya, Beki, Bhelengi	48	25	2	75	
Goalpara (SB)	Krishnai, Dudhnai, Jinjiram	13	32	-	45	
Bongaigaon (NB)	Beki, Manas, Ai					19.920
Dhubri (NB)	Sonkosh, Gaurang, Gadadhar, Diplai	37	75	-	112	
Kokrajhar (NB)	Champabati, Ai, Manas, Salbhanga	4	22	-	26	
II. Barak valley					**322**	**8,000**
Cachar	Barak, Sonai, Rukni	34	21	179	234	
Hailakandi	Dholeswari, Katakhal	11	-	18	29	8.000
Karimganj	Longai, Barak	26	21	12	59	
Total		**423**	**505**	**464**	**1392**	**100,000**

Abbr.: GS= Govt. sector; SG/P= Semi Govt./ Public sector; NB=North bank;
SB= South bank; NSB= North and south bank

(Source: Assam Fisheries Development Corporation)

STATUS OF FISHERIES

The floodplain wetlands (*beel*s) contribute to the major chunk of fishery resources of Assam. The state has the largest area (c. 100,000 ha) covered by *beel*s in the country. The enlisted *beel*s, which cover approximately 72.45% of the total lentic areas of the state. Thus, the *beel*s are the single most important fishery resource of the state. These water bodies are highly productive because of greater percent contact of water with sediments, deeper euphotic zone (shallow depth) and inflow of nutrients from catchment areas. Though precise data on fish production from the beels is not available, they reportedly contribute *c* 12.5% of the total annual fish production from the state. The beels act as 'collection sink' for fish produced in the adjoining low-lying areas in addition to the beel proper. Further, most of the riverine fishes are captured from the adjoining beels since operation of most fishing gear is difficult in the main rivers. In addition to edible fin fishes, the beels also produce edible shell fishes (prawns, molluscs, crabs, etc.), reptiles (turtles), vegetables (*Colocasia* sp., *Ipomoea* sp., *Marsilia* sp., *Nymphaea* sp., etc.), flowers (lotus) and aquatic fruits (*Euryale ferox*, *Trapa* spp., etc.).

Though the *beel*s of Assam reportedly have very high fish production potentials (1000-1500 kg $ha^{-1}y^{-1}$), their present production level is many folds lower owing to habitat modifications, over-exploitation, lack of scientific management and so on. A thorough knowledge of fish and fisheries of the *beel*s of Assam is essential for managing these open waters scientifically. Such information is scanty and fragmented at present. However, extensive field studies conducted by CIFRI (since 1979 till date) in over 60 *beels* spread all over the state have thrown some light on these aspects. The present status of fisheries of the floodplain wetlands of the state has been briefly described in the following account.

FISH YIELD

Beels of Assam generally posses high potential for *in situ* fish production. A number of them also provide a 'collection sink' for fish produced in the surrounding flooded catchment area. Fish yield estimated from 23 *beels* by CIFRI, Guwahati based on point observations and inquiries ranged from as low as 14 kg $ha^{-1}y^{-1}$ (Ghora *jan* Hasilakumari *beel*) to 488 kg $ha^{-1}yr^{-1}$ (Barchunati *beel*) with an average estimated yield of 172.9 kg $ha^{-1}y^{-1}$ (Table 2). Higher average fish yield obtained from six selected Barak valley *beels* (283.5 kg $ha^{-1}y^{-1}$) compared to that of the selected *beels* (17 no.) of Brahmaputra valley (133.8 kg $ha^{-1}y^{-1}$) can be attributed to lower macrophyte infestation and better exploitation efficiencies observed in Barak valley *beels*. The range of fish yields estimated from the *beels* of the state (14 to 488 kg $ha^{-1}y^{-1}$) is many folds higher than that from open water lakes and reservoirs (*c* 5 to 75 kg $ha^{-1}y^{-1}$), which indicates the high fish production potential of these relatively shallower open waters.

Table 2. Estimated fish yield from selected *beels* of Assam .

Geographical zone	Name of *beel*	Average fish production (kg $ha^{-1}y^{-1}$)
I. Brahmaputra valley	Dora	116
	Selsella	243
	Dighali	36
	Kapla	126
	Dipar	21
	Siligurijan	418
	Rangai	31
	Hagal	70
	Ghorajan	14
	Hasilakumari	14
	Potakallong	15
	Samaguri	96
	Mer	71
	Charan	49
	Barmanaha	258
	Dhir	377
	Sareswar	330
Average production (Brahmaputra valley)		*133.8*
II. Barak valley	Sone	97
	Boiya	211
	Barchunati	488
	Banskandi	400
	Algapur	300
	Ramnagar	215
Average production (Barak valley)		*283.5*
Average production (all Assam)		***172.9***

FISH SPECIES COMPOSITION

As many as 70 fish species has recorded and reported from beels of the state so far. These include 4 exotic fish species viz., common carp, silver carp, grass carp and the African catfish recorded from some *beels* of Assam. The common species contributing to commercial landings from *beels* of Assam can be grouped into the following broad groups.

a) ***Major fishes***: these are large sized (usually over 500 g wet weight) fishes and command good market prices. They include Indian major (*Catla catla, Labeo rohita, L. calbasu, Cirrhinus mrigala*) and median (*L. gonius*) carps; large catfishes (*Aorichthys seenghala, A. aor, Wallago attu, etc.*); clown knifefish (*Chitala chitala*); large murrels (*Channa marulius, C. striatus*); Hilsa (*Tenualosa ilisha*) and so on.

b) ***Intermediate fishes***: these are medium sized (usually 50-500 g) fishes and command good market prices. They include: minor carps (*L. bata, C. reba, etc.*) and medium sized barb (*Puntius sarana sarana*); medium sized catfishes (*Clarias batrachus, Heteropneustes fossilis, Ompok* spp., *etc.*); medium sized air-breathers (*Notopterus notopterus, Anabas testudineus*); medium sized murrels (*Channa barca, C. punctatus*)

The medium sized catfishes like *C. batrachus, H. fossilis, Ompok* spp., *etc.* have very good consumer preference and usually command higher market prices than even the major fishes.

c) ***Minor fishes***: these are small (usually less than 50 g) fishes and usually commands lower market prices than the major and intermediate groups. They include ***small economic fishes*** like small catfishes (*Mystus cavasius, M. vittatus*), barbs (*Puntius* spp.), gouramies (*Colisa fasciatus, C. lalia,*), *Gudusia chapra, Amblypharyngodon mola, Nandus nandus, Osteobrama cotio cotio, Glossogobius giuris,* etc., which comprise the largest number of fish-species recorded from the *beels* of the state. Though small in size, they dominate the landings in most *beels* (except where culture-based fisheries are developed). In addition *G. chapra* have good local demand and command good prices.

The second group of minor fishes can be termed as ***miscellaneous fishes.*** They comprise very small sized prawns (*Macrobrachium* spp.,) and fishes (*Rasbora rasbora, Danio/Brachydanio* spp., *C. sota,*.etc.) that fetch very low prices. In addition, three fin-fish species found in the *beels viz., Badis badis, Chaca chaca* and *Tetraodon cutcutia* can be termed as ***trash fishes*** as these are not consumed in the state. In addition, *Xenentodon cancila* is considered as a not-so-palatable species and is consumed only by some segments of the local populace. However, all these four species have potential ornamental value, as they possess unusual shape/ colouration.

Percent contribution of the major fishes declined from 50% earlier to about 25% in most *beels*. Miscellaneous (minor) fishes' share (15 %) increased many folds to more than 50% over the years. This is an unhealthy trend indicating reduced autostocking from rivers, siltation, macrophyte infestation and/or selective overexploitation of stocks of major fishes

Occurrence of exotic fishes: The exotic common, silver and grass carp have been recorded from some *beels* of the state. These exotic species are either washed down from adjacent aquaculture ponds by floodwaters or are stocked deliberately. The African catfish (*Clarias gariepinus*), an unauthorized entrant from West Bengal to the state has also been recorded from an open *beel* (Barali *beel* in Nalbari district). Probable establishment of these exotic species in open waters including rivers may have far-fetching and unforeseen implication for certain native ichthyo-species like catla and *C. batrachus*.

FISHERIES OF OPEN *BEELS*

In *beels* having riverine connection, new recruits come to the fishery mainly from the feeder rivers. They provide breeding grounds and /nursery pastures for commercially important fishes during southwest monsoon months. Migration (for spawning or feeding) of Indian major carps (*Catla catla, Labeo rohita, L. calbasu* and *Cirrhinus mrigala*), median carp (*L. gonius*) and minor carps (*L. bata* and *C. reba*) is significant from the point of view of recruitment/ autostocking in these *beels*. Fishes like *Eutropichthys vacha* and *Gadusia chapra* migrate in large numbers during monsoon and form a considerable post-monsoon fishery. In addition, occurrence of juveniles (32-80 mm) and adults (up to 534 mm) of Hilsa has been observed in certain open *beels* like Dhir, Dora and Sone *beel*. Most recruits enter the fishable stock from rivers in to the open *beels* in their first year (6-8 months). Eventhough the stocks of commercial fishes are continuously exploited, they are replenished through fresh recruitment the next year. However, extensive use of small mesh sized nets (e.g., *Mosori/Maha jal*) coupled with intense fishing during winter and summer months (December to May) may deplete the stocks of commercially important (major/intermediate) riverine fishes below the minimum reproducible stocks in many open *beels* of the state. This coupled with habitat modifications (aquatic pollution, destruction of breeding grounds, etc.) is likely to result in declining yields of major riverine fishes (e.g., IMC, large catfishes, etc.) both in the *beel* and its feeder river. In addition, the connecting channel with the adjoining river is blocked with split bamboo screens (*bana*) during receding floods to prevent back migration of fishes into the feeder river in most open *beels*. This practice, locally known as *bhetaa maara* is a harmful one. Since the *beels* are a continuum of the parent river, hindering free migration between the rivers and the open *beels* is likely to affect the commercial fisheries of both the water bodies in the long run.

Diverse fish populations present in the open *beels* support a multi-species fishery, which is more complex to understand but is more resilient. However, though most open *beels* of the state have multi-species fisheries, usually only a few species dominate the landings.

FISHERIES OF CLOSED *BEELS*

Most of *beels* of the state have been cut-off from the parent rivers due to construction of riverine embankments and natural causes. In the absence of significant recruitment from rivers, fishes that can spawn in stagnant waters inhabit these *beels*. Typically, fish landings of closed beels of the state are dominated by barbs (*Puntius* spp.), rasboras (*Danio/ Rasbora/ Brachydanio* spp.), small catfishes (*Mystus* spp.), murrels (*Channa* spp.), *Notopterus notopterus*, *Wallago attu, etc*. Fish species that spawn in flowing waters (e.g., major/ median/ minor carps, *Bagarius bagarius*, *Pangasius pangasius*, *N. chitala*, *Ompok* spp., *Aspidoparia* spp., etc.) are likely to be absent there. In general, the natural fishery of closed *beels* is overwhelmingly (50 to 90%) dominated by small economic fishes (*Puntius* spp., *Rasbora* spp., *Colisa* spp., *Mystus* spp., *N. notopterus*, etc.). Insectivorous and air-breathing fishes (*Channa* spp., *Anabas testudineus*, *N. notopterus*, *Clarias batrachus*, *Heteropneustes fossilis*, *etc*.) dominated the landings in macrophyte-choked *beels*.

CULTURE-BASED FISHERIES

The vast majority of *beels* of the state are presently being managed along capture fisheries lines. However, owing to gradual decline in autostocking from rivers, some *beels* are partially stocked with seed of Indian major (mainly catla and rohu) and exotic carps (mainly grass carp). Though supplimentary stocking is mostly practised in closed *beels* like Samaguri (Nagaon district), Jaluguti (Morigaon district) and Kapla *beel* (Barpeta district), a few seasonally open *beels* like 46 Morakollong (Morigaon district) are also stocked during the post-monsoon months (September-October). Since carp fingerlings of required size (at least 10 cm TL) and quantity are not available at most places, stocking is usually done with fry (4 - 5 cm TL), which results in low rates of survival and recapture of stocked seed. Only in a few *beels* like 46 Morakollong (Morigaon district) the fry are reared to fingerling in pen enclosures constructed with mosquito netting within the *beel* itself for 3 to 4 months before releasing them to the *beel* proper. Such pen enclosures are becoming popular since these are cheap and easy to erect/ dismantle. In addition, such *in situ* rearing involves little recurring costs as no fertilization or artificial feeding is practiced in the pens. Though predatory and small economic fishes are usually not eradicated in the rearing pens thereby resulting in moderate mortality and growth of the stocked fry, they appear to give better results than stocking the *beel* directly with carp fry.

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ROLE OF HUMAN ELEMENT IN INTEGRATED WETLAND MANAGEMENT

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INTRODUCTION

Mankind is no longer one among many species striving to persist against natural forces that are effective in limiting size and distribution. Human society has, in a sense, broken free – temporarily perhaps – of the bonds of natural checks and balances to become the dominant species in most of the planet's major ecosystems. In the process, society has not only appropriated an enormous amount of the planet's space and resources, but has also introduced some by-products that the earth's ecosystems are unable to recycle or decompose in a timely fashions have polluted our own nest.

When some people deny our environmental exigencies, including damage to wetlands, coastal pollution and the worldwide misuse of water and land, others claim that certain environmental damage have reached dimensions of no repair. Many expect environmental problems to correct themselves naturally or assuming only scientific technology will find the answers. Indeed a number of scientific and technologies advances have been made for the restoration, recovery and management of different ecosystems. However, these technologies only have not been able to stop halt the process of environmental loss.

We could seek ways to mitigate or ameliorate the undesired consequences of meeting human needs and aspirations. This could be accomplished through scientifically designed, socially responsible and economically feasible management of land, waters, biota and the artifacts of human existence – activities labeled as **Integrated Environmental Management (IEM).**

Human behaviour contributes significantly to the degradation of our environment. The slogan "People start pollution – people can stop it" is very popular among Americans. Therefore **Applied Behavioural Analysis Approach (ABAA)** through low technology community – based intervention programme has been found to be most effective method in IEM programme. Behaviour analysts have addressed environmental problems by first defining the problem in terms of relevant human behaviour and then designing and implementing programmes to decrease behaviours causing the problem and / or increase behaviours that can alleviate the problem. Many individuals believe that information about environmental protection should focus on changing people's attitude about the environment, and then, after appropriate attitude change, people will change their behaviours. Although individuals are more apt to follow advise regarding resource conservation after experiencing outcomes related to such advice (the displeasures or inconveniences of resource shortages), ongoing response – consequence contingencies often support behaviour incompatible with the advice. Thus, effective behaviour change for effective wetland management may require the modification of consequences supporting behaviours detrimental to the wetlands, as well as establishing new response – consequence contingencies to motivate the occurrence of behaviours beneficial to the environment.

INTERVENTION PROGRAMMES FOR WETLAND MANAGEMENT

Many field studies in the behavioural sciences focused on the development and evolution of intervention programmes to reduce environmental – destructive behaviours or increase environmental – processing behaviours. A simple **ABC model (Activator-Behaviour-Consequence)** defines the applied behaviour analysis approach to intervention development. The process of intervention design and evaluation can be represented by acronym **"DO RITE"** –

1) **D**efine the target behaviour to be changed
2) **O**bserve the target behaviour
3) **R**ecord the occurrences of the target behaviour
4) **I**ntervene to change the behaviour
5) **T**est the impact and
6) **E**valuate the programme.

DEFINING THE TARGET BEHAVIOUR

Three sectors requiring direct intervention are

1) Residential / Consumer
2) Governmental / Institutional
3) Commercial / Industrial

Some of the targets for intervention programme are

1) Solid waste management
2) Transportation / equipment efficiency
3) Water use and disposal
4) Population explosion
5) Air pollution
6) Land misuse
7) Hazardous waste
8) Noise pollution
9) Heating / cooling

ACTIVATORS FOR ENVIRONMENT MANAGEMENT

i) Verbal messages
ii) Awareness and education
iii) Modeling and demonstration
iv) Commitment and goal setting
v) Engineering and design setting

Impact of an intervention programme is a direct function of

a) the amount of specific response information transmitted by the intervention
b) the degree of participant involvement
c) the extent extrinsic control defined by response –consequence contingencies
d) the amount of participant's social support
e) each individual participant's perception of self efficacy, intrinsic control or empowerment.

ACTIVELY CARING MANAGEMENT MODEL

There are mainly three aspects in this model

1) Empowerment ("I can make a difference"): This comes due to self-efficacy ("I can do it") and optimism ("I expect the best").
2) Self-esteem ("I am valuable")
3) Belongingness ("I belong to a team"): this comes due to a) individual participation, b) communication, c) group loyalty and satisfaction, d) ability to enforce group norms and e) elaboration of group culture.
4) All the above three aspects shall ultimately lead to "we can make valuable difference"

CONCLUSION

Perhaps the time has been reached in human history where current and future economic and environmental challenges cannot be solved by strategies that were designed for a time when the people were few. Sustainable development that blends economic, social and environmental goals is a path for meeting future challenges. Community-based integrated management of wetlands for multiple benefits is the course upon which to chart that path.

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ENHANCEMENT TOOLS FOR AUGMENTING FISH PRODUCTION FROM FLOODPLAIN WETLANDS

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INTRODUCTION

Floodplain wetlands are low-lying areas bordering rivers, which are inundated by floodwaters from the main river or from their catchment areas during the southwest monsoon season. They are either typical ox-bow lakes (cut-off portion of river meander bends), meander scroll depressions, back swamps, residual channels or tectonic depressions (Sugunan, 1995). These riverine wetlands, mainly associated with the Ganga and Brahmaputra river systems, cover an area of 2.02 lakh hectares and constitute important fishery resources in the states of Assam, West Bengal, Bihar, Manipur, Arunachal Pradesh, Tripura and Meghalaya (Sugunan *et al.*, 2000). These water bodies are locally known as *beel, maun, chaur, pat*, etc.

In spite of having very high fish production potential (1000-1500 kg $ha^{-1}yr^{-1}$) (Sugunan *et al.*, 2000) the present production level of the beels is very low (120-320 kg $ha^{-1}yr^{-1}$) (Sinha, 1997) owing to habitat modifications, over-exploitation, lack of scientific management and so on. These resources are amenable to development of capture fisheries and various forms of enhancements including aquaculture and can play an important role in increasing fish production besides generating additional employment and income.

FISHERIES ENHANCEMENT TOOLS

Fisheries enhancements refer to the process by which qualitative and quantitative improvement is achieved from water bodies through exercising specific management options. There are several practices, which together contribute to the intensification of fish production from a water body. These can be in the form of improving the stock, changing the exploitation norms, changing crafts and gear, introducing new forms of access and so on.

ENHANCEMENT TOOLS SUITABLE FOR FLOODPLAIN WETLANDS

The common enhancement tools relevant to the floodplain wetlands of India (e.g., enhancement of species, stock and environment, management enhancement, etc.) are briefly described here.

Species enhancement

Species enhancement comprises planting of economically important, fast-growing fish from outside with a view to colonizing all the diverse niches of the biotope for harvesting maximum sustainable crop from them. This measure aims at increasing the number of species available in the beel by adding new fish species from outside. This measure is also practiced for correcting imbalances in fish species spectrum.

Species enhancement may involve introduction exotic fish (species that are not native to the country) or transplantation of a species from other regions of the country. It comprises one time or repeated stocking of a species deliberately with the objective of establishing its naturalized populations. This widespread management practice has more relevance to medium and large beels (more than 100 ha), where stocking and recapture on a sustainable basis is not feasible. New, commercially important fish species can be transplanted into a beel to utilize its unused food resources. For example, transplantation of molluscivorous (e.g., *Pangasius pangasius*) and indigenous herbivorous fish species (e.g., *Puntius pulchellus*) has been suggested to obtain additional fish production from beels having abundant molluscan population and rich growth of submerged aquatic macrophytes (Bhattacharjya, 2002).

Introduction of exotic species is subject of hot debate in India due to its possible adverse impact on the environment and biodiversity of our aquatic ecosystems. Introduction of exotics in the open beels is not advisable since the possibility of these species establishing themselves in the open water bodies of the country with far-reaching ecological implications cannot be ruled out. The possible establishment of exotic grass carp is a matter of grave concern to farmers growing deep-water paddy varieties in marginal shallow areas of the beels. Fish species transplanted from one geographic region to another within the country is not considered as introduction of exotics and therefore, there is no restriction on them. Nevertheless, while transplanting a new species in a beel, care should be taken to ensure that the transplanted species do not affect the species diversity of indigenous species in the concerned *beel*.

Stock enhancement

Augmenting the stock of desirable fish species has been one of the most common management measures followed in open waters in most countries of the world. Stocking with fingerlings of economically important fast growing species like the Indian major carps (IMC) to utilize all the available food niches is an effective management tool to increase fish yield from *beels*. In most *beels*, which have lost riverine connection due to construction of riverine embankments and siltation (closed *beels*), natural fish stocks of commercially important fish species have been totally depleted due to disruption of the auto-stocking process from the parent rivers. Even in *beels* retaining riverine connection (open *beels*), natural stocks of such fish species have been considerably depleted due to habitat degradation and/or over-fishing both in the *beel* and its parent river. In such cases there is little option but to stock such *beels* with fingerlings of required fish species to increase their fish yield. The three Indian major carps (catla, rohu and mrigal) are being stocked in most managed beels of the country where these are not naturally recruited simply because of easy availability of hatchery-raised seed. The main aspects of stock enhancement are selection of species for stocking, determination of stocking rate and the size at stocking.

Enhancement of stocks of desirable fish species is necessary to prevent unwanted fish species to utilize the available food niches and flourish at the cost of economically important species. Selective stock enhancement of commercially important, fast-growing fish species is necessary to prevent small, less economically valuable fishes like *Puntius* spp. from flourishing in the beel by utilizing the available food sources.

***Culture-based fisheries*:** When the fish harvest in a *beel* depends solely or mainly on artificial recruitment (stocking), it is referred to as culture-based fisheries. The main focus of management here is stocking and recapture. In culture-based fisheries, fish growth is dependent on stocking density and survival is dependent on size of stocked fish. Important parameters determining the success of culture-based fisheries in a beel are:

i) Size at stocking
ii) Stocking density
iii) Fishing effort
iv) Size at capture
v) Species management
vi) Selection of species
vii) Selection of fishing gear

Environmental enhancement (fertilization)

As a consequence of regular and high rate of stocking, the stocked population may exceed the natural carrying capacity of the beel in some cases (especially if its inherent productivity is low). In such cases, stocking alone may not result in a substantial increase in fish yield unless it is accompanied by other measures to increase the productivity of the beel. Environmental enhancement measures like fertilization and bottom raking are required to remedy such a situation.

Though it is a common management option adopted in intensive aquaculture, a careful consideration of the cost-benefit ratio of this measure and the possible adverse impacts on the environment (eutrophication) is needed before this option is resorted to in beels. The type of fertilizer to be applied and their application dose should be carefully prescribed based on a number of relevant parameters like the concentration of plant nutrients (e.g., nitrogen and phosphorus) in soil and water, estimated primary productivity and stocking density in respect of the beel in question. In order to cut down the costs, fertilization may be effected through the discharge of nutrient-rich waste waters from agriculture/ animal husbandry provided such facilities exist in the locality.

Since most of the beels receive a lot of allochthonous inputs from their catchment areas and usually have large organic matter reserves, external fertilization is unwarranted (Sugunan and Bhattacharjya, 2000). Further, external fertilization is not ecologically sustainable since it is likely to hasten the natural eutrophication process of the beels. Instead of external fertilization, plant nutrients trapped in the beel sediments may be made available to the phytoplankton population through bottom raking in order to increase the growth of fish food organisms. Another alternative strategy to channelize the generally high productivity of the beel ecosystem to enhanced fish production is eradication/control of aquatic macrophytes, which compete with phytoplankton for plant nutrients but do not contribute significantly to fish production.

Engineering of the environment

This measure aims at improving the levels of reproduction, shelter, food resources and vital habitat. Brush parks are the most common method of environmental engineering practiced in the beels. These parks mainly act as sheltered areas. These are particularly popular in the beels of the northeastern region. Two different types of brush parks, locally known as *katal/jeng* and *pit/chek*, are erected in the beels of Assam. *Katal/jeng* is a small brush park constructed by submerging branches of bamboos/trees in deeper areas of beels over which a dense patch of floating water hyacinth is secured with the help of bamboo poles and split bamboo in a circular fashion (Yadava *et al.*, 1981). For erection of *pit/chek*, an extensive area covered by water hyacinth is simply barricaded at both the ends with split-bamboo tied to closely spaced bamboo poles from shore to shore so as to prevent chunks of water hyacinth from spreading to clearer areas (Bhattacharjya, 2002). Both the *katal* and *pit* are erected immediately after the monsoon season (August-October) and harvested during January-March).

Another type of brush shelter is popular in the floodplain wetlands (*pats*) of Manipur, which is locally known as *phoom*. The *phooms* are similar to the *katal/jeng* in shape (circular) and size. However, here only a circular boundary is erected using floating mats of macrophytes and the middle portion is clear. Further, no bamboo/tree branches are used for erecting *phooms* unlike in *katals*. Another distinguishing feature of *phoom* is that it is a perennial structure unlike the other two types of brush parks.

Elimination of unwanted species

Presence of predatory fishes like *Wallago attu* and *Chitala chitala* severely affects the survival of economically important and fast growing fish species in *beels* by devouring their young ones. Weed fishes (small, less economically valuable fishes like *Puntius* spp., *Colisa* spp. and *Pseudambassis* spp.), on the other hand, hinder the survival and growth of stocked fishes by utilizing the available food sources.

Controlling unwanted fish populations pose a difficult management problem in medium and large beels. The problem is more acute in *beels* having moderate to heavy infestation of aquatic macrophytes. Repeated netting using shore seines, boat seines and gill nets of appropriate mesh size and use of long lines, traps etc. are normally employed for controlling undesirable fish populations in beels. Allowing the fishers a greater share in the catch of undesirable fishes is a good management decision for encouraging selective fishing of such species.

Biological control of small weed fishes by keeping a limited population of predatory fishes having moderate sized mouth (e.g., *C. chitala, Aorichthys aor, A. seenghala*, etc.) is also suggested as a low-cost option. These riverine species do not normally breed in closed beels and therefore, their population can be kept under control.

Habitat modification

Certain beels have fingerlike projections, which can be cut-off to create fish ponds. These ponds can be used for raising carp fingerlings for stocking the beel proper. Since most beels have predatory fish populations, whose eradication is difficult, they should be stocked with advanced carp fingerlings (at least 10 cm) to ensure good survival and recapture. Such advanced fingerlings are not available in required quantities at the right time at most places. The detached beel areas can also be used for extensive or semi-intensive aquaculture to enhance fish production from them after the rearing operation, which usually lasts for 2-3 months.

Pen and cage culture

Fish culture in pen and cage enclosures in beels can be developed as an independent enterprise parallel to the enhancement of their capture fisheries. For construction of pens, marginal areas of beels are encircled with split-bamboo screens (*bana*) lined with small meshed nets. CIFRI has successfully carried out pen culture experiments in beels both for rearing of carp fingerlings (Assam) and for growing of prawns (West Bengal). The field trials were carried out using locally available materials (bamboo) for pen construction and following semi-intensive culture system. The technology thus refined is found to be economically viable and environment-friendly. The Institute has also initiated experiments on cage culture in the beels of West Bengal and Assam. Although pen and cage culture help enhancement of fish production and economic returns from a beel, their unregulated growth may cause social and environmental problems as witnessed in the Laguna de Bay, Philippines. Further, supplementary feeding of the stocked fish in the pens can lead to eutrophication of the lake (Vinci and Mitra, 1997).

Aquaculture

Aquaculture is the highest form of enhancement, where the whole beel is managed as pond fish culture. This is a combination of enhancement tools like stocking, fertilization, elimination of unwanted species, etc. enumerated above in addition to management of soil and water quality, feeding, health management and so on. Semi-intensive and intensive aquaculture can be practiced only in very small closed beels since the management of culture operations in larger beels is a difficult proposition involving very high material, monetary and managerial inputs.

Management enhancement

In addition to the technical enhancement techniques described above, there are other ways of enhancement of fish production such as when new management options are exercised. This can be in the form of changing the access to the fisheries (e.g., from open to limited access as in case of the leasing system) or adoption of a community management approach for more effective management. In addition to enhancement of fish production from the beels, management enhancement can aim at improving the monetary and aesthetic values of a fishery. For example, a beel can be thrown open for sport fishing to attract amateur fishers or to promote eco-tourism.

CRITERIA FOR SELECTING A SUITABLE ENHANCEMENT TECHNIQUE

The major consideration in choosing a particular enhancement measure suitable for a particular beel is the degree at which the environmental parameters and fish stock can be manipulated to increase its fish yield. Management of medium and large open beels can be considered as similar to that of capture fisheries, where wild untended fish populations are harvested with little scope to modify the eco-system. Fisheries of open beels are mainly dependent on natural recruitment. Thus, open beels are basically managed along capture fisheries norms with limited scope for enhancements (e.g., brush parks).

In closed beels, the manager exercises a certain level of freedom in modifying the ecosystem both in terms of environment (environmental enhancement) and biotic communities (stock/species enhancement). Culture-based fisheries – either alone or in combination with other enhancement tools – can be practised in small sized closed beels for increasing their fish production significantly. More intensive enhancement techniques like fertilization and aquaculture are suitable only in very small closed beels.

CONCLUSION

Fisheries management purely along capture fisheries lines is increasingly becoming rare and is practiced mainly in open beels that retain riverine connection throughout the year. In seasonally open and closed beels, various forms of enhancements including aquaculture are practised. Through fisheries enhancements, qualitative and quantitative improvement in fisheries is achieved from a beel by exercising specific management options. These options include increasing the existing fish stocks (stock enhancements), introduction/transplantation of new fish species (species enhancements), improving the environment (habitat enhancements), changing the exploitation means/norms (management enhancements) and enhancement through new culture systems (e.g., pen and cage culture). In culture fisheries, desirable fish stocks are reared in a water body by controlling the environment (e.g., soil and water quality management, fertilization, etc.) and suitable fish husbandry practices (e.g., feeding, fish health management, etc.) to obtain maximum production. The collapse of shrimp aquaculture in Southeast Asia and the eutrophication of the Laguna de Bay, Philippines as a result of uncontrolled growth of pen culture have demonstrated the potential dangers of intensive aquaculture particularly in open water bodies. Thus, in spite of having potential for higher fish production such enhancement tools should be chosen with abundant caution. In contrast, species and stock enhancements require less investment per unit area and are more environment-friendly.

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FISH YIELD OPTIMIZATION IN *BEELS- SOME CASE STUDIES FROM WEST BENGAL*

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INTRODUCTION

India is endowed with rich and diverse inland water resources in the form of rivers, canals, estuaries, lagoons, backwaters, brackishwater impoundments, mangroves, floodplain wetlands, upland lakes, swamps and man made reservoirs, tanks and ponds. Development and rational exploitation of our capture fisheries resources are challenging tasks, unlike culture fisheries where ecosystem manipulation and production monitoring are easy. Large inland open waters (Table 1), spread among varied geoclimatic conditions exhibit diverse ecodynamics and hence no uniform guidelines can be formulated for their management. India has made big in fish production during the last fifty years, from 0.75 million t in 1950-'51, the annual fish production has increased to 5.6 million t during 1999-2000 and 6.3 million t during 2002-'03. Contribution of inland fisheries to the total fish production has shown a steady increase, 24-29% in the 1950s and 60s to nearly half during 1999-2000 registering a 14 fold increase from 0.2 million t to 2.8 million t. Still the current shortfall of fish production is calculated as about 0.8 million t (Sugunan, 2002). Since marine fishery sector is not expected to grow much, most of the shortfall must be met essentially from inland fisheries.

Table 1. Inland water resources of India.

Water body	Size
Rivers	29,000 Km.
Irrigation canals	120,000 Km
Floodplain lakes	202,231 ha
Upland lakes	72,000 ha
Reservoirs	3,000,000 ha
Estuaries, mangroves, back waters and brackish water lagoons	6,000,000 ha
Estuarine wetlands	50,000 ha
Brackish aquaculture areas	1,200,000 ha
Fresh water ponds	22,54,000 ha

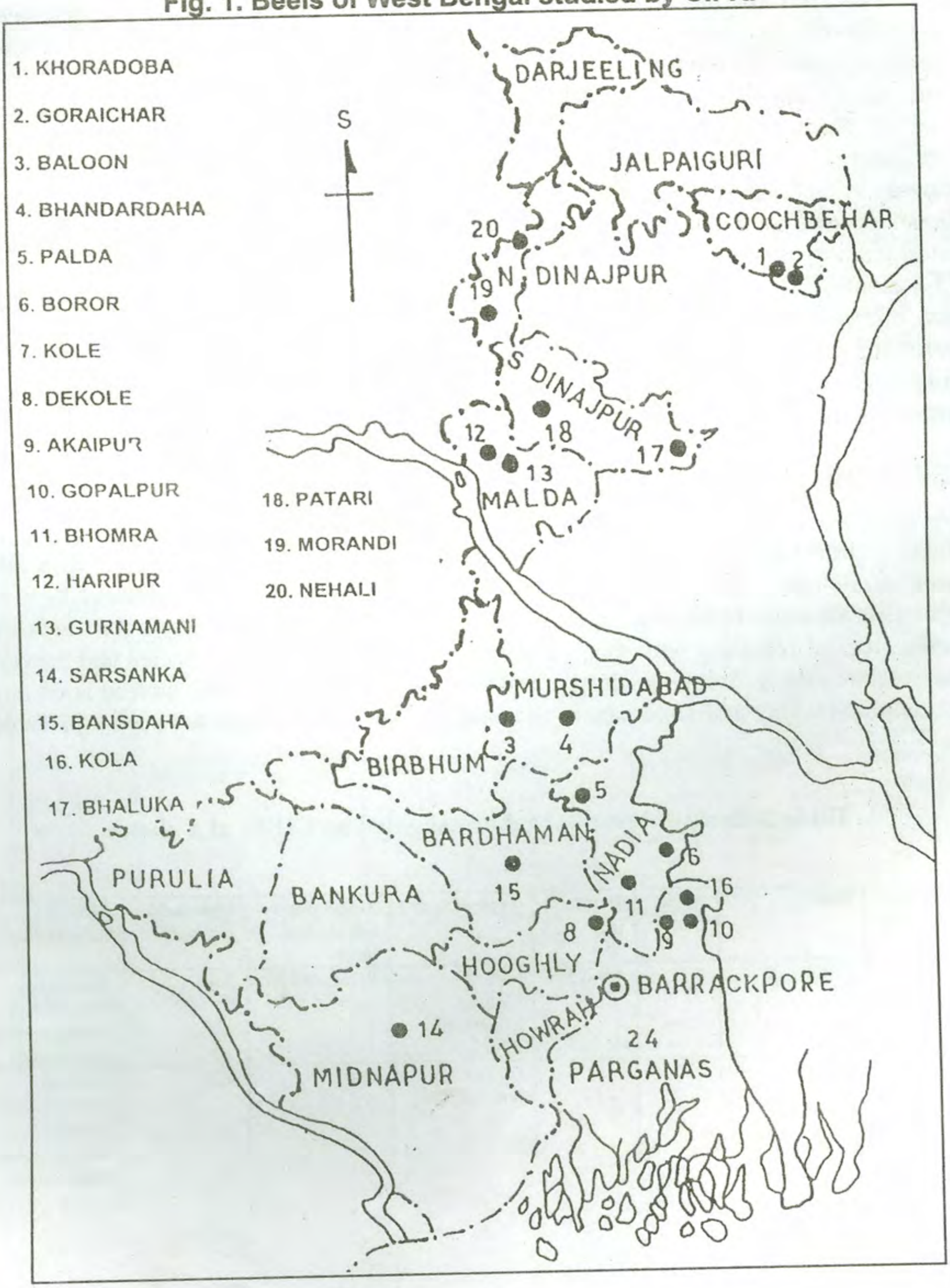
BACKGROUND OF BEEL FISHERIES

West Bengal has more than 150 *beels* covering an area of 42,000 ha constituting 22% of the total freshwater area of the State. They are related to the rivers, Bhagirathi, Hooghly, Icchamati, Jalangi, Churni, Kalindi, Dharub, Dharala, Pagla, Behula, Torsa and Puranabhaba and mainly spread over in the districts of 24 Parganas North and South, Murshidabad, Cooch Behar, Nadia, Maldah, Hooghly, West and North Dinajpur *etc.* of which 20 *beels* were studied by CIFRI (Fig. 1).

Water residence and renewal time as well as the extend of macrophyte infestation are the two most important factors affecting their ecology and fisheries. In *beels* that retain riverine connections the continuous water exchange affects the nutrient input-output ratio. Though these conditions .adversely affect biological productivity, it delays eutrophication of the *beels*. Continuous water flow does not allow plankton species to stabilize also. The *beels* which do not keep the connection with their parent river are more productive but weed choked. The aquatic weeds interfere with the free operation of various gear. Considering the different ecological characteristics the *beels* are classified into two, *open beels*, which retain connection with the parent river and *closed beels* which are cut off from the parent rivers.

A clear distinction is discernible in case of fish fauna of open and closed types of *beels*. The open *beels* harbor many riverine species in addition to the resident fish stocks of the ecosystem while closed *beels* have their own distinctive fauna.

Fig. 1. Beels of West Bengal studied by CIFRI



Fishing in open *beels* continues throughout the year with a peak during September-November and continues till February-March. Faunistic composition of open *beels* generally reflects faunal diversity of the parent river. During monsoon, the breeding season of fishes, the catch is dominated by young ones of various fishes. The practice of catching fry and fingerlings by using fine meshed nets at the entry point is a matter of concern. Such practices lead to depletion or removal of many varieties of fishes from the system. There is another category of seasonally open *beels* which otherwise remain closed. In this type of *beels*, fishes enter along with floodwater and stay there. As the flood recedes, an intensive fishing is carried out to exploit this stock without any consideration of size or maturity stage of fishes. As a result, within a short span of time (3-4 months) almost entire stock is removed and the fishermen remain jobless for the rest of the year. The Co-operative Society can prolong fishing in such systems by enforcing regulatory measures like fish size regulations, quota of harvest for each fishing group and so on. Stocking can also be done after the recession of floodwater to grow fish till the onset of next flood.

CIFRI STUDY

Table 2 shows the fish yield pattern and other morpho-ecological characters of a few *beels* of Bengal. Many of the *beels* are under active management practices by Co-operative Societies following the norms of *culture-based fishery*, wherein the *beels* are being stocked regularly with major carps, minor carps and exotic species and harvest the stock regularly. Stocking density, however, does not seem to have arrived at on any rationale. Stocking and yield pattern of some *beels* of West Bengal are shown in Table 3.

Table 2. Beels of West Bengal investigated by CIFRI at a glance

Distr.	Beel	Area (ha)	Depth (m)	Type of beel	Macrophyte infestation level	Fish yield (kg/ha/yr)	Fishery information
Nadia	Boror	9.2	1.9-3.5	Closed (defunct Bhagirathi river)	Weed choked	240	Stocking. IMC Closed fishing season (Jan-March)
	Kulia	26.5	-	Closed: Ox-bow lake	Low	529	Stocking. IMC, GC, CC Closed fishing season (April-June)

Nadia	Bhomra	83.0	1.0-3.5	Closed, Ox-bow lake	Weed chocked	690	Stocking, IMC, Regulation in capture size
	Mogra	60.0	1.7-5.0	Closed, Ox-bow lake	Weed choked	446-515	Stocking, exotic carps, IMC, Gudusia chapra
	Palda	159.0	3.3-6.4	Open (R. Jalangi & Chumi), Ox-bow lake	Low	34-48	Occasional stocking, Closed fishing (May-July)
	Padma	60.0	1.2-3.5	Closed	Moderate	859	Stocking, IMC
Hooghly	Dekcle	117.6	1.0-1.8	Closed; lake-like	Weed choked	13-36	Capture fishery; closed season (Jan.-April)
	Kol	81.6	1.5-3.5	Open (part of Hooghly); braided channel	Moderate	147	Capture fishery
Murshida-bad	Baloon	200.0	1.6-1.9	Closed; lake-like	Weed choked	24	Capture fishery Indigenous spp., IMC
	Bhandardaha	437.5	4.0-17.0	Open (R. Bhagirathi); Ox-bow lake	Low	150	Capture fishery; Gudusia chapra major group
Cooch Behar	Khorardoba	50.0	0.4-1.5	Closed (R. Dharub); Lake-like	Weed choked	204	Stocking, Indigenous spp., IMC
	Gorai chara	50.0	4.0-6.8	Open (R. Dharala); Ox-bow lake	Moderate	325	Stocking, IMC
Bardhaman	Bansdaha	26	1.7-6.5	Closed (R. Bhagirathi), oxbow lake	Moderate	1100	Stocking, IMC, G. chapra
Midnapore	Sarasanka	24.0	0.2-1.8	Closed, lake-like (oval meteorite lake	Weed choked	250-292	Stocking, IMC

24 parganas	Akaipur	32.0	0.3-1.8	Closed; oxbow lake	Low	406-969	Liming, stocking catch quota fixed (5 kg/day), closed season (March to May)
	Gopalpur (Berir baor	131.0	4.5-12.6	Closed, (R. Ichhmati) (U-shaped cutoff meander)	Low	420-771	Stocking, IMC, grass carp, silver carp, *Gudusia chapra*. Catch quota 15 kg/day/person
	Garapota	122.0	2.0-8.5	Open (R.Ichhmati); oxbow lake	Moderate	332-617	Stocking, IMC
	Ghurna-Mani	40.0	1.4-3.6	Open (R.Pagla); oxbow lake	Moderate	137	Stocking, IMC & indigenous
	Haripur	30.0	1.0-4.5	Open (R. Kalindi); oxbow lake	Moderate	330	Capture fishery, IMC and *Gudusia chapra*

Table 3. Stocking and yield pattern in some beels of West Bengal

Year	Total stocking (kg)	Stocking rate (kg/ha)	Total harvest (kg)	Yield (kg/ha)	Stocking yield
Bhomra beel (83 ha)					
1991-92	11605	140	38485	463	3.3
1992-93	14270	172	41647	502	2.9
1993-94	8107	98	31302	377	3.9
1994-95	9535	115	39158	472	4.1
1995-96	5819	70	25550	308	4.4
1996-97	9677	117	56275	678	5.8
1997-98	8936	108	77762	937	8.7
1998-99	9643	116	53688	647	5.6
Akaipur beel (32 ha)					
1992-93	1895	59	20600	644	10.9
1993-94	4498	141	20277	634	4.5
1994-95	3940	123	31800	994	8.1
1995-96	2892	90	23452	733	8.1
1996-97	6114	191	39796	1244	6.5
1997-98	8108	253	38181	1193	4.7
1998-99	4163	130	61290	1915	14.7
Kola beel (12 ha)					

1991-92	1017	85	7952	663	7.8
1992-93	1289	107	6717	560	5.2
1993-94	1199	100	6409	534	5.3
1994-95	1970	164	10906	909	5.53
1995-96	1938	165	22569	1881	11.4
1996-97	3101	300	36247	3021	10.0
1997-98	-	258	-	2993	11.6
Gopalnagar beel (35 ha)					
1990-91	6722	192	30090	860	4.5
1991-92	6940	198	8334*	238	1.2
1992-93	5630	161	25170	719	4.7
1993-94	6459	185	45029	1286	7.0
1994-95	4710	135	32650	933	6.9
1995-96	6939	198	31836	910	4.6
1996-97	3869	110	74361	2125	19.2
1997-98	5807	166	71777	2051	12.4
1998-99	9091	260	60560	1730	6.7

**abnormal value due to flood*

The percentage composition of fishes indicates the supremacy of carps in the catch (Table 4). The common species encountered are listed in. The information on the fishing crafts and gear and the fishing method followed from *beels* like Bhomra, Pansdaha, Kole, Patari, Bhaluka and Nehali shows *beels* have their own special ways of fishing (Table 5). *Comode* fishing of Bengal is the same as *katal* fishing of Assam. It is by providing artificial shelter of weeds, cut branches and twigs to fishes. Later cover that area by dragnets. All types of gear are not suitable for the weed-infested *beels*.

Catla catla, Cirrhinus mrigala, Labeo rohita, Cyprinus carpio, Hypophthalmichthys molitrix, Ctenopharyngodon idella, Labeo calbasu, Wallago attu, Mystus spp., *Silonia silondia, Bagarius bagarius, Gudusia chapra, Chanda nama, C. ranga, Puntius sophore, P. ticto, P. sarana, P. chola, P. stigma, Barilius bola, B. bendelisis, Chela laubuca, C. utrahi, Notopterus notopterus, N. chitala, Setipina phasa, Danio rerio, D. dangila, Esomus darnicus, Amblypharyngodon mola, Aspidoparia morar and Cirrhinus reba.*

Table 4. Percentage composition of fishes of *beels* in West Bengal (Average)

Fishery	Districts			
	Nadia	**Hooghly**	**Murshidabad**	**24 Parganas**
Carps	30-35	30-65	33-55	30-40
Miscellaneous	21-38	14-43	22-37	25-43
Air-breathing	10-15	10-20	15-16	10-25
Cat fishes	0-5	0-2	0-5	3-5
Murrels	0-5	0-10	0-5	5-8
Feather backs	-	-	2-3	2-5

Table 5. Fishing crafts and gear used in *beels*.

Beel	**Crafts**	**Gears**
Bhomra	1.Dingi nauko 2.Dugout palm trunk	**1.Nets**: Drag net (1/2" mesh size), *Chaut jal* (3/4"mesh), *Chack jal, Kachal jal* or *Berh jal* shore seine type), Cast net, *Baansh jal* (triangular bamboo frame fitted with fine mesh net), *Phans jal* (gill net) *Punti jal* (gill net for small variety fish). **2. Traps:** *Ghuni* (rectangular box type split bamboo frame), Charo-aatol(bigger size rectangular box type split bamboo frame) **3. Hooks and lines:** Hooks for various sizes are being hung with baits comprising earthworm, small prawn, larvae and pupae.
Bansdaha	1.Dinki nauko (Plank built small boat)	**1.Nets**: *Berh jal* (drag net), *Phans jal, Muyea jal, Koi jal, Punti jal* (all are gill net), *Chabi jal*(conical bamboo frame with a net fitted on the inner circumference) **2. Traps:** *Britti* or *Ghuni* (rectangular box type split bamboo frame), Aatol (cubical shaped large size split bamboo frame) **3. Comode fishing:** Fishing by a group of people using a drag net by cvering a fish shelter of cut branches and twigs being provided by fishermen well before fishing.
Kole	1.Nauka 2.Dinki nauka 3.Dugout palm trunk	**1. Nets:** Cast net, *Berh* or *Chaut jal*(drag net), *Dhol jal* (gill net having mesh size of 1-1.5), *Chitke jal* (triangular bamboo frame fitted with fine mesh net), *Bheshal jal* (dip net), *Char patta* (a fine meshed net set vertically parallel to the bajk in the marginal area) **2. Traps:** *Barh bitti* (cylindrical shape split bamboo frame)

Patari	1. Dingi nauka	**1.Nets:** Drag net, cast net and gill net **2. Traps:** *Danrhki*(rectangular box type split bamboo frame) **3.Katal fishing:** The same as commode fishing by encircling the fish shelter.
Bhaluka	1. Dingi nauko	**1. Nets:** *Tana jal* (drag net), *Phans jal* (gill net) **2.Traps:** *Khalsumi* (rectangular box type split bamboo frame)
Nehali	1. Nauko	**1.Nets:** Cast nets and dragnets.

ECOSYSTEM ORIENTED FISHERY MANAGEMENT

Ecosystem oriented fishery management plan implies increasing productivity by utilizing the natural ecosystem processes to the maximum extent. This will be more cost effective and do minimum damage to ecosystem and biodiversity. **Community metabolism** or the transfer of energy from one trophic level to the other can be the major criterion for selecting management options, especially the species selection in culture-based fisheries.

In an ecosystem, the biological output or the production of harvestable organism can be at various trophic levels. Under a ***grazing chain***, a *phytoplankton* > *zooplankton* > *minnows* > *catfishes* system or *a phytoplankton* > *zooplankton* > *fish* system prevails. Since no grazing chain of *macrophytes* > *fish* exists in *beels*, macrophytes are invariably channeled through ***detritus chain.*** There are different detritus chains such as *Phytoplankton* > *detritus* > *benthos* > *bottom feeders* system or *macrophytes* > *associated fauna* > *air breathing fish* system exist. Most of the *beels* are heavily infested with macrophytes. In order to get higher production from *beels* the species which depend more on detritus chain may be stocked.

DETRITAL DYNAMICS

The study of yield potential shows very interesting result. In most cases, fish yield potential estimated as 1% of the primary energy has been found to be much lower than the actual yield obtained. Compared to other ecosystems such as reservoirs, *beels* are biologically highly rich where huge amount of energy is loaded at detritus stage. The conventional method of calculating fish yield potential from the rate of primary productivity is not applicable to the *beels*. In this unique ecosystem, total budget of detritus including accumulated detrital carbon at the bottom and the rate of detrital loading from macrophytes need to be considered. Age of the *beels* is also an important factor in accumulation of energy at the bottom

CAPTURE FISHERIES OF THE OPEN *BEELS*

Open *beels* are typical continuum of rivers where the management strategy is akin to riverine fisheries. In capture fishery management the natural fish stock is managed which need a thorough insight into population dynamics including recruitment, growth and mortality. In order to ensure recruitment it is necessary to identify and protect the breeding grounds, allow free migration of brooders and juveniles from *beel* to river and *vice versa* and protection of brood stock and juveniles by conservation measures.

CULTURE-BASED FISHERY OF THE CLOSED *BEELS*

Management of completely closed *beels* or those with a very brief period of connection with the river is more like small reservoirs. The basic strategy will be stocking and recapture. In culture-based fishery, the growth is dependent on stocking density and survival is dependent on size of stocked fish.

FISHERY OPTIONS

a) *Fishery based on Indian major carps*

The *beels* especially closed ones can be developed as big ponds as their fishery solely depends on stocking with IMC.

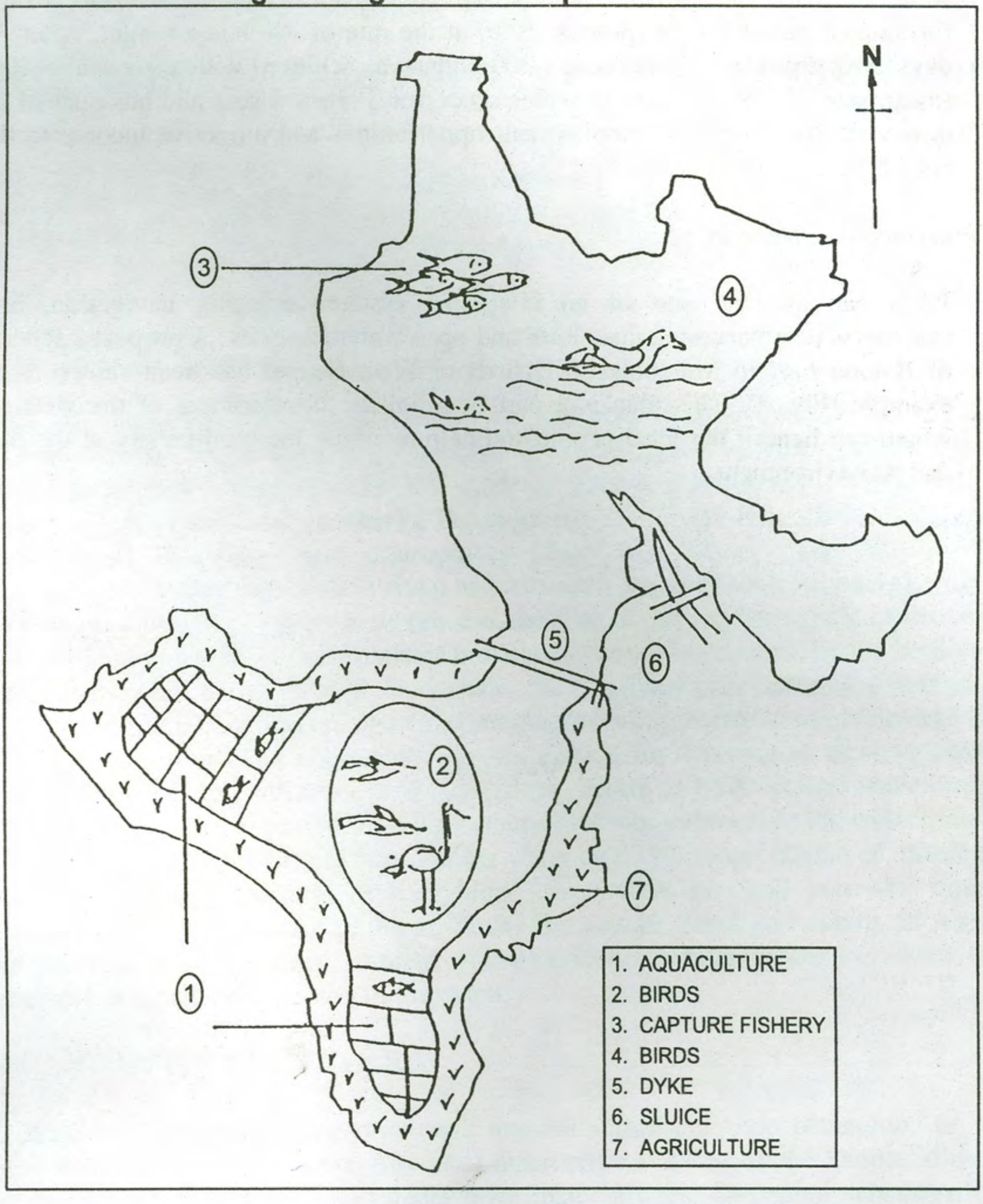
b) *Fishery based on indigenous fishes*

In many *beels* indigenous fish form a substantial share of the catch that fetch good price also in local markets. It is not necessary to develop all *beels* as carp based fisheries. *Amblypharyngodon mola, Puntius sophore, Gudusia chapra* and a number of air-breathing fishes etc. can also sustain economic fishery. Low yield rates can be compensated with the high price the fishes fetch.

c) *Fishery based on pen and cage culture*

Many beels are not productive and it is not practical to fertilize the whole open water area. Therefore manageable parts of the water body can be cordoned off to stock choice species. Pen and cage culture practices are the perfect management option for weed choked and unproductive *beels*.

Fig. 2. Integrated Development of Beel



In an experiment by CIFRI in Akaipur *beel* of west Bengal, juvenile prawns (4 g) were stocked at the rate of 12,000 per ha. Additional feeding was done with a formulated pelleted feed (protein 29%) at the rate of 4% body weight. After 87 days, a total production of about 1,300 kg/ha was achieved with a survival > 50% (mean size 86). The system provides scope for 3 crops a year and has opened up new vistas for providing employment opportunities and attractive income to the rural folk.

d) Integrated development

Beels can also be part of an integrated system including navigation, bird sanctuary, post harvest, aquaculture and open water fisheries. A proposed scheme of Baloon *beel* in Murshidabad District of West Bengal has been shown as an example (Fig. 2). This plan is a part of a holistic development of the wetland, which can benefit the local people and help retaining the biodiversity of the *beel* and its environment.

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MACROPHYTE MANAGEMENT IN FLOODPLAIN WETLANDS

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INTRODUCTION

Our country has significant and varied natural and man-made aquatic habitat, wetlands are one of them. These sustaining very diverse assemblage of macrophytes, that spend whole or at least a part of their life cycle in aquatic environment. These include spermatophytes (seed bearing plants), Pteridophytes (ferns and fern allies), Bryophytes (mosses and liverworts) and Charophytes (algae like *Chara* and *Nitella* etc.). Macrophytes are the base of food chain and as such a major conduit for energy flow in the system. Through photosynthetic process, these plants link the inorganic environment with the biotic one. The organic matter produced is less used directly by the herbivores but is transferred to the detrital food chain. Macrophytes provide critical habitat for other biotic groups, such as epiphytic bacteria, periphyton, macro-invertebrates and fish. The composition of plant community has implication for diversity in these taxonomic groups. They strongly influence water chemistry, acting as both nutrient sinks through up take, and as nutrient pumps, moving compounds from sediment to the water column. They also have the property to improve the water quality through uptake of metals and other contaminants. Because of their high reproduction rate and perennial type of growth has become a global problem. Today the aquatic weed particularly in tropical and subtropical region have resulted in major loss of water resources which have adversely affected the economy of the country.

MACROPHYTES OF WETLANDS

Because of the shallow nature, rich soil, nutrient status and good penetration of light these wetlands support a dense growth of macrophytes. Based on the habitat or niches the wetland plants are classified under three major groups. *Emergent, submerged* and *floating*.

Emergent

These plants generally grow along the margin where there is marked fluctuation in water level. Most of these plants are amphibious in nature and are capable of growing in moist land as well as shallow swampy areas. These are mainly of two types:

i) *Erect*, the plants stand straight eg. *Cyperus procerus*, *C. exaltatus*, *Scirpus grossus*, *S. articulatus*, *Aeschynomene indica*, *Polygonum barbatum*, *P. hydropiper*, *Typha angustata*, *Monochoria hastata* etc.

ii) *Prostrate-floating*, these usually do not remain stand but reaching to the water surface spread much far from the bank up to a certain depth. Their apical region cease growth. As soon as they reach deeper water level, *eg. Ipomea aquatica*, *Alternanthera philoxeroides*, *Commelina longifolia*, *Paspalum paspaloides*, *Hygrorhiza aristata*, *Ludwigia adsendens*, *Leersia hexandria* etc.

Submerged

These plants grow in submerged soil, at all water depth to about 10 m in the so called photic zone where light intensity is 1-4% of the average intensity at the surface level, *eg. Vallisneria spiralis*, *Ceratophyllum demersum*, *Hydrilla verticillata*, *Blyxa octandra*, *Potamogeton crispus*, *Ottelia alismoides*, *Najas indica*, *Chara* sp. *Nitella* sp. etc.

Floating

These are of two type: 1) *rooted floating* and 2) *free floating*.

The rooted floating plants grow in continuous water zone having a depth of about 0.25-3 m. These plants usually have long and flexible petioles and peduncles to enable them to keep their leaves and flowers above the water surface. Common plants are: *Nymphaea nauchali*, *N. pubescens*, *Nymphoides cristatum*, *N. indicum*, *Nelumbo nucifera*, *Potamogeton nodosus*, *Aponogeton natuns* etc.

Free floating macrophytes remains spread all over the water area or get drifted towards the bank by the wind action, eg. *Eichhornia crassipes*, *Pistia stratiotes*, *Spirodella polyrrhiza*, *Lemna perpusilla*, *Azolla pinnata* etc.

The *submerged floating* ones are *Utricularia stellaris*, *U. aurea* which keep their inflorescence above the water surface by means of float.

MACROPHYTE ASSOCIATED FAUNA

Aquatic macrophytes support a dense growth of macroinvertibrates by providing food, shelter, breeding and rearing grounds for their progenies. The fauna comprised mainly insects, gastropods, ostracods, decapods, annelids, arachnids etc. These associated fauna in their different stages of development constitute natural food items for many fishes.

IMPACTS OF MACROPHYTES

The environmental impacts of aquatic macrophytes are both positive and negative in nature. In fact, presence of aquatic macrophytes in manageable quantity provide stability to a system and also keeping the environment relatively clean. But pose many problems when assume the status of weeds (unwanted by its manager) in the system such as considerable loss of water through evapotranspiration, nutrient locking, navigation, hindrance to fish culture, create problems in using various types fishing gears and micro climatic changes in the system as a whole. Besides, deposition of dead and decaying mass shortens the life of the water body if proper management are not being taken.

MACROPHYTE DYNAMICS

Zonation of vegetation is the most familiar feature of all open water bodies. It is primarily associated with the depth of water. In the typical sequence, totally submerged communities in the deeper water give way nearer the bank to a zone of floating leaved plants, which are succeded by emergent communities occupying the marginal zone. In other words, it represents the natural succession of vegetation where one plant community changes in to another. These changes are temporal as both edaphic and biotic factors control their succession. It can be said that steady accumulation of inorganic sediments and organic debris gradually raises the surface nearer and nearer, to the level of water table. As a result submerged communities give way to floating leaved forms, these are in turn replanced by swamp emergents which ultimately pass over to the marsh and terrestrial formulation, there by obliterating the habitat. The pace with which the environmental factors are altered is reflected in their community dynamics. The more gradual the transition, the less conspicuous the gross zonation in a habitat may appear. Therefore, if these water bodies are left unmanaged, they will support dense growth of macrophyte.

MANAGEMENT OF AQUATIC WEED

To maintain equilibrium in aquatic environment growth of certain macrophyte in water is essential but their excessive growth causes various problems. Their proper management therefore, assumes much importance in terms of economic, agricultural and conservation activities.

There are three well established methods to manage the undesirable growth of macrophytes. These are (i) *physical* or *mechanical*, (ii) *chemical* and (iii) *biological*.

Physical or mechanical

Physical removal of weeds is the oldest and still the most common method of weeding water body worldwide. The tools commonly used are scythes, dragnets for free floating weeds and drag chains for submerged weeds. To tackle the problems of greater magnitude manual or small power operated hand tools, fully power operated weed cutting boats harvesters excavators, mowers, dredging machines etc., have come in to use. The harvested weed is usually sun dried and burnt unless some end use like fodder, manure, etc. can be found. This method is laborious requiring repreated operations. Though there is a risk of reinfestation by seeds, left over propagules, vegetative fragments etc. yet, there are some distinctive advantages. This method does not pollute or degrade the water body and dose not affects the non target organisms inhabiting it.

Chemical method

Organic and inorganic herbicides are long being used with varying levels of success to control aquatic weeds in advanced countries. This method has been proved to be easier, faster and cheaper. But due to lack of infrastructural facilities it is still being used in very small scale in the developing countries in the tropics. When applying herbicides one must be cautious about the possible hazards to the user, the consumers of the water and the fishes. Some of the commonly used herbicides are:

a) *2,4 D* – considered to be the best herbicide against *Eichhornia* and other broad leaved species. Fishes are tolerant to amine salt preparation but their flesh may impart temporary phenolic flavor. Treated water is also unfit for irrigation use.

b) *Diaquat and Paraquat-* Both are effective against floating weeds like *Eichhornia, Pistia, Spirodella, Lemna* and submerged weeds like *Najas, Ceratophyllum, Myriophyllum, Potamogeton*, etc. These are non-persistent and treated water is considered safe for all uses.

c) *Dalapon or DCPA* – A foliage active systemic herbicide, easily translocated to subterranean organs; effective against robust grasses and sedges. Though a mild skin irritant it is considered nonpoisonous to man, livestock and probably to fishes.

Besides, Coppersulphate, grammaxon, hydrothol, N-N-dimethalklamine, 2,4-6 trichlorophonic acid, 2,3-6 trichlorophenoxyacetic acid, 1,1 dimethyle urea are used for management of aquatic weeds.

Biological method

Deployment of a suitable organism like fish, snail, insect and pathogen to check the growth and spread of weed to an acceptable limit is called biological control. Though this method of control is cheaper and has minimum detrimental side effects yet has got its own limitations.

Fishes like *Ctenopharyngodon idella, Puntius javanicus, P. pulchellus, Osphronemus gourami* and *Cyprinus carpio* are known as good vegetative feeders. Among these the Chinese grass carp *C. idella* is considered to be the best which is reported to consume 40-70% of its body weight per day.

In Surahatal (U.P.) and Loktak lake (Manipur) weevils *Neochetina eichhornae* and *N. bruchi* have shown encouraging results as bio-controlling agent against *Eichhornia crassipes.*

In Kerala common tropical snail *Pila globosa* has also proved to be a good biocontrolling agent against *Salvinia molesta.*

MANAGEMENT THROUGH UTILIZATION

Among the several uses of aquatic weeds the pre dominants are fodder for animals, compost for crop field, mulching materials, extracting medicinal ingredients, making paper and fiber pulp, food for carps and as pollution abatement.

CONCLUSION

- Macrophyte in all the cases may not be treated as weeds. They are important component of biodiversity and have a role to play in maintaining equilibrium in the ecosystem.
- The aim should be to reduce the degree of infestation to an acceptable level to avoid problems raised up by their presence.
- The control of weeds should not be attempted in isolation. It should form the well thought and properly designed strategy to improve the ecosystem of entire lake.
- In view of the shallow nature of the floodplain lakes in general, manual removal of aquatic weeds need be preferred and linked with the cottage industry.
- Bio-control of aquatic weeds should be encouraged with the introduction of insects for large foliar weeds and fishes for submerged weeds.
- Integration of duck farming with fisheries in weed infested water may be highly advantageous to the fishers.
- Pen and cage culture is the best option for increasing the fish production in such weed infested wetlands.

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OX-BOW LAKES IN BIHAR - AN IMPORTANT RESOURCE FOR DEVELOPMENT OF CULTURE BASED FISHERIES

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INTRODUCTION

Bihar is a vast alluvial plain intersected by a number of large semi circular ox-bow lakes locally called *Mauns*. In fact, these water bodies are the abandoned channels of the Himalayan rivers and formed due to fluviatile and seismic activities in the Gandak, Burhi Gandak, Bagmati, Kosi, Kamla and Lakhandei basin. Some of these lakes still retain their connection with the parent river directly or indirectly and receive water from the river during flood season in contrast to this many has lost their connection completely with the parent river due to construction of embankment and developmental activities. The ecological character of these water bodies are persistently changing due to many unsustainable activities.

PRODUCTIVITY STATUS OX-BOW LAKES

Investigation has shown these lakes are very large elongated and shallow in nature. The shore line is irregular and their depth vary from place to place and season to season. During monsoon months the spread over area of water increases considerably whereas in winter and summer the water in the lake is dried up. From the culture point of view the peripheral zone of the lake more productive than deeper zone of the lake. The hydrological features also indicate their productive nature. The yield of fish from these lakes further support that the carrying capacity of these water bodies are extremely high. Therefore, these lakes have enormous biotic potentialities and basic morphometric and hydrological factors responsible for the fish production is quite congenial for the culture of commercially important food fishes.

MANAGEMENT PROBLEMS FOR CULTURE BASED FISHERIES

From productivity point of view, these lakes are excellent resource base but due to multiplicity of factors management of culture based fishery is a redious task. The extensive areas of these lakes are heavily infested with several species of floating, submerged and rooted emergent weeds especially with *Eichhornia crassipes, Hydrilla verticillata, Najas minor, Ceratophyllum demersum, Nelumbium* spp. and *Nelumbo* spp. The infestation density per unit area of these weeds are extremely high therefore the ecological niche of various fish species is lost and the production of natural fish food organisms is adversely affected. Aquatic weed provide congenial condition for the growth and multiplication of the predatory and weed fishes but adverse condition for the commercially important carps. Under prevailing adverse condition, these water bodies can not be effectively utilized for fish culture unless weed eradication programme is taken on the mass scale.

Siltation, sedimentation and nutrient enrichment are the other major problem for the exploitation of these lakes. These water bodies are organically very rich due to organic load coming from the surface run off, domestic sewage, and agricultural runoff. The level of nutrients increases during summer and monsoon but decreases during rest of the year. As a result of persistent accumulation of plant debris, silt and sediments the nutrient cycling at lake bottom is badly affected. The water of the lakes are also utilized for irrigation purpose therefore these lakes are becoming shallower day by day all these unsustainable activities are badly affecting the production and productivity of the valuable water bodies.

The north Bihar is thickly populated zone of the country, therefore many socio economic factors are also creating problem for the development of culture based fisheries in these lakes. Owing to multiple ownership, great number of uses, conflicting land use pattern high investment cost on reclamation, the exploitation and management of these resources are not an easy task and aqua farmers are facing problem for undertaking fish production activities in these lakes. Hence, these valuable water bodies are lying in derelict condition and going out of productive use. These problems have to be resolved if the enormous potentialities of these water bodies are to be tapped for the production of commercially important finfish and shell fish.

PRODUCTION TECHNOLOGY FOR DEVELOPMENT OF CULTURE BASED FISHERIES IN THE OX BOW LAKES OF BIHAR

To meet the above challenges, investigations has been carried out by the Central Inland Fisheries Research Institute, Barrackpore to develop fish production technology for these lakes. Studies has shown that the pen culture technology is most relevant technology for production of commercially important fishes in these lakes.

Basically a pen is fixed barrier through which fishes are kept out of danger in the farming zone. As the device ensure complete control over farming zone, the management of fish stock become easier. This blocking device is very effective in preventing the entry of undesirable element from lake to enclosed area on one hand and controlling enemies, predators, competitors and unwanted element inside the enclosed farming zone on the other. The system ensures higher survival rate and better yield of return. The technique enables the fish farmer to utilize his own portion of water area without disturbing the interest of other users. A number of experiment on the pen culture has been conducted in oxbow lakes of Bihar and it has been demonstrated that by adopting this technology, a remunerative fish yield can be obtained (Table-1).

In all the experiments, pen screen or enclosure were made from locally available bamboo strips and fishes were fed with non pelleted feed containing mustard oil cake and rice bran daily @ 1 to 4% of the standing crop. The estimated fish production in these experiments were 4.0, 3.17, 2.54 ton/ha in Manika, Kanti and Muktapur respectively. These studies indicated the technical feasibility and economic viability of pen culture in oxbow lake ecosystem of Bihar.

The success of pen culture to a great extent depends on the suitability of site and proper installation of pen. Gentle slopping terrain where water level fluctuation is not extreme is the suitable site for the installation of pen. The areas, get drastically reduced and where floating weed islands are formed must be discarded as they may pose problem in the management. From the economic point of view, pen is generally installed when water level is minimum. Before installation, selected area is demarcated renovated and made free from marginal, floating and sub-merged weeds. Sufficient space must be reserved so that in case of emergency pen can be extended.

Table-1. Results of pen culture experiments conducted at Oxbow lakes of Bihar

Details of experiments	Manika lake (Muzaffarpur)	Kanti lake (Muzaffarpur)	Muktapur lake (Samastipur)
Year of experiment	1983	1986	1990
Pen size (ha)	0.1 Ha (50 X 20 m)	0.08 (40 X 20m)	0.08 (40 X 20m)
Type of culture	Polyculture of India Major Carps	Polyculture of Indian Major Carps	Polyculture of Indian Major Carps
Stocking rate (no/ha)	5000	5000	10000
Stocking ratio			
Catla	5	3	3
Rohu	5	5	3
Mrigal	1	2	4
Average initial weight (gm) at the time of stocking			
Catla	160	177	15
Rohu	100	75	20
Mrigal	130	102	20
Final weight (gm) at the time of harvesting			
Catla	1100	1100	450
Rohu	900	800	475
Mrigal	100	750	700
Net production (kg/pen)	400	317	203.5
Estimated production (tons/ha)	**4.0**	**3.17**	**2.54**

The prime purpose of pen culture is to ensure the safety of the fish stock therefore, the condition of the farming zone is improved by cleaning the undesirable elements and disinfection. To release the harmful gases and for prophylactic measures excess muck need be removed and liming should be done. Raking is used to turnover the bottom sediment. For better remunerative result, healthy and large sized fingerlings are stocked during warmer months of the year.and nutritious diet is to be provided.

MANAGEMENT PROBLEMS IN PEN CULTURE

The problems which generally encountered during pen culture experiments are given below-

- Damage of pen screen is common. It may be due to constructional defects, installation defects, heavy downpour, entry of water from the surrounding areas and water level fluctuation during flood season. Due to damage of screen, undesirable element find entry in to the farming zone. Periodic checking is essential to eliminate these problems. The damage can be corrected either by repairing or replacing the damaged part of the pen.

- Overtopping and escapement of fish from bottom is very common in pen. It is due to constructional and installation defects.

Algal clogging is very common. In the pen screen and net. The gastropods and algae make the net heavier and create problem in the management. Therefore pen screen and net needs to be checked and cleaned regularly.

Incidence of fish disease is very common due to organic load in the lake. Therefore health monitoring is very important aspect in pen culature.

CONCLUSION

The worth of the technical feasibility and economic viability of pen culture technology has been successfully demonstrated in many oxbow lakes of Bihar. The technology is not only ideal for exploiting the production potential of lake for the production of commercially important finfish and shellfish but also enables fish farmers to utilize one portion of the lake without disturbing the interest of other users.

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BIOLOGICAL PRODUCTION PROCESSES IN FLOODPLAIN WETLANDS IN THE CONTEXT OF ENHANCING FISHERIES

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INTRODUCTION

Floodplain wetlands locally called *'Beels'*, *'Jheels'*, *'Chaurs'*, *'Mauns'*, *'Pats'*, *'Baor'*, *'Charah'* etc. are very complex and unique biotopes due to several geo-morphological factors. Heavy infestation of hydrophytes aggravates the situation to its worst extent in these shallow, nutritionally enriched water bodies, pushing them further to the dying situation silently. So, a holistic and concerted management approach is the immediate need to revitalize the potentialities of such ecosystem by slowing down their process of dyeing/extinction in order to conserve the rich pool of biodiversity thriving their in.

LIMNOLOGICAL CLASSIFICATION OF FLOODPLAIN WETLANDS

The most important classification is ecological which is more conspicuous in unrevealing the production dynamics of this ecosystem and is categorized as (1) Live or open lakes (2) Dead or closed *beels* and (3) Partially fluviatile incomplete lakes.

Ecologically, the open *beels* show greater potentialities in relation to nutrient dynamics, resulting in higher fish production. The influx of flood water also brings substantial amount of allochthonous energy input, replenishing the energy budget through easily available dissolved inorganic nutrients leading to sharp increase in primary production – a prime requisite factor for aquatic productivity. The open *beels* have their own drawbacks also as they are getting silted at a faster rate during influx of flood water from river making them shallower every year depending on the degree of silt concentration in riverine water. This sudden accumulation of silt affects the benthic communities severely by dislodging their niche. In addition to this, the silting mat covers the oxidative microzones, inhibiting the release of available nutrients, thus disturbing total equilibrium of on going production processes.

Closed *beels* are facing serious threat due to massive growth of hydrophytes, converting them slowly to swamps. Besides, these vigorously proliferating macrophytes form dense mat of semi-decomposed vegetative matter, utilizing bulk of oxygen leaving the bottom layer highly reduced state with the formation of CH_4, NH_3, H_2S type anoxic foul gases, exerting tremendous stress to the biota thriving therein.

Beels having "partially fluviatile characters" are unsuitable for imposing management strategies for fishery point of view as they get lost during monsoons. During post-monsoon onwards, application of capture fisheries provides suitable harvest due to receding of flood water along with natural recruitment in this water body. Though, it is to some extent resembling live *beel* (open type), its life span is very short owing to faster rate of siltation.

TROPHIC STATUS OF *BEEL* ECOSYSTEM

Higher trophic status prevails in most of the *beels* in India. The predominant role in defining trophic status of *beel* ecosystem is governed by massive growth of hydrophytes especially floating (*Eichhornia*), submerged (*Najas, Vallisneria, Potamogeton, Hydrilla, Chara*) and marginal (*Typha* etc) leading to eutrophication. The ecological succession of macrophytes dictates the trophic scenario in a *beel* ecosystem more vividly.

Oligotrophic	→	Mesotrophic	→	Eutrophic	→	Ultra-Eutrophic
↓		↓		↓		↓
Najas/Chara		*Hydrilla*		*Vallisneria, Ceratophyllum*		*Potamogeton* → Reeds

Greater emphasis has to be given in understanding trophic condition in this ecosystem before planning for their management in augmenting fish production. In *beels*, growth of planktonic algae is limited by macrophytes either by shading or by competing for nutrients. Macrophyte grazers are less efficient than algal ones, leading to accumulation of semi- decomposed/partially decomposed organic matter in the form of detritus, which penultimately gets reflected into low production of zooplankton culminating to low fish yield. Thus, the detrital food chain appearing more prominent over pelagic planktonic food chain which has to be fully utilized by strengthening the number of detritivores so as to utilize the detrital energy directly keeping no gap between producers and consumers which will result in better energy output as also suggested by several workers (Juday, 1948; Odum, 1957; Ganapati, 1970; Pathak *et al.*, 1985 and Das, 2000) who emphasized the study of trophic structure and energy flow in aquatic systems and shown importance of both the food chains.

IMPORTANT INDICES FOR BIOLOGICAL PRODUCTIVITY

Morpho-hydrographic features

Amongst morpho-hydrographic features the important ones are area, mean depth, irregularity of shoreline, slopes, degree of exposition of littoral areas during summer, inflow & drainage, period of water retentivity, fluctuation in water level and catchment characteristics. The degree of anthropogenic intervention has predominant role in explaining morpho-hydrodynamics of *beel* ecosystem.

Physical factors

The important physical factors governing aquatic productivity in this ecosystem are temperature, transparency/turbidity, wind action, flow and turbulance of water etc. Temperature is not a limiting factor of production in tropical and sub-tropical India. The dual action of light penetration and temperature favours increased rate of decomposition of bottom organic load in this ecosystem, thereby releasing occluded nutrients in available form to water phase (Das, 2003). This also increases the effective photosynthetic zone making the system more productive.

SIGNIFICANCE OF SEDIMENT IN PRODUCTION PROCESSES

The very basis of productivity in any aquatic medium is the basin sediment, which not only play significant role by releasing nutrients to water phase but also provides shelter and acts as niche for benthic flora and fauna. The important parameters in soil which either act singly or synergetically culminating to productivity are soil pH, organic matter content, C/N ratio and available nutrients.etc.

Particle size distribution of sediment is to be monitored regularly as to know any shift of the volume of particles whether sand, silt or clay regulating productivity. In *beels*, infested with macrophytes, the size of organic particles as well as volume of organic load clearly dictates in particle size distribution of sediment and the process is augmented with the exposure of littoral areas during summer and subsequent flooding during monsoon. Therefore, water retentivity/drainage, macrophytic load as well as climatic conditions have a great bearing on particle size distribution of soil in this ecosystem resulting in undecomposed/semi-decomposed organic matter piled up above underlying clay-loam layer. Nevertheless, regular application of lime in *beels* (< 50 ha) may accentuate the decomposition rate of organic matter, thus providing favourable and ideal soil type at the basin for economic utilization of the nutrients.

Soil reaction (pH) is one of the most important characteristics regulating not only life processes but also availability of nutrients in water phase in optimum quantity for the survival of fish food organisms. Soil is more acidic in the *beels* of Assam as compared to West Bengal barring 'Sarasanka' (Midnapur), 'Bhaluka' & 'Nehali' (N. Bengal) due to inherent soil properties while *beels* of N. Bihar show alkaline soil reaction. In Assam, *beels* under Brahmaputra valley have slightly higher mean soil pH (5.3) than the *beels* of Barak valley districts (pH 5.0) (Saha *et al.*, 2001). The ideal range of soil pH for proper fish growth is 6.5 to 7.5 and soil pH below 4.0 or above 9.0 will have detrimental effect on fish health and overall productivity.

Soil organic matter has predominant role in the process of biological production. It not only serves as food source for benthic feeding fishes and invertebrates as well as a substrate for bacterial growth and other micro-organisms but also controls the overall dynamics of nutrients. Its breakdown is carried out by facultative and obligate anaerobes with slower decomposition rate, releasing organically bound nutrients. In this process, dissolved oxygen in water is being utilized and with time production of reduced gases like CH_4, free NH_3, H_2S etc. takes place affecting biological production adversely. Soil organic carbon varied to a great extent in different *beels* might be due to variation in macrophytic load, their rate of degradation coupled with nature of soil reaction. In acidic soil as in the *beels* of Assam, the degradation process is very slow as compared to Bihar or Southern West Bengal. Again, in the *beels* with high water level year round, degradation process is also hindered resulting in more organic carbon content as in case of 'Bansdaha', West Bengal. Water bodies having more content of organic carbon are more productive (Moyle, 1946; Banerjea, 1967) which is not exactly true in case of floodplain wetlands with heavy infestation of macrophytes, might be due to locking up of available nutrients in the huge partially decomposed organic matter showing less productivity (Das, 2003).

In floodplain wetlands, due attention must be given in monitoring C/N ratio, the prime predictor of mineralization/immobilization thus controlling availability of inorganic-N in water phase from sediment especially in shallow weed infested lakes. For good aquatic production, sediment C/N ratio should lie in the range 10 to 17.

Amongst dissolved nutrients, nitrogen and its role in fish nutrition is well known (Boyd, 1984). The amplitude of variation is wide in case of available-N in different *beels*, attributed to fluctuation in water level, climatic factors, soil reaction and types of vegetation, catchment ecology and characteristics of flood water entering into open *beels*. Aquatic ecosystem having 25-75 mg avail-N/100g soil is said be designated as medium to high productive. Available-P, on the other hand, in *beel* ecosystem is a limiting factor of production primarily because of its quicker utilization by emergent as well as rooted submerged hydrophytes and its fixation in acidic soil. Accordingly, its status is very poor in majority of the *beels* studied. Soil available P should be in the range 4.7 to 6.2 mg/100g for aquatic productivity which is of far lower order in the *beels* of India generally.

Potassium, the third major nutrient for aquatic production, is not a limiting factor in the *beel* ecosystem mainly that the basin sediment characteristics of most of the *beels* have old alluvial or newly alluvial type with predominance of illitic clay. Thus, optimum potassium level is being maintained for aquatic productivity.

Proper attention has to be given to micronutrients or secondary nutrients required for aquatic production, which is a neglected field so far. Huge amount of Fe^{+2} and Mn^{+2} ions are produced and come to water phase during anaerobic reduction in soil displacing Na^{+}, K^{+}, Ca^{+2}, Mg^{+2} ions from the clay exchange site, thus making them available for aquatic production. Phenomenal alteration in the surface properties are taking place owing to changes in redox potential, pH, content of electrolytes held by covalent bonding/electrostatic attraction, the above nutrient ions are easily be released into soil solution after submergence in floodplain with the onset of monsoon especially. Flood water influx also brings substantial amount of these nutrient ions into the *beels*. Soil Mn acts as a mineralizing agent for organic matter playing significant role in water productivity. Bottom sediment of fine texture with rich in organic matter can retain larger amount of micronutrient cations in the exchange sites.

Sulphur, an essential constituent of protoplasm and available to biotic organisms in the form of SO_4^{-2}, is being derived through microbial transformation of pyrites. In the process of anaerobic reduction, Fe^{+3} ion is reduced to soluble Fe^{+2} which precipitates in presence of H_2S to ferrous sulphide or even, FeS is produced by the reduction of SO_4 by anaerobic bacteria – a very important reaction especially in floodplain wetlands in controlling the toxicity of H_2S in the bottom sediment.

In *beels*, soil acidity is a common phenomenon. Soil organic matter contains reactive carboxylic, phenolic and amino acid groups which are capable of binding H^+ ion rendering soil acidity. Lime accentuates the availability of mud phosphate. A productive soil should contain 0.5 to 2.5% free $CaCO_3$ and if its amount is less than this particularly in *beel* system, it should be increased in soil by adding externally to raise aquatic productivity.

LIMNO-CHEMICAL FEATURES OF WATER

Amongst number of limno-chemical parameters, the important ones influencing productivity are water reaction, specific conductance, total dissolved salts, dissolved gases, alkalinity, hardness, chloride content and nutrient dynamics of water.

Dissolved oxygen (DO) is a prime important critical factor in natural waters. A good productive water should have DO concentration more than 5 mg/l. Free carbondioxide, a minor constituent of atmosphere but highly soluble in water is present optimally in general in *beel* ecosystem within the range 1.0-6.0 mg/l. At times, with increased microbial degradation of bottom organic matter especially during summer, its concentration goes beyond 12.0 mg/l as noticed in North Bihar *beels* like Brahampura, Kanti and Motijheel, some of the *beels* of Assam viz. Dikhowmomai, Ramnagar, Mer, Dighali and in some West Bengal *beels* showing sign of highly eutrophied ecosystem.

Water reaction in most of the *beels* in Assam, West Bengal as well as Bihar are near neutral to moderately alkaline. Water reaction is in conducive level year round for good aquatic production in most of the *beels* of India.

Wide range of variations is encountered in the level of specific conductance, total alkalinity, hardness, availability of Ca^{+2} and Mg^{+2} as well as chloride content. Spatial variations are pronounced phenomenally and the values are increased to a great extent with fluctuation in water level in association with degree of infestation of macrophytes and their decaying products.

Nutrient dynamics

In *beels*, nutrients enter the system through autochthonous as well allochthonous sources, the latter was more phenomenal in open *beel* depending on catchment characteristics. Phosphorus, the critical limiting factor in this ecosystem is hardly encountered in water phase barring initial monsoon months. Nitrogen, on the other hand is found maximum in water corresponding to the samples collected during monsoons. There is drastic fall in nutrient contents both in surface as well in column waters during peak pre-monsoon period might be due to quicker utilization by macrophytes. Again, substantial amount of available nutrients are noticed in the *beels* free from surface as well as submerged macrophytes (Das, 2003; Kuldeep Kumar, 1990).

Though decomposition of bottom organic matter including detritus (Das, 1998) are at peak in summer months, releasing nutrients into available forms, they are utilized at a faster rate both from soil as well as water phase by submerged and floating hydrophytes. So to overcome this, productivity profiles of these water bodies could be assessed only through stoichiometric determination of total –N as well as total-P in water. As, organic nitrogen occupies prime share in total-N, presence of total-N (µg/l) in water was overwhelming in these ecosystem especially during monsoon and post monsoon.

Silicate-silicon remains as silicate in natural freshwater which is in available form. Silica, being the structural constituent of diatoms and many sponges regulates their growth. in these ecosystem. Silicate-Si content was very poor during summer months and moderately present in monsoon and post-monsoon months to a low of 1.2 mgl^{-1} (Patari) and to a high of 12 mgl^{-1} in Haripur - open, supporting a moderate crop of Bacillariophyceae in these water bodies. Exceptionally high concentration of silicate-Si was found in Kulia *beel* even during March-May (18.9-24.0 mgl^{-1}) (Kuldip Kumar, 1990), otherwise it was low to moderate in most of the *beels* of West Bengal.

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Table 1. Limno-chemical features of water of some *beels* of India.

Beels	Temp. (°C)	Trans. (cm)	pH	DO (mg/l)	TA (mg/l)	NO_3-N (µg/l)	PO_4-P (µg/l)	SiO_2-Si (mg/l)
West Bengal								
Sarasanka	25.0-33.0	15-50	6.4-8.2	3.4-5.6	20-28	2-280	2-130	2.2-5.5
Bansdaha	19.5-32.8	90-168	6.8-8.6	4.2-9.2	88-112	2-10	2-210	1.0-3.9
Talbona	26.0-34.0	12-60	6.4-8.2	3.4-5.6	96-108	2-10	2-50	2.4-6.2
Haripur	26.0-35.0	25-120	6.9-7.9	7.2-10.8	88-96	2-30	2-50	5.2-1.2
Bhomra	19.5-31.0	130-200	8.3-8.7	4.4-11.2	130-192	10-340	5-170	0.4-6.8
Bhomra (SMF)	22.0-34.0	bottom	7.8-8.1	4.4-12.0	125-188	10-480	10-350	2.0-8.5
Assam								
Banskandi	20.0-30.0	30-94	6.0-7.6	7.0-9.0	20-36	Tr-70	Tr-10	2.5-8.5
Barchumati	16.0-24.0	Bottom	6.0-7.7	6.0-10.4	28-44	Tr-40	Tr-10	1.8-2.2
Sakaity	16.0-24.0	15-37	6.0-7.2	6.5-12.5	18-24	Tr-30	Tr-10	1.5-4.5
Langhari	14.022.0	10-26	6.0-7.2	4.0-6.8	28-45	Tr-20	Tr-10	2.2-4.6
Nabeel	15.0-23.0	bottom	7.0-8.2	7.5-16.7	39-60	Tr-10	Tr-10	0.4-2.0
N. Bihar								
Brahmapura	16.5-31.0.	45-160	6.5-8.2	1.6-14.0	155-610	100-500	Tr-8	11-19
Manika	15.0-33.0	35-165	7.3-9.4	1.0-12.0	80-130	20-160	Tr-10	5-17
Kanti	17.0-30.0	40-160	6.8-9.0	1.0-10.0	110-250	25-180	Tr-10	4-16
Motijheel	17.0-31.0	60-153	7.0-8.4	3.5-13.0	220-510	180-890	20-50	10-20

Table 2. Sediment characteristics of some selected *beels* of West Bengal

Beels	pH	Org-C (%)	Total-N (%)	C/N ratio	Avail-N (mg/100g)	Avail-P (mg/100g)
Sarasanka	5.52-6.13	3.20-4.44	0.18-0.35	13-23	58.05-63.20	Tr-0.30
Talbona	7.68-7.92	1.42-1.69	0.12-0.15	11-12	33.04-37.92	Tr-0.50
Haripur	7.57-7.95	0.95-1.77	0.10-0.12	10-15	24.08-36.66	Tr-0.64
Bansdaha	6.89-7.76	3.15-5.64	0.38-0.63	8-9	72.80-86.80	0.20-1.40
Kole	7.80-8.29	0.23-0.42	0.04-0.13	3-6	14.02-26.88	0.20-1.00
Bhomra	7.46-8.64	0.90-5.76	0.36-0.65	3-9	43.12-88.48	1.08-20.30
Bhomra (SMF)	7.35-8.10	0.72-3.82	0.35-0.78	2-5	56.85-94.57	1.25-26.54
Kola	6.09-6.96	2.50-3.09	0.25-0.34	9-10	58.80-82.90	2.05-10.40
Bhaluka	5.30-5.80	1.50-3.90	0.12-0.13	13-30	58.02-62.44	Tr-0.30
Patari	5.90-7.70	1.30-1.90	0.11-0.16	11-12	42.00-44.50	Tr-0.28
Nehali	5.20-7.00	6.20-10.90	0.16-0.20	39-55	72.50-109.20	Tr-1.60
Moranadi	5.70-5.80	1.20-1.50	0.17-0.20	7-8	54.00-62.50	Tr-10.30

SMF= Surface macrophyte free

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DETRITAL DYNAMICS AND ITS ROLE IN FLOODPLAIN WETLAND FISHERIES

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INTRODUCTION

Our country is naturally bestowed with approximately 2.5 lakh ha of wetlands resources spreading over the floodplains of two major river systems, namely Ganga and Brahmaputra. Compared to the vastness of the resources, the fish production from these resources is remarkably meager. It is known that wetlands are the most productive ecosystem on earth. Much of this very high primary productivity is contributed by lush growth of hydrophytes. To exploit these aquatic ecosystems as fisheries resource by transforming the huge amount of primary production in to secondary production the mechanism of energy flow operating in the system is to be understood.

The functioning of aquatic ecosystem, in general, centers on the cycling of organic carbon between living and nonliving components. The living biota of wetlands constitutes only a very small of the total organic matter of this ecosystem. Most of the organic matter in aquatic ecosystem is nonliving and is collectively called detritus. In wetland ecosystem, more of the energy fixed by autotrophic organisms is transmitted to other trophic levels from dead decomposing plant tissue (detritus) than from living tissue consumed by grazer.

DEFINITION

Detritus consists of organic carbon lost from any trophic level (egestion, excretion, secretion and so forth) or inputs from sources external to the ecosystem that enter and cycle in the ecosystem (allochthonous organic carbon). More simply, detritus is all dead organic carbon, distinguishable from living organic and inorganic carbon.

The detritus food chain is route by which chemical energy contained within detrital organic carbon becomes available to the biota. The definition of detrital food chain emphasizes the actual trophic linkages between the nonliving detritus and living organisms. The detrital food chain include the cycling of detrital organic carbon, both dissolved and particulate. to the biota by direct heterotrophy of dissolved organic carbon (DOC), chemoorganotrophy, or absorption and ingestion.

SOURCE AND FORM OF DETRITUS

Detritus consists of all nonliving organic matter, in both dissolved and particulate form. In aquatic ecosystems in general, organic matter consists of dissolved organic carbon compounds (DOC) and particulate organic compound (POC). The ratio of DOC to POC is usually 6:1. The basic source of organic matter in wetlands is through photosynthesis of autotrophs (autochthonous). The other source of organic matter in wetlands is allochthonous. Most of the allochthonous organic matter in wetlands is in dissolved form rather than particulate. Similarly, the very high primary productivity of wetlands enters the open-water region as dissolved organic matter. (Fig.1).

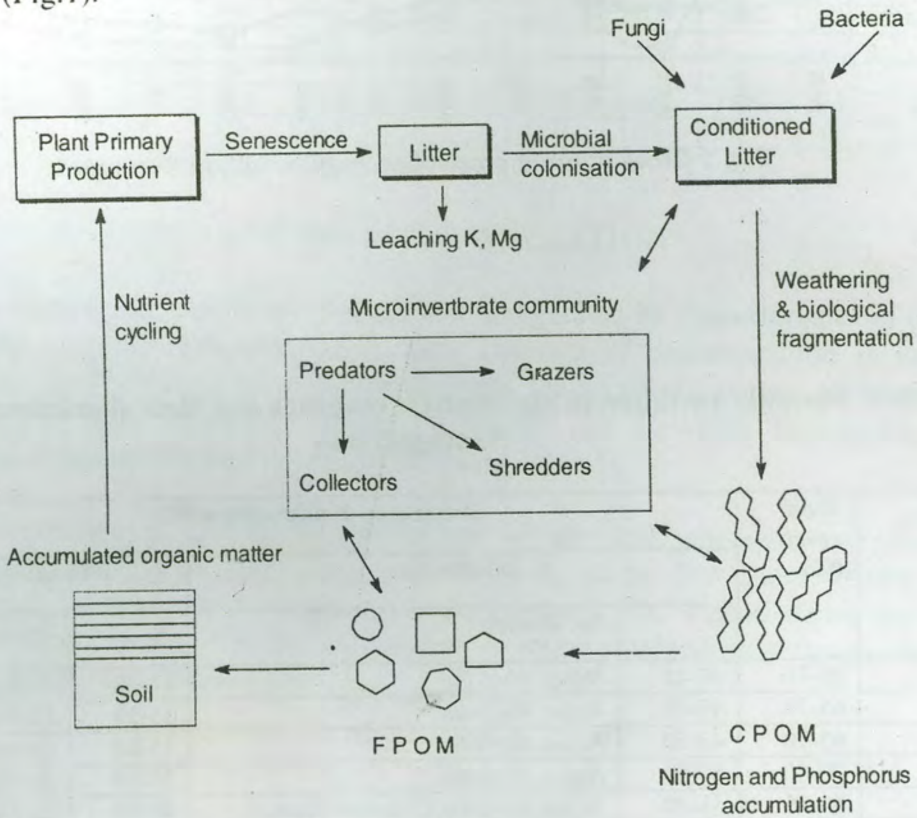


Fig.1. **Detrital dynamics**

WETLANDS ECOSYSTEM AND PRODUCTIVITY OF HYDROPHYTES

The floodplain wetlands are characterized by shallow water depth leading to very expansive littoral zone. This basic feature of wetlands favours the lush growth of hydrophytes. Macrophyte coverage of various *beels* (wetlands) ranged from 65-85% and peak growth recorded during the month of August-September (Table1). During peak growth, the biomass of submerged macrophytes on dry weight basis recorded was 545g m^2, while 2208 g m^2 was recorded for floating variety (Table 2). As a result, synthesis of organic matter by macrophytes is several times higher compared to their microscopic counterparts (phytoplankton) (Fig.2)

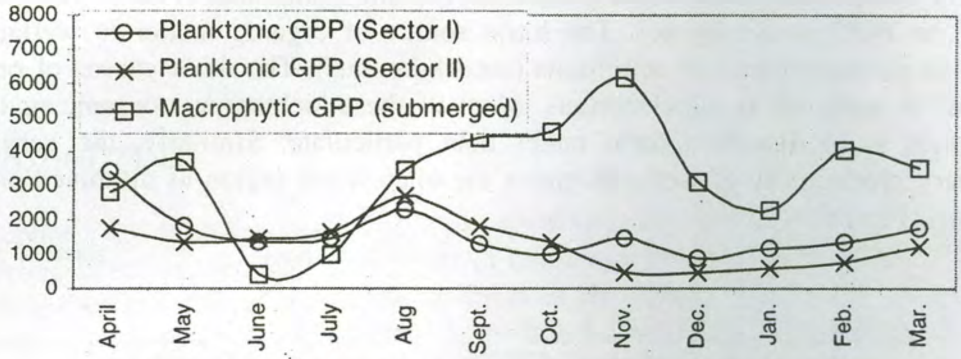


Fig. 2 Gross primary production ($mgCm^{-3}d^{-1}$) in Samaguri

Table 1: Monthly variation in macrophyte coverage and their dominance in Samaguri beel

Months	Weed cover (%)	Dominance of macrophyte (%)			
		Submerged		Floating	
		%	Sp. domint	%	Sp. domint
April	65-70	40-45	*Najas, Hydrilla*	15-20	*Eichhornia*
May	65-70	40-45	*Najas, Hydrilla*	15-20	*Eichhornia*
June	65-70	40-50	*Najas, Hydrilla*	15-20	*Eichhornia*
July	70-80	50-55	*Najas, Hydrilla*	25-30	*Eichhornia*
August	80-85	35-40	*Najas, Hydrilla,Ceratophyllum*	40-45	*Eichhornia*
September	70-80	35-40	*Ceratophyllm, Hydrilla*	40-45	*Eichhornia*
October	70-80	35-40	*Hydrilla, Ceratophyllum*	35-40	*Eichhornia*

November	65-70	30-35	*Hydrilla, Ceratophyllum*	35-40	*Eichhornia*
December	65-70	30-35	*Hydrilla, Ceratophyllum*	35-40	*Eichhornia*
January	65-70	30-35	*Potamogeton, Valllisneria, Hydrilla, Najas*	30-35	*Eichhornia*
February	65-70	30-35	*Potamogeton, Valllisneria, Hydrilla, Najas*	30-35	*Eichhornia*
March		50	*Potamogeton, Valllisneria, Hydrilla, Ceratophyllum, Najas*	20-25	*Eichhornia*

Table 2: Monthly variations in macrophyte biomass, oven dry basis (g m^{-2})

Station	Months										
	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
1	236	274	350	**684**	**1741**	**2340**	**1760**	**1380**	**1868**	**1400**	**1793**
2	98	220	1004	685	407	460	500	480	700	420	280
3	-	266	248	500	413	420	420	320	260	280	280
4	194	184	251	424	144	400	360	280	460	440	160
5	146	366	374	403	438	**2414**	**1640**	**1500**	**1520**	**1740**	**480**
6	373	418	726	511	257	**2163**	**1701**	180	-	280	100
7	273	366	546	652.	190	**1937**	**1678**	**1600**	460	140	60
8	231	345	486	858	**2675**	**2140**	**1410**	**1400**	380	300	256
9	315	216	162	325	-	-	-	-	-	-	-
	1348	**778**	**709**	-	-	-	-	-	-	-	-
Total	3214	3433	4856	5042	6265	12274	9469	7140	5648	5000	3409
Mean	321	343	486	560	783	1534	1184	892	706	625	426

Bold figures are floating macrophytes

DECOMPOSITION AND DETRITUS FORMATION

Decomposition is a complex process that is regulated by characteristics of the litter and by external environmental factors. The rate of decomposition is important because it affects the release rate of nutrients, the accumulation rate of litter and the quality of litter substrate. Submerged variety like *Hydrilla*, *Vallisneria* decays rapidly compared to the floating *Eichhornia*.(Table 3).

Decomposition is a complex interaction of physical, chemical and biological processes and has at least two phases (Table 4). In the first phase, loosely bound nutrients, such as Ca, K, Mg are rapidly released. The second phase consists of mechanical fragmentation by wind and wave action and biological fragmentation by invertebrates called detritivores.

Table 3 . Detritus formation rate (%) in different macrophyte species

No	Macrophyte	Loss of dry matter (%)		
		1st week	3rd week	6th week
1	*Eichhornia*	24.38	64.7	87.31
2	*Hydrilla*	73.04	99.5	-
3	*Najas*	83.52	98.2	98.96
4	*Potamogeton*	51.69	92.24	98.78
5	*Ceratophyllum*	87.24	89.86	98.04

Table 4. Some factors of litter decomposition rate.

Properties	Rate of decomposition	
	Fast	Slow
Intrinsic	Low lignin	High lignin
	High phosphorus	Low phosphorus
	High nitrogen	Low nitrogen
	Low carbon to nitrogen	High carbon to nitrogen
	Low carbon to phosphorus	High carbon to phosphorus
	Low tannic acid	High tannic acid
	Leaf tissue	Woody tissue
Environmental	Microbes present	Low microbial biomass
	Shredders present	Low shredder biomass
	Flowing water	Stagnant water
	High water temperature	Low water temperature
	Water with high pH	Water with low pH

FISHERIES OF WETLANDS AND GUT CONTENTS

Wetlands are the abode of varieties of fish fauna. Diversified ecological features make it a suitable habitat for various fish groups. Fishes use wetlands for various purposes including feeding, breeding, nursery and refuge. The following diagram depicts the fishery of two ecologically different wetlands (Fig.3) To understand the role of detritus in sustaining the fish biomass, it is pertinent to study their trophic composition. The figure indicates that bulk of the fishery is contributed by major and minor carp and one clupeid species. The gut contents analysis of the dominant fish species shows that plant origin components constitute 49-82% of the food consumed (Table 5) indicating the efficiency of these fishes to utilize this food resources. But none of these species directly consume the hydrophytes when they are alive. The huge mass of autotrophs (macrophytes) enters the fish gut only when they are dead or senescned and formed detritus. Thus, it emphatically proves that detrital load provide the nourishment of many of the commercially important fishes living in the ecosystem.

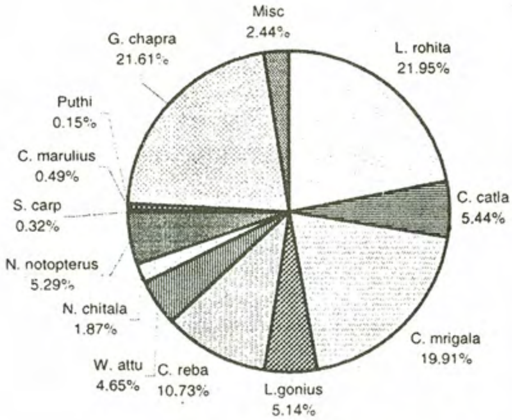
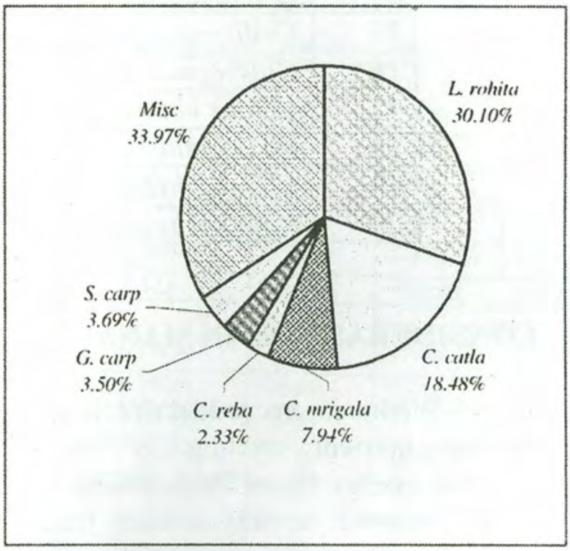


Fig. Species spectrum of Samaguri beel (2002-03)



Seasonally open beel	Closed beel

Fig 3 Fish species composition of two typical wetland ecosystem

Table 5. Food habits of some wetland fishes

Sl no	Species	No. examined	Plant food %	Animal food%
1	*Labeo rohita*	55	78.5	10.75
2	*L. calbasu*	16	76.8	1.2
3	*L.gonius*	25	76	5
4	*L.bata*	16	78.7	-
5	*Cirrhinus mrigala*	24	90	-
6	*C.reba*	224	82.3	1.4
7	*A.mola*	258	81	1.1
8	*Catla catla*	21	41.6	58.4
9	*Gudusia chapra*	48	79	14.6
10	*Puntius sophore*	333	58.2	29.2

11	*P. sarana*	66	69.2	24.3
12	*Rohtee cotio*	356	32.4	56.5
13	*Oxygaster bacaila*	69	11.9	78.1
14	*Colisa fasciatus*	38	49.4	44.6
15	*Callichrous pabda*	54	13.1	85.2
16	*Glossogobius giuris*	25	13.2	86.2
17	*Mystus vittatus*	20	14.4	81.1
18	*M. cavasius*	27	11.4	82.5
19	*Channa striatus*	25	4	96
20	*Notopterus chitala*	30	15	80

CONSIDERATIONS IN MANAGEMENT

Wetlands are productive because the base of biotic pyramid is large and diverse nutrient cycling is dynamic. Because energy flows from lowest levels of the pyramid, detritus sustains much of the biomass and structure of the community (Fig.4). Furthermore, detrital processing releases and transforms nutrients tied up in plant tissues and make them available for uptake by wetland flora and .fauna. Management, particularly hydrological manipulations, may enhance energy and nutrient flow in wetlands. Detritus becomes an important energy source when wetlands are flooded. Inundation triggers the dynamic process of litter decomposition. Maintenance of long term hydrological regimes is the key to maintaining the balance between litter decay and accumulation and to sustaining the biotic components of detrital processing and wetland productivity.

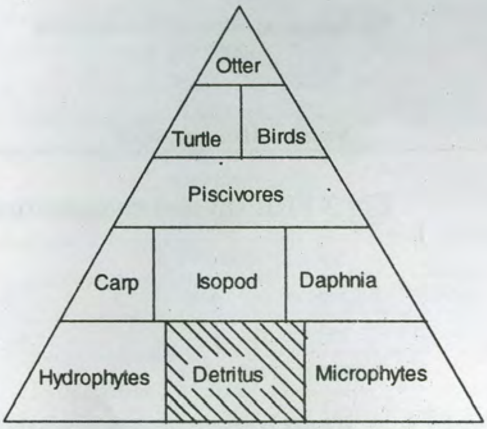


Fig 4. Trophic pyramid operating in wetlands

As it is clear that detritus plays the central role in energy transfer, their exploitation through the secondary production in terms of fish biomass is to be judiciously planned. To harness maximum production from wetland resouce more number of detritivore fishes is to be stocked.

ENERGY DYNAMICS AND ESTMATION OF PRODCTION POTENTIAL OF FLOOD PLAIN WETLANDS

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INTRODUCTION

The energy source for living organisms is sun, which releases energy as a pulsating field of electromagnetic radiations in the wavelength range of 1 to 135000 A^0. Only a small fraction of this energy in the wave length range 3800 A^0 to 7800 A^0 is captured by the photosynthetic organisms and is transformed into potential chemical energy and stored as plant tissues. The quantitative assessment of energy fixed by producers gives a measure of the potential energy resource of the system and its pattern of utilization by consumers at various levels reflects the efficiency of management. A sound knowledge of the two efficiencies is the primary requirement for getting maximum energy harvest from the system by adopting various management norms. Studies on the energy dynamics of wetlands located in various states have been studied by Jhingran and Pathak (1987), Pathak et. al. (1985), Pathak (1990 and 2000), Vass (1989), Yadav (1989), Jha (1997), Das (2000) etc.

ENERGY TRANSFORMATION THROUGH PRIMARY PRODUCTION

The rate of energy transformation from solar electromagnetic waves into chemical energy by producers gives a dependable parameter for assessing the potential energy resource of any aquatic system.

In wetlands, which are generally infested with aquatic macrophytes, the primary production is contributed both by phytoplankton and macrophytes. Both the producers sysnthesise energy rich organic compounds utilizing solar radiation and nutrient material through photo synthetic reaction.

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

$$n\ CO_2 + n\ (\text{ H Donar }) \longrightarrow (\ CH_2O\ )n + n \text{ Oxidized Donar}$$

This redox process is endregonic in nature and consequently through this process plants can store large amount of energy in the form of energy rich organic compounds either carbohydrates or proteins. As fishes feeding at various trophic levels utilize the energy stored by producers the final productivity of the system depends on the magnitude of this energy.

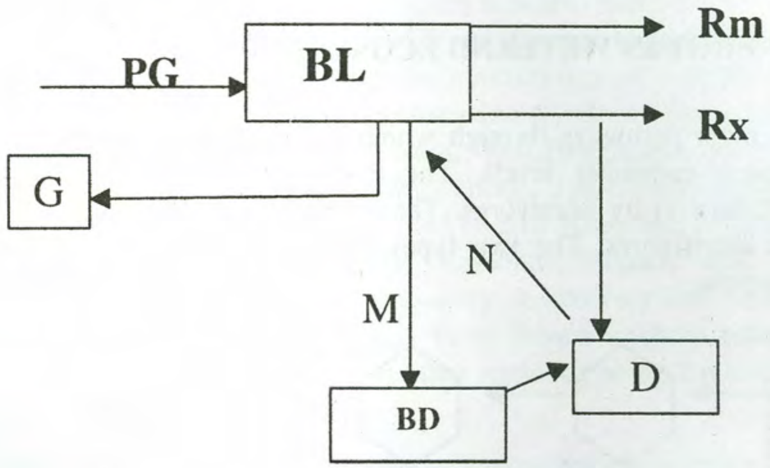
The light energy available on the water surface, its rate of transformation and photosynthetic efficiencies in different wetlands have been presented in table – 1. The rate of energy transformation by phytoplankton in different wetland ranged between 3560 $Calm^{-2}day^{-1}$ and 19908 $Calm^{-2}day^{-1}$ (0.19 to 1.04 % of light) while that by macrophytes between 18790 $Calm^{-2}day^{-1}$ to 48502 $Calm^{-2}day^{-1}$ (1.01 to 2.44 % of light). Thus out of a total 29300 $Calm^{-2}day^{-1}$ to 57815 $Calm^{-2}day^{-1}$ energy fixed through primary production in wetlands (1.58 to 3.09 % of light) the contribution of phytoplankton was only 9.3 to 35 % and the rest 65 to 90.7 % was contributed by macrophytes. Studies made in a number of water bodies by Natarajan and Pathak (1985) have shown the photosynthetic efficiencies ranging between 0.202 to 0.682 and it rarely exceeded 1 % of light. The rate of energy transformation and photosynthetic efficiency in the wetland was thus comparatively higher than many aquatic ecosystems. Part of the gross energy fixed by producers is used by them for their own metabolic activities and the rest is lost as heat of respiration and hence according to the first law of thermodynamics.

Solar energy fixed by producers	=	Chemical energy stored by producers	+	Heat energy of Respiration

Studies in several wetlands have shown that 56.2 to 78.3 % of the energy fixed by producers was stored by them.

DYNAMICS OF MACROPHYTES IN WETLANDS AND DETRITUS ENERGY

Most of the wetlands in the country are heavily infested with macrophytes and as they are the main energy converters it is very essential to know the role of these producers in ultimate harvest of energy from these systems. The dynamics of macrophytes is diagrammatically represented below.



PG = Gross production	Rm = Respiration
M = mortality	Rx = Excretion of organic matter
G = Grazing	BD = Dead macrophyte (Detritus)
D = decomposers	BL = living macrophytes
N = Nutrient flow	

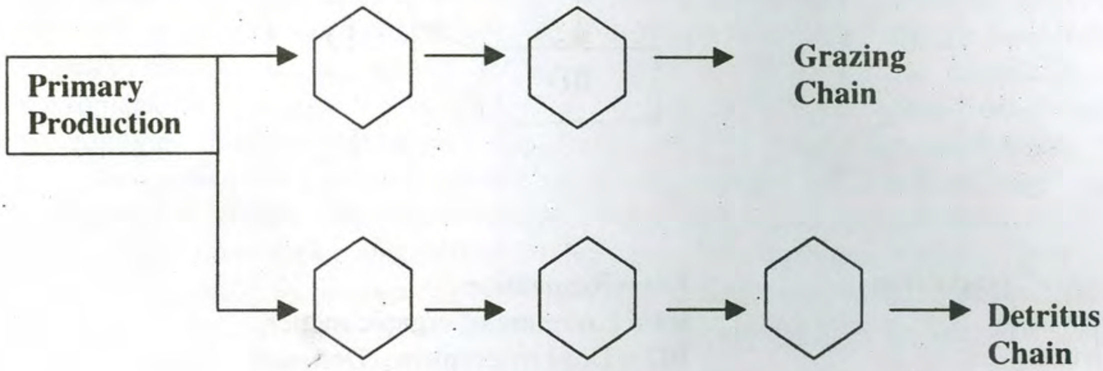
Most of the macropphytes in the systems are not directly grazed by herbivores and the unused material gets deposited at the bottom after their death. From the above diagrammatic representation it is obvious that the energy input in the living macrophytes is through gross production while losses are grazing herbivores (G), excretion of organic matter (Rx) and respiration. The loss of energy being of very low order the entire energy of macrophytes gets deposited at the bottom as detritus pool (BD).

$$\mathbf{BL = PG - G - Rm - Rx \longrightarrow BD}$$

Some amount of detritus is again is used by decomposers (D) and nutrients are released for further circulation (N). Studies made in number of wetlands have shown that they are very rich in detritus energy being of the order of 10.8 x 10^5 to 28.0 x 10^5 $Kcalha^{-1}$. Thus in order to get maximum energy harvest from wetlands this vast source of energy must be properly utilized.

FLOW OF ENERGY IN WETLAND ECOSYSTEMS

There are two main pathways through which the primary energy fixed by producers flows to different consumer levels. The first of these involves grazing of green organisms (producers) by herbivores. The second pathway involves consumption of detritus by the detritivores. The two types of food chains are shown below in Y – shaped flow models.



The potential energy resource, actual energy harvest as fish and the conversion efficiencies in several wetlands have been presented in Table – 2.

All the wetlands have shown very high efficiency of energy transformation (1.60 to 3.09 %) and the fish production potential was also high in all of them ranging between

765000 $Kcalha^{-1}yr^{-1}$and 1591202 $Kcalha^{-1}yr^{-1}$.But against such high potential energy resource the actual energy harvest from these wetlands ranged from 51600 to 353400 $Kcalha^{-1}yr^{-1}$.

DETRITUS ENERGY AND ITS UTILIZATION IN WETLANDS

The detritus energy, energy harvest, contribution of detritus feeders and conversion efficiencies in wetlands of West Bengal, Assam, Bihar and Uttar pradesh have been presented in Table – 3. All the wetlands are very rich in bottom organic deposits and detritus energy ranging from 1080000 to 2800000 $Kcalha^{-1}$. Comparatively wetlands of West Bengal, Assam and Bihar have shown better energy harvest (228400 to 6922000 $Kcalha^{-1}yr^{-1}$) than the wetlands of U.P. (51600 to 353000 $Kcalha^{-1}yr^{-1}$). The contribution of detritus feeders in the wetlands of other states was also much higher (28.0 to 48 % of the total) than those U.P. (9.7 to 26.7 %). Exept Rohua, Gujartal, Bhaghar, Sangara, Ratnapur, Sonaari, Aheerwna and Saman the contribution of detritus feeders was less than 10 % in the total energy output. The conversion efficiency from detritus to fish was comparatively higher in the wetlands of Assam, West Bengal and Bihar (10.2 to 24.7%) there by showing better utilization of detritus energy and consequently these wetlands have also shown better utilization of potential (18.2 to 50%). But in case of wetlands of U.P except Gujartal, Bhaghar, Sangara, Ratanpur, Sonari, and Aheerawan the conversion efficiency from detritus to energy harvest was very low (less than 10%) as a result only the above mentioned wetlands have shown slightly better utilization of potential (12.0 to 24.2%), the utilization in other wetlands being 2.6 to 8.7% only.

The above observations clearly reflects that the energy harvest is better from wetlands if the vast detritus energy is properly utilized. Thus in order to enhance energy harvest from wetlands the proper utilization of detritus energy is an important tool.

EVALUATION OF FISH PRODUCTION POTENTIAL

Many workers have used the energy flow models for calculating the potential energy resource or fish production potential in aquatic ecosystems. The energy available at the n^{th} level is $\lambda m/\lambda n$ and this efficiency is more or less a constant figure(almost 10%) and thus according to the second law of thermodynamics almost 90% of the energy is lost in passing from one trophic level to the next. The production potential of any water body directly depends on the efficiency with which producers transform and store solar energy into chemical energy because this is the available energy which flows to other higher trophic levels . In natural aquatic systems which have wide spectrum of fish belonging to various trophic levels and keeping in view that almost 90% of the energy lost in passing from one level to the other the fish production potential can be taken as 1% of gross or 0.5% of net energy fixed by producers .The fish production potential of all the wetlands in the present study has been estimated by taking 0.5% of net energy fixed by producers as energy available at fish level.

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Table –3. Utilization of detritus energy and production efficiencies in various wetlands.

Wetlands	Energy available as Organic Detritus (Kcal ha^{-1})	Energy harvest as fish (Kcal ha^{-1})	Contribution of Detritus feeder (Kcal ha^{-1}dy^{-1}	Conversion efficiency	
				Detritus to fish (%)	Potential to fish
Kuliabeel (West Bengal)	26.00.000	4.04.569	1.61.827	16.2	26.5
Mediabeel (West Bengal)	28.00.000	2.84.400	79.632	10.2	18.2
Dheerbeel (Assam)	22.40.000	3,96,000	1,74,240	17.8	30.0
Bilmukh (Assam)	28.00.000	6.92.028	3.32.173	24.7	50.0
Muktapur (Bihar)	24.00.000	4.91.518	2,06.442	20.5	35.0
Rewati (U.P.)	20.00.000	1.35.240	17.312	6.7	8.7
Mundiri (U.P.)	22.50.000	59.280	5.809	2.6	6.5
Rohua (U.P.)	11.58.000	98,400	11.808	8.5	12.0
Gujartal (U.P.)	10.80.000	1.23.400	22.212	11.4	15.0
Naraini (U.P.)	14.22.000	70.000	8.260	4.9	7.2
Raini (U.P.)	12.20.000	51.600	4.483	4.2	6.7
Bhaghar (U.P.)	23.50.000	3.53.400	70.780	15.0	22.4
Sangara (U.P.)	16.11.304	2.22.360	40.025	14.4	20.0
Ratnapur (U.P.)	14,91,176	1.52,160	24,345	10.2	18.0
Sonari (U.P.)	15.89.814	2.55.960	68.363	16.1	24.2
Kuthala (U.P.)	25.88.265	2.53.650	45.930	9.8	18.0
Aheerawan (U.P.)	13.50.000	1,99,680	43,930	15.2	22.5
Samari (U.P.)	16.40.000	1.18.080	12,044	8.2	10.8

TABLE – 1. Energy Transformation through Primary Production in Different Wetlands

Ecosystems	Solar energy Penetrating The Water Surface (Calm^{-2}day^{-2})	Rate of Gross Energy Transformation By Producers						Energy Assimilated by Producers % of Gross (Total)
		Total		Phytoplankton		Macrophytes		
		Energy (Calm^{-2}day^{-2})	Efficiency (%)	Energy (Calm^{-2}day^{-2})	Efficiency (%)	Energy (Calm^{-2}day^{-2})	Efficiency (%)	
Rewati	1912000	55974	2.93	19908	1.04	369065	1.89	66.2
Mundian	1912000	36883	1.93	6885	0.36	29998	1.57	59.2
Rohuatal	1892000	34939	1.85	11898	0.63	23041	1.22	56.2
Gugartal	1892000	32938	1.74	8487	0.45	24449	1.29	60.0
Narainital	1858000	37070	2	11758	0.63	25312	1.37	62.9
Lohsar	1872000	29905	1.6	7551	0.4	22335	1.2	64.0
Rainital	1872000	30687	1.64	11895	0.63	18790	1.01	60.0
Bhaghar jheel	1862000	51555	2.77	4846	0.26	46709	2.51	73.3
Sangara	1862000	36702	1.97	5272	0.28	31429	1.69	72.9
Ratnapur	1850000	29300	1.58	4267	0.23	26180	1.35	69.3
Sonari	1850000	33005	1.78	6049	0.33	26008	1.45	77.1
Kuthala	1868000	51442	2.75	7939	0.42	43502	2.33	70.7
Bahausi	1868000	57815	3.09	12113	0.65	45701	2.44	66.2
Aheerawan	1878000	31483	1.68	3560	0.19	27923	1.49	67.8
Saman jheel	1878000	36437	1.94	7549	0.4	28890	1.54	71.2

Photosynthetic Energy Transformation

Ecosystems	Visible Radiant Energy ($Kcal ha^{-1} yr^{-1} x 10^{-6}$	Auto tropic energy fixed by producers ($Kcal ha^{-1} yr^{-1} x 10^{-4}$)	Photosynthetic Efficiency %	Fish Production potential ($Kcal ha^{-1} yr^{-1}$)	Actual Energy Harvest as Fish ($Kcal ha^{-1} yr^{-1}$)	Conversion Efficiency (%)		
						Photosynthesis to fish	Light to Fish	Potential to Fish
Rewati	**6979**	**20420**	2.93	1540200	**135240**	0.066	0.0019	8.7
Mundiari	**6979**	**13280**	1.93	907800	**59280**	0.045	0.00085	6.5
Rahuatal	**6906**	**12450**	1.85	816000	**98400**	0.077	0.0014	12.0
Gugartal	**6906**	**13530**	1.74	820896	**123400**	0.102	0.0018	15.0
Naraini	**6782**	**11530**	2.00	969000	**70000**	0.052	0.001	7.2
Rainital	**6833**	**11200**	1.64	765000	**51600**	0.046	0.00075	6.7
Lohsar	**6833**	**11200**	1.60	795600	**74400**	0.068	0.0011	9.3
Bhaghar	**6796**	**18817**	2.77	1570800	**353400**	0.188	0.0052	22.4

Sagara	**6796**	**13396**	1.97	1111200	**222360**	0.166	0.0033	20.0
Ratnapur	**6752**	**10694**	1.58	844560	**152160**	0.142	0.0022	18.0
Sonari	**6752**	**12047**	1.78	1057800	**155960**	0.212	0.0038	24.2
Kuthla	**6818**	**18776**	2.75	1509960	**253680**	0.135	0.0037	16.8
Bahausi	**6818**	**21102**	3.09	1591202	**203640**	0.096	0.0030	12.8
Aheerwan	**6855**	**13316**	1.68	887400	**199680**	0.150	0.0029	22.5
Saman jheel	**6855**	**13300**	1.94	1077960	**118080**	0.089	0.0017	10.9

ROLE OF SOIL QUALITY IN *BEEL* ECOSYSTEM

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INTRODUCTION

Soil is a major component of any aquatic environment, which not only holds water for aquatic animals but also enriches the water body with various nutrients required for biological production. A series of physical, chemical, biochemical and microbial reactions continuously take place at bottom soil resulting in release of different nutrient elements to overlying water. A dynamic equilibrium is maintained between the sediment and water due to their interdependence and thereby exerts a favourable influence on the environment for aquatic animals. It is, therefore, necessary to have a proper knowledge of the more important physical and chemical properties of soil that influence the productivity of any water body.

Soils of floodplain wetlands receive an additional input in terms of organic matter, inorganic minerals and silt and clay through precipitation, incursion of river water and washings from the catchments areas. Moreover, most of the floodplain wetlands are infested with macrophytes, which after death are deposited at the bottom and undergo decomposition. Consequently, the nature and properties of bottom soil of such water areas changes from year to year. Therefore, soils of such water bodies should be analysed every year in order to determine their actual productivity. The most important physical and chemical properties of soil influencing the productivity of floodplain wetlands are as follows:

Texture

Soil texture is an indicator of the proportionate composition of mineral fractions in soil and is grouped into sand, silt and clay depending on the particle size. Clay particles, smallest in size (< 0.002 mm dia.) are colloidal in nature and exhibit colloidal properties like adsorption and exchange phenomenon in soil. These fraction along with organic matter contents of the soil influence the water holding capacity, exchange of nutrients and fertility status of soil. Sand (>0.02 mm dia.) and silt (0.002-0.02 mm dia.) particles are not very important from the nutritional point of view but perform a very important role in gas exchange and nutrient movement through soil phase to solution phase by providing the required passage to them. Both sandy and clayey soils are not desirable as in the former nutrients are lost due to heavy leaching while in the later, high adsorption capacity impoverish the water from all its nutrients. Loamy soils with a balanced composition of sand (23-52%), silt (28-50%) and clay (7-27%) are considered most productive because they are not too much adsorptive to impoverish water of all its nutrients and at the same time do not permit excess loss of nutrients

Soil reaction (pH)

pH of soil is one of the most important factors for maintaining the productivity of any water body since it controls most of the chemical reactions. The availability of nutrient elements native as well as added, rate of mineralization of organic matter, fixation of P and other elements and growth and survival of different biotic communities are greatly influenced by pH. Soils are classified in to acidic (pH < 7.0), neutral (pH 7.0) and alkaline (pH > 7.0) according to its pH or H^+ ion concentration. When sediments contains high organic matter with slower decomposition rate, acidity develops due to humic and short chain fatty acids leading to less productivity Most of the floodplain wetlands soils exhibit wide variation in soil pH (4.2-8.5) in different parts of the country. Soil pH in the range of 6.5-7.5 is considered ideal.

Organic matter

Soil organic matter plays a dominant role in maintaining the biological productivity of aquatic ecosystem. It acts as a source of energy for the microbes participating in various biochemical processes resulting release of different nutrients, influences the physical, chemical and biological activities in soil, improves soil structure, aeration, increase water holding capacity, buffering and exchange capacity in soil including solubility of soil minerals. It also serves as a storehouse of various nutrients essential for biological production and as food source for benthic feeding fishes and invertebrates. Soils of floodplain wetlands contain more organic matter than upland field due to accumulation through autochthonous as well as allochthonous sources. Soils having less than 0.5% organic carbon are considered low productive while those in the range of 0.5-1.5% and 1.5-2.5% are considered medium and high productive respectively.

C/N ratio

The carbon to nitrogen (C/N) ratio of soil influences the microbial activity of soil to a great extent and thereby effects the rate of release of nutrients from organic matter. If the C/N ratio is very wide (> 20) most of the mineralized nitrogen will be consumed by the soil micro organisms for their own sustenance. Most productive range of C/N ratio is 17:1 to 10:1. Below 10:1 decomposition is very slow and consequently availability of nitrogen is not up to satisfaction.

NUTRIENT STATUS

A large number of elements are required for biological production. Among these nitrogen, phosphorus and potassium are termed as primary nutrient elements, calcium, magnesium and sulphur are termed as secondary nutrient elements and boron, copper, manganese,zinc, molybdenum, iron and cobalt are termed as micronutrients on the basis of their requirement.

Nitrogen

Nitrogen being a basic and primary constituent of protein is required to stimulate primary production in aquatic environments and is essential for the formation of living matter. In soils nitrogen occurs almost entirely in organic form, which is gradually mineralized, to soluble inorganic nitrogenous compounds (NH_4, NO_3, NO_2) by obligate as well as facultative anaerobes and subsequently utilized by fish food organisms. It is the easily decomposable form of organic nitrogen known as available nitrogen which is important in aquatic productivity. For any productive soil available nitrogen must be above 250 ppm. Available nitrogen status of most of the floodplain wetlands soils are conducive for biological production.

Phosphorus

Phosphorus is another element essential for assimilation of nitrogen into cellular matter besides respiration, cell division, metabolism, growth and synthesis of protein. It is considered a key element in maintaining the productivity of beel ecosystem. In soil, both organic and inorganic forms of phosphorus occur but organic-P is of little significance in supplying phosphorous to primary producers because of its slower rate of liberalization under anaerobic condition at the bottom in aquatic ecosystem. The native phosphorus status of most soils is rather low compared to nitrogen and potassium. Moreover, inorganic form of phosphorus becomes unavailable as insoluble ferric as well as aluminum and calcium phosphates under acidic and alkaline condition respectively. A productive soil must have above 30 ppm of available phosphorus. Sediments of most of the *beels* are poor in available phosphorus.

Potassium

Potassium helps in the formation of protein, chlorophyll and in stimulating the growth of aquatic plants. Compared to nitrogen and phosphorus, the importance of potassium in aquatic production is less recognised due to its low requirement. Potassium usually occurs in greater concentration in soils and only a fraction of 1-2% remain in easily available form. The available form exhibits equilibrium with relatively unavailable and slowly available form comprising of 90-98% and 1-10% of the total potassium respectively. Further, the readily available potassium remain in soil solution and in exchangeable form. The exchangeable form remain adsorbed on soil colloids and the soluble form in the soil solution maintain a dynamic equilibrium and removal of one form or the other, cause restoration of the equilibrium with the conversion of one form to another. In general potassium availability is sufficient in Indian soil as well as water, but soils of floodplain wetlands may be deficient in available K due to the presence of profuse macro vegetation.

Calcium, magnesium and sulphur

Calcium, magnesium and sulphur are termed as the secondary nutrients in aquaculture. Calcium is an integral part of the plant tissues. Sulphur is an essential constituent of protoplasm. Ca influences the concentration of $CO2$ in water and Mg. Calcium also acts to increase the availability of other ions in water and in general ameliorates the chemical conditions of water. Calcium is generally present in soil as calcium carbonate. The amount of exchangeable phosphorus in the sediment is inversely related to the calcium carbonate- organic matter ratio so that in highly organic soil with low calcium soluble phosphorus remain adsorbed in exchangeable forms and when sediment is very low in organic matter and high in calcium, phosphorus is fixed as insoluble precipitate. In floodplain wetlands large amount of Ca, Mg and sulphur are added with the floodwater. Therefore availability of these elements is more in floodplain wetlands than in upland soils.

Micronutrients

Micronutrients are essential for healthy growth of phytoplankton. But presence of excess amount of some micronutrients may directly or indirectly affect the growth of fish food organisms. Availability of other nutrient elements is also influenced to a great extent by micronutrients. Since floodwater washings of catchment areas and river water enter in reservoir and floodplain wetlands amount of some micronutrients may exceed toxic limit. Detailed studies on the micronutrients status in soil and water of aquatic ecosystem are needed.

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MANAGEMENT OF SEWAGE FED AND ESTUARINE WETLANDS (BHERIES) IN THE FLOOD PLAINS AND DEFUNCT RIVER BEDS OF WEST BENGAL, FOR ENHANCING AQUA CROP PRODUCTION

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INTRODUCTION

The flood plain wetlands of the Hooghly-Matlah and Ichhamati estuaries spreading over an area of around 40000 ha in 24 Parganas(North and South) districts, are important fishery resources of West Bengal. The famous sewage fed east Kolkata wetlands situated in the floodplains and basin of the defunct Bidyadhari river , spreading on an area of slightly less than 4000 ha, receive large volume of city sewage, present a unique example of very low cost waste utilization through aquacrop production. The whole wetland system, however, demonstrate ecotypic differences and the aqua crop production system varies accordingly.The piscicultural activities in these wetlands not only ensure sustained supply of fish and shell fish to Kolkata market but also provide employment to a large number of rural people and according to a recent report about 26,000 persons are directly involved in-different piscicultural activities in the freshwater sewage-fed bheri system alone.

TYPES OF ESTUARINE WETLANDS

Based on the salinity the bheries can basically be categorized as :-

1. Freshwater bheries
2. Saline bheries

The freshwater (sewage-fed) bheries - may be of three types:

i) Strong sewage-fed wetlands
ii) Moderately diluted sewage-fed wetlands and
iii) Diluted sewage -fed wetlands.

The Saline bheries

As per Saha *et.al.*,(1986) the saline bheries, depending upon the water salinity, may be classified into following 3 categories :-

i) Low-saline bheries, the salinity never exceeds 10 ppt.
ii) Medium- saline bheries, the salinity does not generally exceed 20 ppt.
iii) High -saline bheries, the salinity may even exceed 30 ppt but never drops down below 6 ppt.

There has been, however, considerable changes in the salinity patterns over the period of about two decades and the salinity zones are now required to be freshly categorized as per the changed salinity regime. Some of the low- and medium saline wetlands (e.g., those at Machhi-bhanga, Haroa, Kulti, Minakhan, Malancha etc.) receive diluted sewage mixed saline water and therefore, may be categorized as saline sewage fed wetlands.

FISH AND PRAWN SPECIES REARED IN DIFFERENT SYSTEMS

A. *In freshwater sewage-fed bheries :*

Catla catla, Labeo rohita, Cirrhinus mrigala, Hypophthalmichthys molitrix, Cyprinus carpio, Oreochromis niloticus, O. mossambicus. Recently some farmers are stocking *Labeo bata*. The giant freshwater prawn *Macrobrachium rosenbergii* is also being tried by some of the farmers. The grass carp , *Ctenopharyngodon idella* is generally not reared. Miscellaneous species of fishes like *Channa punctatus, C. striatus, Glossogobius guiris, Chanda* spp., *Mystus* spp. and *Puntius* spp. are also encountered in these bheries.

B. *In saline bheries :*

Previously tiger shrimp, *Penaeus monodon* was the main component along with different species of mullets like *Liza parsia* (in the low, medium and high saline zones). *L. tade and Mugil cephalus* (in the high saline zone). Fishes entering with the ingress water like those of *Lates calcarifer, Mystus gulio, Glossogobius guiris, Elutheronema tetradactylum, Gobioides rubicundus, Scatophagus argus etc.* and miscellaneous species of prawns (e.g., *Metapenaeus spp.,Penaeus sp, Parapenaeopsis sp. etc.),*were also being grown in the high and medium saline zones. The production was principally dependent on the stocking material entering with the ingress water and virtually there was no stocking system save and except for the tiger shrimp in high- and medium saline zones.

During the last fifteen years or so the whole system has changed altogether along with changed salinity regime and partial adoption of scientific culture system. The decline in water salinity has led to the adoption of carp culture in the low and medium saline zones. Indian major carps, silver carp and bata are reared in many wetlands in these zones. Very recently the farmers in these two saline zones are stocking giant freshwater prawns though not in a very regular manner. Alongwith monodon and parsia most of the farmers are stocking Nile tilapia or mossambicus. Both the tilapia species ,however, are auto stocked also in many of these wetlands. In high saline bheries also many of the farmers stock , tilapias along with mullets and tiger shrimps. Breeding and recruitment of both the species of tilapias have been observed in some high saline bheries.

THE PRODUCTION SYSTEMS

In freshwater sewage-fed wet-lands , which are shallow water bodies, the sewage is drawn in by regulating the flow of water through wooden sluices. Fifteen to 25% of water is exchanged every fortnightly or as per the requirement. The wetlands are generally stocked heavily and sometimes the stocking density may even exceed 50,000/ha. The culture system may be called a "continuous stocking and harvesting system" in which the stock is continuously being replenished after harvesting . Since the whole system of production is based on utilization of nutrient rich sewage effluent no feeding or fertilization is generally done.

In the saline bheries the tidal water is drawn from the rivers or tributaries during the new or full moon days when the tidal amplitude is high. This is however, a generalized practice and the farmers sometimes go for water exchange on other days also . The ingress water enters through the inlets guarded by thick meshed nets to prevent entry of larger carnivorous fishes. Sometimes the water is retained for longer periods of 1 to 2 months. The water exchange provide conducive environment for the stocked animals and at the same time provide a continuous source of natural food . Now a days most of the bheries in the low and medium saline zones are selectively stocked . Some of the high saline wetlands are also selectively stocked to a good extent in addition to natural stocking and recruitment.

PRODUCTION FROM ESTUARINE WETLANDS :

The production from the freshwater zone (sewage-fed) has always been found to be much higher compared to those of the saline zones. The annual average production from strong and moderately strong sewage-fed area is around 5000 kg/ha whereas in the bheries receiving diluted sewage the average production is about 2500 kg/ha. Studies conducted earlier in the saline zones demonstrated the medium saline zone to be the highest producer of aquacrops compared to other two zones. Recent studies reveal a change in the production pattern in the three zones. The production from the low-saline zone has been found to be the highest which may be attributed to the introduction of carp culture in a large scale in this region. Though the production of tiger shrimp is generally higher in the medium saline zone compared to other two zones, in recent years the production from the low-saline bheries has surpassed the other two types. A recent investigation showed that the production from low-saline wetlands (Av. salinity 2.05 ppt.) receiving sewage mixed diluted saline water, was to the tune of 631.29 kg/ha/yr which was much higher than medium saline wetlands (Mean salinity 3.58 ppt.) where the production rate was 296.99 kg /ha/yr (Ghosh et . al ., 2001). The percentage contribution of monodon was also found to be higher (37.90 %) in the low saline compared to the medium saline ones (29.0 %). Ghosh et. al., (1999) obtained similar higher production of tiger shrimp from bheries having mean salinity of around 3.40 ppt. Thus for monodon production a salinity range of 2.0-3.5 ppt. is quite congenial . During recent years the average production from selected veries in the low, medium, and high saline zones were of the order of 1125, 354 and 376 kg/ha/year. Therefore, it may be assumed that the production from the saline zone as a whole has come down to a little extent compared to those obtained by Saha et.al., (1987) or Ghosh et.al., (1997).

The low rate of production during recent years may be attributed principally to heavy infestation of white spot disease in the saline bheries which took a heavy toll of the bagda (*P. monodon)* crop. The other most important reason of low monodon production is probably under stocking of some of the bheries in the medium saline zone in particular (e.g.,Harishpur). Scarcity and exorbitant price hike of monodon seed resulted in such under stocking.

PRODUCTION CONSTRAINTS

In the freshwater bheries phytoplankton bloom may occur leading to heavy depletion of dissolved oxygen by mid-night hours causing stress to the stocked animals .

Many of the freshwater bheries are overstocked, which added with auto stocking of tilapias create over crowding condition and vitiates the stocking density.

The depth of these water bodies are low (0.40 to 1 m) and there is in general huge accumulation of muck at the bottom over the years.

Some of the farms draw water un- judiciously causing increase in BOD load resulting in stress or even mortality of the stocked fishes.

Irregular supply of sewage causes problem to the fish producers since the fishery is based on the availability of nutrients through sewage effluents.

Some farmers use slaughter house refuge , pig dung or cow dung or poultry wastes as food for the stocked fishes without knowing that the left out food may cause problem by increasing the organic load.

Waste water used for piscicultural purposes is raw sewage which may lead to contamination of various substances deleterious to fish health.

In saline bheries procurement of quality monodon seed itself is a problem.

Plankton production in many of the saline wetlands is hindered by over Growth of macrophytes.

Entry of carnivorous fishes like *Lates calcarifer, Glossogobius guiris etc.*, may cause heavy damage to bagda (*P. monodon*) and parsia (*L. parsia*) and other mullet seeds.

MANAGEMENT MEASURES FOR ENHANCING PRODUCTION

Regular monitoring of the water bodies is the prime pre-requisite for maintaining water quality which will not only help boosting production but also help preventing disease infestations.

Freshwater sewage-fed fisheries are either carp based or though to a low extent, tilapia based. Some other compatible species should be tried to bring a diversification in the system.

Some of the wetlands have heavy infestations of molluscs particularly gastropods. In these wetlands in the freshwater and low saline zones, *Pangasius pangasius* may be stocked judiciously taking into consideration that though the species is an omnivore has inclination to take fishes and prawns as food besides, molluscs.

Control of algal bloom in the freshwater and low-saline sewage-fed bheries is a must since this may sometimes be hazardous. As soon as there is any indication of bloom sewage intake should immediately be stopped and more standing water (Sada jal) from adjacent water bodies should be mixed so as to dilute the sewage concentration. Chemical control in such huge water bodies is not only expensive but also may cause stress to the stocked fishes.

Farmers are growing tilapias in their farms which they believe to help them by way of the monitory return for maintaining the day to day expenditure in running the farm. But reduction of size due to heavy recruitment causes problem. Since tilapia acts as a bio controlling agent for green and blue-greens in the sewage-fed bheries it helps in controlling the algal bloom. Therefore , the excess tilapias can be reared as forage fish for culturing bhetki. *Lates calcarifer* in separate water bodies which will help producing a sizeable crop of this priced perch and at the same time good sized tilapias since the recruitment of tilapias will be kept under control by Bhetki. It should however. be ensured that bhetki does not enter in to the main water body.
The giant freshwater prawn *M. rosenbergii*, culture should be taken up in an organized manner.

Adoption of paddy-cum-fish culture in more low - and medium saline wetlands, with or without sewage influence, may help getting higher yields from such eco-systems.

The bottom soil of the wetlands should be excavated at regular intervals (of say three years) so as to remove the accumulated muck at the bottom .

Proper aeration in prawn growing wetlands in freshwater and low saline sewage-fed areas during night hours will help enhancing survival and growth of prawns and thus lead to better yield.

People involved in wetland fisheries should be given proper training on scientific management so that they may tackle some of the problems themselves as and when such problems arise.

CONCLUSION

The wetland fisheries provide a sustained supply of fish to Kolkata market. There are more swampy/derelict water bodies in the estuarine zones which can be developed for piscicultural purposes. However, such developmental activities should not be by destroying the Sundarbans mangrove forest. Urban development has already caused reduction of East Kolkata wetland area. Wetlands are important ecosystems not only from the point of view of fisheries but also from the point of view of their rich biodiversity. The fishery provides employment to a large section of rural population. Thus conservation of these ecosystems has now become essential and such activities should be initiated without further delay.

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ORNAMENTAL FISHERY RESOURCES OF FLOODPLAIN WETLANDS

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INTRODUCTION

The practice of ornamental fish keeping is said to have originated in China, several hundred years ago, with gold fishes held in glass bowls. Keeping them in aquaria started during the 1805s. The first public display aquarium was opened at Regent's Park in England in 1853, triggering the craze for aquarium keeping at home. Earlier, attractive fishes of local origin were domesticated as pets. The development of air transport and oxygen packing helped the rapid expansion of ornamental fish trade. The number of ornamental fish species and varieties continues to grow. Today, there are thousands of aquarium hobbyists and hundreds of public aquaria, functioning through out the world. In India the hobby of keeping ornamental fishes took off in a big way with the opening of the Taraporevala Aquarium at Mumbai in 1951 and also with the opening of several aquarium societies. Since then aquarium keeping has been growing steadily through out the country.

CRITERIA FOR SELECTING ORNAMENTAL FISHES

The major criteria for assessing the suitability of fishes for ornamental purpose are

- Attractive coloration and shape
- Peaceful behavior
- Compatible with other species
- Adaptability to confinement
- Acceptability of artificial feed.

However, of late, these criteria seems to be changing, as demand for unique or unusual looking fishes, which need not necessarily be beautiful, but definitely different, is increasing all over the world. Now variety and difference rule the aquarium fish industry.

ORNAMENTAL FISH FAUNA

The fauna of ornamental fishes can be divided into three main groups. Each one of these is made up of various genera and species. Body shape, fins, mouth, coloration and some other specialized traits help their broad grouping. The major groups of ornamental fishes, their origin and species availability are listed in table 1.

Table 1. Categorization and origin of ornamental fishes.

Category	Main sources	Species	Wild/Farmed
Cold water	Japan, Israel, USA, China	20 species	100% farmed
Tropical freshwater	Singapore, Brazil, Czech Republic	1000 + species	95% farmed
Tropical marine	Indonesia, Philippines and Pacific Islands.	1000 + species	99% wild caught

Keith Devenport (2001)

Amongst the freshwater varieties of ornamental fishes, the important groups are carps (Carracius, Barbs, Rasboras *etc.*), catfishes, anabantids, danios, livebearers, topminnows, cichlids *etc.* The common marine groups include surgeonfish, angelfish, butterfly fish, cardinal fish, squirrelfish, puffers, scorpion fish, triggerfish, blennies, gobies, damselfish *etc.*

FRESHWATER ORNAMENTAL FISHERY RESOURCES OF INDIA

The Indian subcontinent possesses rich variety of ornamental fishes. These include over 100 varieties of indigenous species. There is also equal number of exotic species that are bred in captivity. The country has vast aquatic resources, offering good scope for export as well as domestic use. Many of the Indian ornamental fishes are well known in international aquarium hobby circles. Some of these like the *Colisa fasciatus* have maintained steady demand abroad. The country posses two global hot spots of freshwater biodiversity *viz.*. the northeastern states and the Western Ghats. As many as 123 species are assessed to have potential ornamental value in the northeast alone and about 52 species have international demand. In addition to this there are several more species with potential ornamental value and intensive explorations in future may reveal several more species. The Western Ghats posses as many as 64 species belonging to 14 families as endemic to the region (NBFGR. 1998). The common freshwater ornamental fish species in India are *Chanda nama*. *C.ranga*. *Colisa fasciata*. *C. sota*. *Aplocheilus panchax*. *A. blochii*. *A. lineatus*. *Puntius ticto*. *P. sophore*. *P. conchonius*. *Botis* spp. *Nemacheilus* spp. *Notopterus* spp. *Danio* spp. *Badis badis*. *Rasbora daniconius*. *Botio dero etc.*

RESOURCES OF FLOODPLAIN WETLANDS

The floodplain wetlands spread mainly along the Ganga and Brahmaputra river basins. cover an area of 0.2 million ha. These wetlands are treasures of rich biological life and form an important fishery resource in the country. Thousands of poor fishermen depend on these water bodies for their daily livelihood. None of these water bodies presently meet their actual fish production and economic potential. Explorations in these water bodies in the past revealed that apart from food fishes. they also harbor several fish species. which are smaller. attractive and can be considered ornamental. These revelations coupled with the ever-growing demand for aquarium fishes provide ample scope for augmenting the economic return from these water bodies. However specific studies. with reference to ornamental fish resource. their potential. species availability *etc.* in floodplain wetlands are few and far between. Available information suggest the existence of 45 species belonging to 16 families in the floodplain wetlands of Assam and 63 species belonging to 23 families in West Bengal. with potential for aquarium purposes. Intensive explorations in future may reveal the existence of several more species. Table 2 shows the species of fishes. from floodplain wetlands. possessing ornamental value.

Table 2. List of fishes, having potential ornamental value, from floodplain wetlands of India.

ORDER	FAMILY	SPECIES
OSTEOGLOSSIFORMES	NOTOPTERIDAE	*Notopterus notopterus* *Notopterus chitala*
ANGUILLIFORMES	MORINGUIDAE	*Moringua raitaborua*
	MURAENIDAE	*Lycodontis tile*
	OPHICHTHIDAE	*Pisodonofis boro*
	CYPRINIDAE	*Labeo calbasu*

CYPRINIFORMES:		*Oreichthys cosuatis Puntius conchonius Puntius gelius* *Puntius phutunio* *Puntius sophore* *Puntius terio* *Puntius ticto* *Puntius chola* *Puntius conchonius* *Puntius phutonius* *Chela cachius* *C. laubuca* *Salmostoma phulo* *S. bacaila* *Amblypharyngodon mola* *Barilius barila* *Barilius bendelisis* *Brachydanio rerio* *Danio aequipinnatus* *Danio dangila* *Danio devario* *Danio regina* *Esomus danricus* *Parluciosoma daniconius* *Rasbora rasbora* *Crossocheilus latius latius* *Garra gotyla gotyla*
	BALITORIDAE	*Nemacheilus botia* *Nemacheilus corica* *Nemacheilus scaturigina* *Nemocheilus beavani*
	COBITIDAE	*Lepidocephalus guntea* *Pangio pangia* *Somileptes gongota* *Botia dario* *Botia lohachata* *Botiya dayi*
SILURIFORMES	SCHILBEIDAE	*Pseudeutropius atherinoides*
	BAGRIDAE	*Batasio batasio* *Mystus Tengara* *Mystus vittatus* *M. cavasius* *Aorichthys aor* *Rama chadramara* *Rita rita*
	SILURIDAE	*Ompok pabdah*
	PANGASIIDAE	*Pangasius pangasius*

	AMBLYCIPITIDAE	*Amblyceps mangois*
	SISORIDAE	*Bagarius bagarius* *Erethistes pussilus* *Gagata cenia* *Hara hara* *Hara jerdoni* *Nangra viridescens*
	CHACIDAE	*Chaca chaca*
CYPRINODONTIFORMES	BELONIDAE	*Xenentodon cancila*
	APLOCHEILIDAE	*Aplocheilus panchax*
PERCIFORMES	AMBASSIDAE	*Chanda nama* *Pseudambassis ranga* *p. lala* *p. baculis* *Badis sp*
	GOBIIDAE	*Stigmatogobius sadanundio* *Acentrogobius viridipunctatus* *Glossogobius giuris* *Apocryptes bato* *Periophthalmus pearsei* *Periophthalmodon schlosseri* *Periophthalmodon tredecemradiatus*
	ELEOTRIDIDAE	*Butis butis*
	GOBIOIDIDAE	*Odontamblyopus rubicundus* *Taenioides cirratus*
	ANABANTIDAE	*Anabas testudineus*
	BELONTIDAE	*Ctenops nobilis* *Colisa fasciata* *Colisa lalia* *Colisa sota*
	CHANNIDAE	*Channa barca* *Channa orientalis* *Channa marulius* *Channa punctatus*
	MASTOCEMBELIDAE	*Macrognathus aral* *Macrognathus pancalus* *Mastocembelus armatus*
PLEURONECTIFORMES	SOLEIDAE	*Euryglossa pan*
TETRAODONTIFORMES	TETROADONTIDAE	*Tetradon cutcutia*
	SYMBRANCHIDAE	*Heteropneustes fossilis*
	NANDIDAE	*Badis badis* *Nandus nandus*

Final report of research project "Ecology, fishery biology and fish production dynamics of floodplain wetlands of India", 1999-2002, CIFRI.

GLOBAL ORNAMENTAL FISH TRADE

The world trade of ornamental fishes has been estimated to be around US $ 4.5 billion in 1995 and has been steadily increasing with an annual growth of about 10%. USA is the largest market for ornamental fishes, importing worth over US $ 500 million every year, followed by European Union and Japan. It has been estimated that 7.2 million homes in USA keep fish, followed by European Union with 3.2 million homes. Japan constitutes the third largest market with 1.2 million homes having aquaria. The demand is more for freshwater ornamental fishes because of their easy availability, maintenance *etc*. Records from the FAO shows that 146 countries exported and 133 countries imported ornamental fishes. Table 3 shows the global export of ornamental fishes by value in 1998 and Table 4 shows the global import. Presently more than 65% of the total export of these fishes is from Asian countries.

Table 3. Global export of ornamental fishes (by value) in 1998.

Country	Value (US $ million)
Singapore	43.0
USA.	10.7
Czech-republic	10.6
China-Hong Kong	10.3
Malaysia	8.6
Sri Lanka	8.2
Japan	7.5
Israel	6.5
Philippines	4.5

Keith Devenport(2001)

Table 4. Global import of ornamental fishes (by value) in 1998.

Country	Value (US $ million)
USA	67.3
Japan	39.3
Germany	24.7
France	21.1
UK	20.1
Netherlands	11.7
Belgium	10.1
Italy	9.9
Singapore	9.0
Spain	6.0

Keith Devenport(2001)

PROSPECTS IN INDIA.

Freshwater ornamental fishes from India have good potential for export as well as demand in domestic markets. About 85% of the country's export constitute species from the northeastern region and the rest are locally bred exotic species (Swain *et al.* 2003). The major export markets for the country were USA (41.12%) followed by Japan (21.17%). UK (13.64%). Germany (8.03%) and the rest were Nepal. Singapore. Thailand. Saudi Arabia. France. Italy. Holland. Sweeden *etc.* Kolkata has been the largest exit point for Indian ornamental fishes (90%) followed by Mumbai (8%) and (2%) from Chennai (Sahu and Mohanty. 2000). There were more than 150 full time and 1500 part time ornamental fish breeders in the country during 1996-2000. The port-wise export of ornamental fishes from the country is shown in Table 5. Of a total of 220 species exported from India. about 178 were indigenous. The export value for some of the Indian ornamental fishes in international markets is shown in Table 6.

Table 5. Port wise export of aquarium fishes during 1996-2000 from India (Value Rs.)

Port	Value (million)			
	1996-97	1997-98	1998-99	1999-2000
Mumbai	0.17	0.28	0.46	0.01
Trivandrum	--	--	0.64	0.07
Chennai	0.39	0.33	0.47	1.10
Kolkata	10.20	7.33	14.26	15.27
Total	**10.76**	**7.94**	**15.83**	**16.45**

MPEDA. Cochin

Table 6. Export value of some of the fresh water ornamental fishes (per pair)

Species	Trade name	Price (US $)
Hypselobarbus curmucea		5.0-12.0
H. thomassi		10.0
Puntius denisoni	Red line torpedo	8.0-11.0
P. filamentosus	Filament barb	0.5
P. ticto	Tic-tac-toe barb	0.2
P. vittatus	Kooli barb	0.15-1.0
Wallago attu		10.0
Channa orientalis	Special snakehead	11
Horabagrus brachysoma	Yellow catfish	7.0
H. nigricollaris		5.0
Macropodus cupanus	Paradise fish	7.0
Aplocheilus panchax	Red panchax	0.15-1.0
Anabus testudineus	Climbing perch	0.4
Barilius bakeri	Blue dotted hill trout	0.5-2.0
Esomus danricus	Flying barb	0.08
Nemacheilus triangularis	Zodiac loach	0.5-1.0
Mastocembelus armatus	Tyre track eel	0.5
Botia dario	Golden banded loach	0.2
Chanda ranga	Glass fish	0.09
Badis badis	Dwarf chameleon fish	0.2
Nandus nandus	Leaf fish	0.8

The fact that the country possesses vast resources in terms of natural water bodies and species diversity, the potential of ornamental fish export can be increased up to atleast US S 30 million (about Rs. 110 corers) per annum (Swain *et al.*, 2003). For the expansion of the trade more varieties in sufficient quantity is needed. More intensive exploration of our floodplain wetlands would reveal several more species. Along with these explorations studies on their ecology, biology, breeding and maintenance in aquaria need to be intensified.

PROBLEMS

The resourse size and species of ornamental fishes available in our country, especially in floodplain wetlands are not fully assessed. There have not been efforts to design collection methods, gears, acclimatization and transportation to avoid mortality.

Dependence on wild stocks may soon deplete the natural population of many of these indigenous species. Proper breeding and rearing technologies have to be worked out. Illegal trade of these fishes cause concern on loosing our property rights over many species. Unauthorized introductions contaminate our water bodies. The Red Piranhas are example to this. Unscrupulous cross breeding to create new varieties cause considerable genetic imbalance in the native species. Use on antibiotics and chemicals in aquarium maintenance and treatment of diseases also cause concern over environment.

FUTURE STRATEGIES.

1. Potential ornamental species from floodplain wetlands should be identified and properly catalogued to protect our intellectual property rights over those resources.
2. Studies on the distribution, ecology, biology, behavior, breeding and maintenance in aquaria should be intensified.
3. Studies on disease and health, both in nature and in confinement.
4. Research support on acclimatization, natural requirements, artificial feeding and feed formulation.
5. Regulation of import/export, prevention of unauthorized or clandestine introductions.
6. Need based developmental assistance for setting up of ornamental fish collection and breeding units, distribution centers etc. in potential locations along our floodplain wetlands.
7. Training for fishers, breeders, collectors as well as foe other target groups.
8. Registration of indigenous ornamental fish collectors, breeders, exporters for legalization and control of trade.
9. Use of modern techniques to establish species of doubtful varieties.

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PRESNET STATUS OF FLOODPLAIN WETLANDS VIS-A-VIS FISH HEALTH AND ENVIRONMENT

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INTRODUCTION

In culture based fisheries practiced in beels, bheries or small reservoirs which constitute approximately 1.3 m ha of inland fisheries resource the average yield is 120-300 kg ha^{-1}. The ecological status of various beels reveal that they are in various stages of eutrofication and choked with submerged or floating vegetation showing sub optimal water quality. The effects of adverse environmental conditions have a profound effect on the health status of the resident fish population. The succeeding pages will elaborate on the water quality parameters of importance, the stress being created and the various fish diseases being encountered in these water areas.

ENVIRONMENTAL PARAMETRS OF IMPORTANCE IN RELATION TO FISH HEALTH

Oxygen

Often fishes swim on the surface of water gulping air with mouth wide open. This stress condition of fish is due to oxygen depletion in water. Three main factors influence the amount of oxygen which a water body can hold.

a) Temperature - water holds less oxygen at higher temperature

b) Salinity- water holds less oxygen at higher salinities.

c) Atmospheric pressure- Water holds less oxygen at low atmospheric pressure. Other factors which affect the amount of DO in water include phytoplankton blooms, organic loading and respiration of fish and other aquatic vertebrates and invertebrates.

Ammonia

It is commonly the second important parameter after DO. The total ammonia concentration in water consists of two forms.

NH_3 – unionized ammonia
NH_4 – ionized ammonia

The unionized fraction is most toxic to fish. As a general rule, the higher the pH and temperature the higher the percentage of total ammonia *i.e.*, the toxic unionized form. Ammonia in water originates from:

i. Decomposing organic matter
ii. Excretion of aquatic organisms
iii. Death of phytoplankton bloom

Hydrogen sulphide

Very often the muck in the sediments smell like rotten eggs and the bottom dwelling fishes surface and die. This is due to accumulation of H_2S gas which is produced by chemical reduction of organic matter.

Nitrite

Fish gills frequently turn brick red in colour. This is because of excess nitrite in the water which is absorbed by fish and reacts with haemoglobin to form methaemoglobin and this gives brick red colour to the gills.

Suspended solids

It originates from phytoplankton blooms, uneaten food particles and fish faecal matter. Suspended solids are important in reducing the penetration of light thus reducing productivity.

PH

It is an important parameter affecting fish health. The optimum range of pH for most of the freshwater fishes is 6-9. The factors which affect toxicity of acid to fish are:

CO_2 - Free CO_2 is toxic to fish. High concentration of 12-50 mg/l^{-1} of free CO_2 hinders uptake of DO by fish and thus the effects of high CO_2 are accentuated at low DO concentrations.

Alkalinity - Water with low alkalinity of less than 20 mg/l^{-1} have low buffering capacity and consequently are very vulnerable to fluctuations in pH due to rainfall or phytoplankton bloom.

STATUS OF WATER QUALITY IN WETLANDS CREATING STRESS TO FISH

Freshwater wetland (beel): Garrapota beel a typical open beel with 40% macrophyte infestation was investigated (Das, 1999). The range of water quality parameters during a year and diurnal variation of some important chemical parameters are given in Table 1. The diel variation of the chemical parameters indicates the important stress factor to be dissolved oxygen. The DO level is reduced to nearly 3.5 mgl^{-1} around 10 pm at night and remain below this level for more than 8 hours causing stress to resident fish. Unionised ammonia recorded in the range of 0.05 to 0.25 mgl^{-1} is also acting as a stress factor. As a result the normal growth of fish has been affected and the average yield from this beel was 550 kg ha^{-1}. The results obtained has similarity with the ecological status of the various beels in West Bengal, Assam and Bihar which are mostly in various stages of eutrophication and choked with submerged or floating vegetation and suboptimal water quality (Sugunan 1999, Anon 1998, 99). As a result the average yield from these wetlands is only 120-300 kg ha^{-1} against the potential yield of 1000-1500 kg ha^{-1}.

INDIACATORS OF HEALTH CONDITION OF FISH STOCK

Any occurrence of fish disease in a water body is generally recognized by fish becoming restless, rubbing its body against pond dykes, splashing, surfacing, whirling non-acceptance of food etc. However, there are some external symptoms of healthy fish as reflected by:

i) Escape reflex

Healthy fish react to external agitation such as quick motion, stamping on the bank, sound etc. and quickly submerge under water. Sick fish do not react to external agitation and can be caught easily.

ii) Defensive reflex

A freshly caught fish from water toss about quite violently when laid on ground. After a while the fish calms down. Sick fishes are sluggish in water as well as out of it.

iii) Tail reflex

When a live fish is held by the head and the posterior is free, it exhibits the tail reflex which occurs irregulary. Here the fish keeps the posterior and caudal fin in a horizontal position or even slightly obliquely upward, while the caudal fin is always stretched in a fan-shape.

Table 2. Physico-chemical characteristics of Garrapota *beel*

	Range of water quality parameters during year	Diurnal variation of water quality parameters											
		10 AM	*12 PM*	*2 PM*	*4 PM*	*6 PM*	*8 PM*	*10 PM*	*12 PM*	*2 AM*	*4 AM*	*6 AM*	*8 AM*
Temperature (water)	26-36	22.5	24.0	24.5	24.0	22.0	21.0	21.5	20.5	20.5	21.5	22	22.5
Alkalinity (mgl^{-1})	133-212	212	214	201	206	214	209	212	210	209	210	215	210
Hardness (mgl^{-1})	120-199	195	199	187	190	193	195	198	198	190	197	199	196
Unionised ammon (mgl^{-1})	0.05-0.25	0.1	0.1	0.1	0.15	0.11	0.1	0.1	0.2	0.1	0.1	0.1	2.1
CO_2 (mgl^{-1})	1.0-8.0	1.0	1.0	1.0	1.0	1.5	1.0	1.5	2.0	2.0	2.0	1.5	3.0
Chloride (mgl^{-1})	3.7-9.5	7.5	7.0	7.8	6.9	7.2	7.5	7.5	7.3	7.4	7.9	7.8	3.0
DO (mgl^{-1})	6.0-9.0	6.5	8.0	9.0	9.0	7.5	5.2	3.5	3.0	2.0	2.0	2.0	3.0
pH	7.8-8.0	8.0	8.0	8.1	8.0	8.0	8.0	7.9	7.9	8.0	7.8	8.0	3.0

FISH DISEASE COMMONLY ENCOUNTERED IN *BEELS* CREATING STRESS TO FISH

Disease caused by protozoan parasites

They are probably the most important group of animal parasites affecting fish. The protozoan parasites afflicting fish fall under the phylum Ciliophora with the typical parasites *Trichodina* and *Tripartiella;* Phylum Sacromastigophora with the typical parasite *Costia* and Phylum Myxozoa with the typical parasite *Myxobolus* spp., *Thelohanellus* spp etc.

Trichodinid Parasites

General morphology and identification

The trichodinid parasites *viz. Trichodina* or *Tripartiella* are hemispherical-bell shaped. The aboral surface is concave. The adoral cilia surround the buccal cavity and the marginal cilia give it a spiral rotating movement. The parasite attaches itself to the host surface by the attachment disc reinforced by border membrane. The ring of denticles and radial pins located internally provide rigidity to the parasite.

Life cycle and transmission

They have a simple life cycle and reproduce by binary fission and is directly transmitted from one host to the other.

Common disease encountered in fish culture

Trichodinosis

The disease is very common in the fry and fingerlings of cultured fishes. The most common symptom in an affected fish is pale colour of the gills with a creamish coating due to excessive secretion of mucus. The causative organism is urceolariid ciliates of the genus *Trichodina* and *Tripartiella.*

Myxozoan Parasites

General morphology and identification

The prominent feature of the myxozoan parasite is the spore. The spore usually consists of two valves joined by a suture. The valves are of various shapes. Within the spore there are one, two or more polar capsules. Within the capsule is the coiled polar filament opening outside the capsule by an aperture. The remainder of the spore cavity is occupied by the sporoplasma, the infective part of the spore.

Life cycle and transmission

It has a direct life cycle. The spores are ingested by the fish. The sporoplasma comes out and moves through the blood stream and reaches the appropriate site of infection. Here it undergoes repeated nuclear division in the trophozoit and forms mature spores.

Common disease encountered in fish culture

White gill spot disease

The gills of fishes predominantly *Catla catla* are covered with whitish cysts of different sizes. This infection reduces the absorptive surface of gills. Excessive mucus secretion occurs and fishes surface for gulping air. The causative organisms are *Thelohanellus catlae* and *Myxobolus bengalensis.*

Scale spot disease

The scales are covered with whitish cysts. In acute cases scales become perforated and degenerated. Scales become loose with ulceration. The causative organisms are *Myxobolus rohitae* in *L. rohita* and *Myxobolus sphericum* in *C. mrigala.*

Fish diseases caused by helminth parasites

These flatworms are predominantly parasitic in fish and have a varied type of host parasite relationship. They are mostly dorso-ventrally flattened and bilaterally symmetrical. They may be segmented or unsegmented and most of them are attached to the host by characteristic attachment organs. The flatworms which infect fishes in aquaculture or open waters broadly fall under three classes; the Monogenea, Cestoda and Trematoda.

Monogenea

General morphology and identification

They are small worms and ectoparasitic in nature. The posterior extremity of the body has the characteristic attachment organ called opisthapter. It is armed with chitinoid structure important for identification. The anterior end of the parasite bears a small sucker. Eyespots are frequently present anteriorly.

Life cycle and transmission

Monogeneans predominantly have direct life cycle. Most of them are oviparous depositing eggs which on hatching release a free swimming larva which seeks a host becomes attached to it and metamorphose to adult ones. Some are viviparous and give birth to young worms which attach to new host on their release.

Common disease encountered in fish

Dactylogyrosis and ***Gyrodactylosis:*** The causative organism for the disease is *Dactylogyrus* sp. And *Gyrodactylus* sp. While *Dactylogyrus* predominantly infests the gills, *Gyrodactylus* sp. Mostly infests different body surface and occasionally gills. When gills are infected there is hypersecretion of mucus affecting respiratory surface and very often the fishes are irritable and surfacing takes place. There is growth retardation and loss of weight.

Trematoda

General morphology and identification

They are dorso-ventrally flattened, unsegmented and usually oval in shape. Two attachment organs are present, the oral sucker near anterior end and the ventral sucker or acetabulum, a little below the oral sucker.

Life cycle and transmission

The digeneans are oviparous and in most cases the eggs hatch outside the host to release a free swimming miracidium larva. This larva locates the first intermediate host *i.e.*, the gastropod. Within this host the parasite undergoes asexual reproduction and forms the cercaria larvae which, when released, locates the suitable second intermediate host which is the fish. Here the cercaria encyst to form the metacercarial stage. The life cycle here is completed when the infected fish is eaten by a suitable final host i.e., the bird.

Common diseases encountered in fish culture

Black spot disease

The fingerlings and young ones of mostly *Catla catla* are affected with black ovoid patches on the body surface. These are pigment patches overlying metacercarial cysts of digenetic trematodes, *Diplostomum* sp. The presence of these black spots is the diagnostic feature of the disease.

Cestoda

General morphology and identification of cestode parasite

Cestodes do not have an alimentary canal or any body cavity. Most of them are equipped with one attachment organ, scolex. The scolex is normally followed by a narrow unsegmented neck passing into the long body. The body is dorso-ventrally flattened, segmented, and is called proglottids.

Life cycle and transmission

The eggs of this parasite is released by the faeces of bird (*Anhinga melanogaster*) in water where it hatches into a coracidium larva which enters the first intermediate host an invertebrate where it develops into a procercoid. The procercoid enters the second intermediate host, the fish and develops into the plerocercoid larvae.

Common disease encountered in fish culture

Ligulosis: The pleurocercoid larva of the cestoda *Ligula intestinalis* cause this disease. This larval stage is very often found infecting *Catla catla*. The symptoms are abdominal distension, reduced growth and dark colouration.

Fish disease caused by crustacean parasites

Crustacean parasites are frequently reported in fishes. Crustacean parasites in most cases do not cause serious problems to fish health except irritation and localized ulceration. But several instances are reported where severe infestation by the crustacean parasites resulted in mortality of fish in different fish culture areas.

The crustaceans which infest fishes in our fish culture systems fall under the sub classes (1) Entomostracea – having the orders Copepoda and Branchiura and (2) Malacostraca – having the order Isopoda.

Copepoda

General morphology and identification

They are ecto-parasites. In head region they bear six pairs of appendages *viz.*, two pairs of antenna, one pair of mandible, two pairs maxillae, and one pair of maxillipeds. The thoracic region bears six pairs of swimming legs. The abdomen consists of 1-4 segments the last segment terminates into to flat branches the caudal rami. The shape of the body varies from oblongate to elongated shape in parasitic forms.

Life cycle and transmission

The development of most parasitic copepods is direct without change of host. Most of the larval development is completed within the eggs. Thus, when the eggs hatch they either give rise to metanauplius larva or copepodite larva. This process shortens the free living period. They produce 3-4 broods in a year. Females are generally the parasitic ones and attach themselves to the host fish.

Common disease encountered in fish culture

Lernaeosis

The disease is caused by parasitic females of genus *Lernae*, commonly known as anchor worms. They are relatively large. 5-22 mm and during attachment to the host they assume a vermiform shape with anterior attachment organ buried deep in host tissues. An infested fish exhibits symptoms of rubbing against the sides or bottom of the pond. Heavy infestation leads to lethargy, emaciation and retardation of growth. The parasite destroys scales and causes haemorrhagic and ulcerated areas at the point of penetration. A large number of fish species *viz.*, *C. catla*, *L. rohita*, *O. gouramy*, *C. idella* and a number of minor carps are susceptible to lernaeosis.

Ergasilosis

The disease is caused by the parasitic females of the genus *Ergasilus, Neoergasilus* sp. They have a cyclops like body, narrowing posteriorly and has a total length of 1.5-2.5 mm. They predominantly attach to the gills and fins of fish by means of the second antenna which is stout and clawed and feed on the blood and epithelium. Sometimes infestation may be to the tune of 150 number per square cm. Heavy infestation results in respiratory distress, anemia and retarded growth. Prominently symptoms exhibited by heavily infested fishes are frequent surfacing, restlessness and mortality under oxygen depleted conditions.

Branchiura

General morphology and identification

The most important fish parasite under Branchiura, as far as fish culture is concerned, is *Argulus* sp. The parasites, commonly called fish lice are flattened dorsoventrally. The cephlothorax is broad, the dorsal part has a convex cephalothoracic side, on which there are two faceted eyes, first antenna is transformed into a clasing organ. The papilla are transformed into enormous suckers. The abdomen is small and its rear end forms two lobes.

Life cycle and transmission

Argulus matures remaining attached to the host. It is capable of free swimming for sometimes either to lay eggs or in search of new host. The fertilized females leave the host and lay eggs which are stiking in nature on submerged vegetation, rocks, sticks etc. The nauplius, metanauplius and in some species the first copepodid stages develop within the eggs which hatch as metanauplius or copepodids. The copepodid stages are seven in number, fianally forming adult. The period for completion of this life cycle is 3-6 weeks. Because of the parasite infestation, affected are as develop ulceration. The toxic secretion of the buccal gland of the parasite causes intense inflammatory reaction. Infestation is accompanied by excessive mucus secretion, lethargy, irrigation and retarded growth.

Epizootic ulcerative syndrome

Fish species affected: Channa sp., *Mastocembelus* sp., *Puntius* sp., *Nandus* sp., *C. catla, L. rohita, C. mrigala, C. carpio* and *G. chapra.*

Symptoms: The fishes become lethargic and float on the surface of the water, sometimes with the head projected out of water. Initially, the disease appears as red coloured lesion, haemorrhagic in nature. These red lesions spread and enlarge gradually becoming deeper and assuming the form of ulcers. With further advancement, scales fall of ulcers become deep necrotizing ulcerative lesions. Histopathologically, it is characterized in having mycotic granuloma in epidermis.

Causative agents: Role of suspected causative agents namely, virus, bacteria and fungus could not be established conclusively. In India, so far 20 species of pathogenic bacteria have been isolated from affected fishes of which *A. hydrophila* has been consistently found along with fungus *Saprolegnia*. The latest investigations point out the prime causative agent to be a fungus called *Aphanomyces* sp.

Treatments: can be tried only in lakes below 40 ha.

Prophylactic: During post-monsoon period, the desease prone water areas can be treated with lime, CaO @ 50 kg/ha followed by application of bleaching powder @ 0.5 ppm after one week.

Therapeutic: At the initial stage of lesion formation, lime (CaO) is applied @ 100 kg/ha followed by application of bleacing powder @ 1 ppm after one week.

STRESS IN FISH AND ITS METHOD OF DIAGNOSIS

Fish is in a state of equilibrium with the environment and fish disease organism, many of which are always present in the environment. A change in the environmental parameters beyond the tolerance limit disturb this equilibrium resulting in stress response in the fish and making it vulnerable to disease. The response of fish to stress from the environment is known as stress response. The most extreme response is mortality but below this level there may be several other responses *viz.*,

i. changes in fish behaviour
ii. reduced growth/food conversion efficiency
iii. reduced reproductive potential
iv. reduced tolerance to disease
v. reduced ability to tolerate further stress.

Several of the many changes that occur in response to stress can be used as measurable indices of the severity of stress on fish. These changes are a direct or indirect result of the physiological response to environmental changes and can be quantified and used as predictive indices.

Methods for stress diagnosis

Several biochemical and physiological procedures have been developed to assess the severity of the physiological effects resulting from stress. The physiological parameters of importance for assessing stress in fish at the primary, secondary and tertiary levels are discussed below.

Primary stress response

Plasma cortisol: A relatively direct assessment of the severity and duration of the primary stress response can be obtained by monitoring the rise and fall of plasma cortisol or catecholamines (epinephrine and nor epinephrine) concentrations.

Secondary stress response

The secondary changes that occur mainly in the blood chemistry also characterise the severity of stress in fishes *viz.*, blood glucose, chloride, lactic acid. They are frequently used for assessing stress response. Hyperglycemia for blood glucose and hypochloremia for blood chloride is the physiological effect of concern during stress response. Accumulation of lactic acid in muscle or blood hyperlacticemia is also an indicator of stress due to bright to severe exertion. The haematological parameters also provide useful information about an animals tolerance to stress.

Haemoglobin/Haematocrit : - It increase or decrease following acute stress can indicate whether haemodilution or haemoconcentration has occurred.

Leucocyte decrease (leucopenia): - Commonly occur during the physiological response to acute stressors. The blood clotting time and changes in the leucocyte count are among the most sensitive parameters indicating stress response.

Histopathology: - Since many of the biochemical changes that occur in response to stress are the end result of cellular pathology histological examinations can frequently provide information on the effect of stress factors on fish. For example interrenal hypertrophy, atrophy of the gastric mucosa and cellular changes in gills are indicative of stress response.

Tertiary stress response

Experience have shown that several tertiary stress responses including changes in the metabolic rate, health behaviour, growth, survival and reproductive success can indicate that unfavourable environmental conditions have exceeded acclimation tolerance limits of fish.

Common fish disease, their symptoms and control measures

Specific fish disease	Species prone to disease	Symptoms	Control measures
Environmental diseases			
Depletion of oxygen		Mouth remains open Gills look pale	Aeration of the water areas
Growth of algae		Pond water turn green fishes gape for like respiration	Sprinkling of cowdung, growth of water hyacinth
Increase of hydrogen sulphide		Pond muck smells like rotten eggs resulted in respiratory distress.	Raking pond bottom and exchange of water
Excess of CO_2 or high pH of water		Excessive secretion of mucus by gills and body surface	Aeration of the water areas
Protozoan diseases			
Trichodinosis			
White gill spot disease	Catla Indian major carps and exotic carp	Pale colour of gills with a coating of cream layer of mucus	3-5% common salt bath 25 ppm formalin treatment in pond
White scale spot disease	Rohu, Mrigal	Gills covered with white spots like pox	3-5% common salt solution bath Decreasing density of fishes in pond
Helminth disease			
Dactylogyrosis and Gyrodactylosis	Catla, Rohu, Mrigal	Scales covered with white spots	3-5% common salt solution bath Decreasing density of fishes in ponds
Black sport disease	Catla		
Ligulosis	Catla		

Crustacean diseases			
Lernaeosis	Catla. Rohu. Mrigal	Excessive secretion of mucus in gills	3-5% common salt solution bath
		Irritability and surfacing	200 ppm formalin bath
Ergasilosis		Black oval shaped patches on body	Removal of molluscan population from water area
Argulosis		Abdomen enlarges abnormally and body becomes dark	Removal of birds from and around affected areas
		Rubbing against pond dykes or even bottom	Gammaxene @ 1 ppm application in the pond.
		Irritation and emaciation sometimes	5% common salt bath to the affected fishes.
		Parasites visible on gills and body surface	Removal of eggs of Argulus by hanging corrugated sheets in water and removing them and drying after a week to kill eggs.

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FISH HELATH MANAGEMENT IN *BHERY* FISHERIES

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INTRODUCTION

Bheries are typical of wetland impoundments in West Bengal, spanning over vast areas of Bidyadhari river basin east/southeast of Kolkata metropolis. These aquatic systems are unique, utilizing Kolkata city sewage water in fish production process and thus solving the problems of waste water treatment to a great extent. These eco-systems differ in many ways from those of virgin water bodies. The physico-chemical environment is widely variant which besides posing life threats in extremities creates physiological pressure on aquatic lives specially those requiring high oxygen budget and some favourable physico-chemical conditions to live and grow freely.

The production potential of aquatic system is related to carrying capacity and effective conversion at different levels of food chains. The whole process of production is dependent on good healthy environment for the producing target organism. In *Bhery* systems the introduction of waste waters results in high load of organics of varying degradability. To neutralize or break the organics down to effective nutrients the bacterial populations get activated and proliferate tremendously turning the environment unhealthy for the target organisms.

In view of achieving maximum benefit out of the introduced organic waste water in *bhery* system the health condition of the target fish/prawn needs proper attention and thus the adoption of scientific management techniques to help in attaining production targets besides keeping control over the environment of the eco-system and thus save the aquatic resources from degradation and derelict loss.

FISH HEALTH MANAGEMENT

Fish though similar in many ways to those of all animals are adopted to live under water with unique characteristics of the process of respiration, osmo-regulation, feeding digestion and excretion. These features are important to understand for creating the condition to meet the physiological requirements of the target organisms. The economic success of any culture operation depends on achieving the growth and survival rates to the tune of compensating the increased expenses. Obviously, careful management of rearing environment is necessary to prevent adverse effects on fish/prawn health and physiological conditions that would otherwise often occur because of more crowded condition and physico-chemical alterations.

ENVIRONMENTAL FACTORS

Effective fish health management requires species specificity and more detailed information on water quality including safe tolerance limits for contaminants and other toxic substances. A summary of such water quality requirements is presented below.

Table 1. Concentration of permissible limits of important water quality parameters for fish environment.

Parameters	Recommended limits
Acidity	PH 6-9
Arsenic	< 400 $\mu g/l^{-1}$
Alkalinity	>20 $\mu g/l^{-1}$ (as $CaCO_3$)
Aluminium	<0.075 $\mu g/l^{-1}$
Ammonia	<0.02 $\mu g/l^{-1}$
Cadmium	<0.0005 $\mu g/l^{-1}$ (soft water) <0.005 $\mu g/l^{-1}$ (hard water)
Calcium	>5 $\mu g/l^{-1}$
Carbon dioxide	<5-10 $\mu g/l^{-1}$
Chloride	>4.0 $\mu g/l^{-1}$
Chlorine	<0.003 $\mu g/l^{-1}$
Copper	<0.0006 $\mu g/l^{-1}$ (soft water) <0.003 $\mu g/l^{-1}$ (hard water
Hydrogen sulfide	<0.0003 $\mu g/l^{-1}$
Iron	<0.1 $\mu g/l^{-1}$
Lead	<0.02 $\mu g/l^{-1}$
Mercury	<0.0002 $\mu g/l^{-1}$

Nitrate (NO3)	<1.0 µg/l^{-1}
Nitrate (NO2)	<0.1 µg/l^{-1}
Oxygen	6 µg/l^{-1} (cold water 4 µg/l^{-1} (warm water)
TDS	<200 µg/l^{-1}
TSS	<80 µg/l^{-1}
Zinc	<0.005 µg/l^{-1}

Among chemical environmental factors important one like acidity, alkalinity, ammonia, carbon di-oxide, chlorine, dissolved oxygen, hardness, hydrogen sulphide, nitrate and nitrite have well defined roles in fish health management.

Acidity

Acidity in water is the result dissolved carbon di-oxide from the atmosphere or produced from the metabolism of aquatic organism, mineral acids, naturally occurring organic acids from humus deposits or hydrolysis of salts of mineral deposits leached into the supplied water. Acidity, in other words the pH, is not the fixed value but varies with the other environment the lower limit is raised to 6.5. The pH in *bheri* systems varying between 6.5 and 9.0 is conducive for the fishes. But occasional fall in hydrogen ion concentration *ie.*, acidification of environment needs neuralization by application of lime. The doses of lime required is dependent on the level of acidification of environment.

Alkalinity

Alkalinity provides the buffering capacity for protecting fish against wide swings of water pH in intensive and semi intensive culture environment. In *bheri* systems the alkalinity fluctuates within moderately high range indicating rich productive potentiality. However, for intensive or semi-intensive fish culture an alakalinity of 100 to 150 mg/l^{-1} is recommended for buffering capacity to prevent wide fluctuation in pH, promote algal growth, prevent leaching of heavy metals and allow the use of copper compounds for disease treatment.

Ammonia

The major source of ammonia in aquatic environment is fish metabolism relatively larger amount of ammonia together with smaller amounts of urea, creatine, creatinine, uric acid and other nitrogenous wastes are more or less continuously created. In properly managed culture environment most of the ammonia is assimilated and removed by algae and aquatic plants. A naturally occurring zeolite mineral clinoptilolite, can remove ammonia by exchange process from aquatic environment. The maximum safe exposure level for un-ionized ammonia has not so far been completely defined for the fish under intensive or semi intensive culture condition. Concentration at or below 0.01 mg/l^{-1} is safe but for intensive or semi intensive culture conditions the limit may be up 0.1 mg/l^{-1} allowing the condition of health of the fish unaffected.

Carbon dioxide

In aquatic environment microbial decomposition of organic matter in bottom sediments, respiration of micro-organisms, algae and other aquatic plants besides the cultured species are the sources of carbon dioxide supply. However, in intensive or semi intensive culture environment the major source for CO_2 lies with the accumulated metabolites. The adverse effects of CO_2 on fish health are affected by ambient temperature and dissolved oxygen concentration. Low DO increase CO_2 toxicity whereas increasd water temperature decreases it by decreasing its solubility. As the ambient CO_2 level rise, blood CO_2 increased and the oxygen carrying capacity of the haemoglobin begins to decrease. Respiratory distress from reduced O_2 transport to the tissues occur at ambient CO_2 level of > 40 mg/l^{-1}. The desirable level of CO_2 is < 10-20 mg/l. In intensive or semi intensive culture environment the level may be on higher side of 30-40 mg/l^{-1} but not for longer duration

Chlorine

Chlorine is not a natural constituent of surface or ground water. However, application of chlorine as disinfectant is often tried to destroy pathogens. Sodium or calcium hypochlorite solution, calcium hypochloride or chlorine gas are usually applied as sources of chlorine of which gaseous form of chlorine is most preferred in large volume of water because of its lower cost. Chlorine gas added to water react to form a mixture of HOCL (hypo-chlorous acid), hydrogen ions (H^+) and non toxic chloride ion (CI).

$$Cl_2 + H_2O \leftrightarrow H^+ + Cl^- + HOCl$$

The fish toxicity of chlorine is very high. At concentration of 0.1 to 0.3 ppm chlorine kills most of the commercially important species. The compound can be applied safely at a dose between 3 and 5 $\mu g/l^{-1}$.

Dissolve oxygen

In intensive or semi intensive culture systems there is need to provide adequate amount of dissolve oxygen for the excess stock of fish population. Too low DO concentrations lead to serious adverse effects on health including anorexia, respiratory stress, tissue hypoxia, unconsciousness and eventually death. In aquaculture it is a challenge to balance the economic benefits to health, feed conversion and growth. An increased DO will provide against the cost of aeration required in the process. The maximum amount of oxygen that will dissolve in water is a function of several variables including altitude, temperature and salinity. For fresh water at sea level and over the temperature range of 0-30 °C (30-86 °F), oxygen solubility can be calculated from the simplified equation by Soderberge (1995).

$$DO\ (mg/l) = 125.9/t^{\ 0.625}$$

(Where t= Temperature in °F)

For best physiological conditions it is recommended to keep the DO closer to saturation. Where feeding is unrestricted like in sewage-fed *bheries* it is possible that DO level below air saturation may cause minor effects on growth and other physiological functions. The lower limits of DO to sustain life are well documented for tilapia (>0.6 mg/l) and carp (>0.8 mg/l^{-1}) depending on water temperature. Dissolved oxygen below 4 mg/l^{-1} is avoided to protect the health problems due to hypoxia in warm water species.

In *bheri* ecosystem the DO balance is conducive to the fish health except for the occassions when the concentration of the dissolved gas depletes to almost nil, mainly during the early morning hours of the day. The cloudy days in monsoon and also the foggy winters are most vulnerable for the oxygen depleted environment the *bheri* systems. Artificial aeration through physical churning of water or mechanical aerator are practiced in *bheries* whenever required. The recommended minimum DO levels for promoting fish health and physiological quality as well as assuring Hb-O_2 saturation are tabulated below:-

Table 2. Oxygen and temperature relationship in aquatic ecocystem

Temperature		Oxygen saturation	Minimum DO level recommended	
^{0}C	*^{0}F*	*(mg/l)*	*(mg/l)*	*% saturation*
5	41	12.8	9.1	71
10	50	11.3	8.8	78
15	59	10.2	8.3	81
20	68	9.2	7.8	85
25	77	8.2	7.4	90
30	86	7.5	6.9	92

Hardness

Total hardness primarily measures the amounts of calcium and magnesium salts. Other divellent dissolved metals such as iron, copper, zinc and lead can also add to total hardness. Natural waters can be classified in terms of total hardness as follows (EPA 1986)

Soft	-	upto 5 mg/l^{-1} (as $CaCO_3$)
Moderate	-	> 5-150 mg/l^{-1}
Hard	-	> 150-300 mg/l^{-1}
Very hard	-	> 300 mg/l^{-1}

Fish in hard water may be slightly less susceptible to infectious pancreatic necrosis virus and bacterial kidney disease. Epizootic ulcerative syndrome (EUS), a disease affecting warm water fishes appear more severe in waters of low hardness. As a guide line, water hardness in the range of 50-200 mg/l^{-1} pH 6-9 and alkalinity between 100 and 200 mg/l^{-1} (as $CaCO_3$) is considered desirable for the intensive culture and also in *bheri* fishery.

Heavy metals

Heavy metals such as Zn, Cu, Hg and Pb are normally found in trace amounts in surface water. These metals are highly soluble and toxic in soft water, but they usually precipitate as insoluble carbonates or hydroxides in hard alkaline water (> 150 mg/l-$CaCO_3$, pH 8.0), which greatly reduces their toxicity. The unwanted introduction of heavy metals mostly through the industrial effluents in soluble chloride and sulfate forms creates problems of varying orders affecting the physico-chemical and biological environment of the recipient ecosystem. The problem of heavy metal contamination is more complicated in aquatic environment because of their high water solubility and quick dispersion in the media. In combined forms these toxic elements produce either synergistic or additive effects on the aquatic lives. Apart from the interactions amongst the elements the physico-chemical environment also influences the toxicity of the metals. The safe limits for some commonly encountered heavy metals in aquatic environment have been indicated in Table 1.

Hydrogen sulphide

Hydrogen sulfide (H_2S) is highly toxic water-soluble gas that occurs in polluted aquatic environment. This gas readily penetrates the gill epithelium and exerts its toxic effects by blocking the ability of the cells to use oxygen. The net result is hypoxia similar to the effect of cyanide or oxygen depletion. Fishes exposed to lethal levels of H_2S first show increase ventilation rates, then cessation of ventiliation procersses. Death follows within a few minutes as toxicity of H_2S increases and the DO level decreases in the environment. The recommended maximum safe exposure level for H_2S is 0.002 mg/l for fish and otgher aquatic life in natural waters.

In *bheri* systems the dissolved H_2S level sometimes increases to alarming concentration and creates threat for the aquatic life. The undesirable levels of H_2S can be removed from the water by aeration which volatizes it to the atmosphere.

Nitrate, Nitrite

Nitrates (NO3) and Nitrites (NO2) are often creating problems in *bheri* environment because of the introduction of sewage waters. Further, the normal sources, which are the microbial oxidation of ammonia produced by the metabolism and decomposition of faeces and bottom debris also attribute to the problems. Nitrite exposure may cause fish health problems such as gill hypertrophy. hyperplasia and lamellar separation together with haemorrhages and necrotic lesions in the thymus. Exposure at sub-lethal doses of nitrite increases the susceptibility to infectious diseases and longer exposure causes methemoglobinemia, commonly termed as brown blood disease.

Nitrite is commonly considered to be essentially non toxic to fish. However, high nitrate exposure has been reported to have adverse effects on embryo development in fish. A nitrite level of < 0.1 mg/l is considered to be safe for fish health and the toxicity of nitrate for fish health may not be problem in intensive fish culture system and *bheri* fishery.

Temperature

In culture situations the effects of temperature on fish physiology are of more practical importance than lethal extremes. Warming of water increases the toxicity of any dissolved contaminants, generally promotes the growth and invasiveness of fish pathogens, decreases the DO concentration and increases oxygen consumption by increasing the body temperature and thus the metabolic rate. Cooling, on the other hand lowers the body temperature, slows the immune response and reduces the feeding activity and growth. This indicates that the water temperature probably has a greater effect on fish health and physiological condition than any other environmental variables with possible exception of dissolved oxygen.

The fishes at higher temperature suffer from low O_2 levels in blood, declined oxygen supply to different tissues, ability loss to maintain energy resources and decline in serum electrolyte concentrations. Death due to low temperature likely involves physiological mechanisms similar to those responsible for heat death. The chronic temperature variables result physiological traces on fish health and undesirable impact on growth performance. Temperature affects the rate of growth and development by affecting a variety of metabolic processes including respiration, feeding and digestion.

In *bheri* system the low depths, fluctuating in the range of 60 to 100 cm. Keep the fishes in slightly higher range of temperature and extreme temperature stresses occur very rarely. However, partial covering with surface floating aquatic vegetation provides shelter to the fishes under extreme hot summer days.

Temperature plays a major role in spreading of infectious diseases. The severity of the infectious diseases caused by most gram-negative bacteria is greater at elevated water temperature.

BIOLOGICAL MANAGEMENT

The fish to fish interactions are bheavioural and include aggression, hierarchal dominance and inter specific competition. In natural population behavioural interaction are adoptive and enhance access to sources such as food, space, favourable water quality and breeding partners. In culture system the natural compatibility gets top priority besides the growth, power of resistance and commercial value of species selection. Even after proper selection of species the health problem results from social dominance in fish to fish interaction. Dominance hierarchies are based largely on fish size and form relatively quickly in many species, particularly at low population densities. Aggression is the prevalent method used to establish and maintain hierarchies. Fin nipping, scale loss from ramming, reduced growth, pathological changes in gastrointestinal tissues and increased susceptibility to infectious diseases due to chronic physiological stresses can all so occur in defeated individuals. Considering these biological interactions within the species population rationality must be followed in selection of species size and density for rearing in culture system.

The interactions between fish and micro-organisms are potentially main sources of fish mortality in culture systems. These interactions occur at the physiological/biochemical level and are strongly affected by physico-chemical conditions of the rearing environment. In *bheri* system though waste water are often introduced, the problems of fish/prawn health disorders are not of common occurrence excepting mass mortality of the stocks in extreme condition of environmental deterioration. Disease infestations mainly with external parasites are encountered in *bheri* without proper water management. However, in recent years the white spot disease has become a serious problem for the prawn growers in *bheri* and also prawn culture ponds. Biological management for fish health protection thus includes maintenance of fish to fish hierarchy status, avoid aggression and keeping control over the fish to microorganisms interactions of unwanted nature.

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BIOTECHNOLOGICAL TOOLS IN FISH HEALTH MANAGEMENT

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INTRODUCTION

Development of suitable diagnostic and control measures has assumed a high priority to combat diseases problems in fish culture. A multitude of factors has been responsible for disease outbreaks both in hatchery and culture conditions. Involvement of different bacterial, viral, fungal and parasitic pathogens have been reported and identified in different culture systems. The Office International des Epizootics (OIE – World organization for animal health) lists 29 diseases of finfish, molluscs and crustaceans which fit the criteria of the OIE as being of significant economic importance and thus reportable to the OIE (OIE, 2000). The important OIE-notifiable viral diseases, as important for fish and shellfish have been presented in Table-1. In addition to OIE–listed diseases, many more diseases of regional and national interest, have significant impact on aquaculture productivity, which warrant considerable attention for all aquaculturing nations.

Disease prevention and control programme should focus on the basic approaches like (i) Ecosystem management : environmental management with optimum water, soil quality maintenance and proper stocking density, avoiding stress to animals (ii) Disease diagnostics : development of rapid and sensitive immunological and molecular techniques for detection and characterization different fish and shellfish pathogens (iii) Genetics & Breeding : development of brood stock animals with higher disease resistant capacity or pathogen free for healthy seed production (iv) Microbiology : development of effective vaccines, probiotics and immunostimulants for protection against different diseases. The developments in this regard would help to enhance fish production, avoiding frequent occurrence of diseases in fish and shellfish culture and overall development in a sustainable manner. Application of these possible approaches, their impact and achievements made in this regard have been elaborated.

Table – 1. Prevalence of important OIE notifiable and significant diseases in Fish and shellfish

I-Fish diseases	Causative agent	Species affected
Epizootic haematopoietic necrosis (EHN)	EHNV, ESV & ECV,(Ranavirus) Iridovirus group	Red perch, Rainbow trout, Sheathfish, Catfish
Infectious haematopoietic necrosis	IHNV	Rainbow trout, Pacific salmon,Atlantic salmon
Oncorhynchus masou virus disease (OMVD)	Oncorhynchus masou virus (OMV)	Salmonid fishes
Spring viraemia of carp (SVC)	SVCV, Rhabdo virus	Common carp, grass carp, Silver carp, sheathfish,
Viral haemorrhagic septicaemia	VHSV, Novi-rhabdovirus, Family : Rhabdoviridae	Raibow trout, Brown trout, Pike, Turbot, Pacific salmon
Channel catfish virus disease (CCVD)	Channel catfish virus(CCV), Herpes virus	Channel catfish
Viral Encephalopathy and reticulopathy/ Viral nervous necrosis (VNN)	VERV/ VNNV, Nodavirus, family : Nodaviridae	Seabass, Stripped jack, Groupers, Puffer, Flatfish
Infectious pancreatic necrosis (IPN)	IPNV Birnavirus/ Birnaviridae family	Salmonids, Rainbow trout, Brook trout, brown trout, Atlantic salmon
Infectious salmon anaemia (ISA)	ISAV, Orthomyxo- like virus	Atlantic salmon, Rainbow trout
Red sea bream Iridoviral disease (RSIVD)	RSBIV, Iridovirus	Marine fish, Red sea bream, Yellowtail, Sea bass, Grouper
Epizootic Ulcerative syndrome/red spot disease/mycotic granulomatosis	*Aphanomyces invadans/A. piscicida/ A.invaderis* with secondary Rhabdoviruses and Gram negative bacteria	Most farmed freshwater and estuarine fish susceptible but Tilapia, milk fish and Chinese carp are resistant
Bacterial kidney disease	*Renibacterium salmoninarum, Corynrform* bacteria, Genus: Renibactrium	Pacific salmon,
Enteric septicaemia of catfish	*Edwardsiella ictaluri*, Family, Entreobactericeae	Channel catfish, Clarius batrachus, several ornamental fishes, Salmonids
Piscirickettsiosis	*Piscirickettsia salmonaris*	Salmonids,

II – Shellfish Diseases		
White spot disease/ White spot syndrome	WSSV)/ WSV : Under WSSV complex or Whispo virus (New genus)	Penaeid shrimp
Yellow head viral Disease	YHV/ Lymphoid organ virus (LOV) and Gill-associated virus (GAV), Coronaviridae family	Penaeid shrimp
Taura Syndrome	TSV, Picorna- viridae family	*P.vennamei, P.stylirostis*
Baculoviral midgut gland necrosis (BMN)	BMNV, PjNOB I. Type C Baculovirus	*P.japonocus, P.monodon*
Nuclear polyhedrosis/ Tetrahedral baculovirosis/ Baculovirus penaei disease	Baculovirus penaei (BP). PvSNPV (variable strains involved)	*P.vennamei, P.penicillatus, P.aztecus, P.duorarum*
Spherical baculovirosis/ Monodon-type baculovirus disease	*Penaeus monodon*- type baculovirus (MBV), PmSNPV	Cultured and wild penaeid prawns and shrimp
Infectious hypodermal and hematopoietic necrosis / Runt deformity Syndrome (RDS)	IHHNV, 22nm size. Family-Parvoviridae	*P.vennamei, P.stylirostis, P.semisulcatus, P.japonicus*
Spawner isolated mortality virus (SMV)disease/ Mid-crop mortality syndrome.	SMV, Parvovirus, 20nm size. Family Parvoviridae	*P.monodon*

APPLICATION OF MOLECULAR DIAGNOSTIC METHODS

Nucleic acid techniques such as plasmid profiling, DNA-restriction fragment analysis, Randomly amplified polymorphic DNA (RAPD), Restriction fragment length polymorphism (RFLP), Polymerase chain reaction (PCR) etc. are making increasing inroads into clinical laboratories. Molecular methods have surpassed traditional methods of detection for many fastidious organisms, both in terms of sensitivity and rapidity. The scope of application of such molecular and immunological techniques in fish disease diagnosis have been elaborated.

POLYMERASE CHAIN REACTION (PCR) TECHNIQUES

Advancements made in PCR technology in amplifying a required piece of gene or DNA segment has revolutionised the diagnostic methods in human and animal medicine. PCR is a rapid and inexpensive way of preparing specific DNA segment by cyclic amplification, which can be used in characterizing the pathogen and disease condition. In PCR, Selected sequences of DNA are amplified over a million times in few hours using specific primers, DNA polymerase and nucleotide mixture in a PCR machine or Thermal cycler. Thus from a small segment of DNA microgram quantities of DNA can be produced. The basic requirement of PCR is to design specific primer sequence for target gene of importance that can be able to characterize and differentiate specific strain/species of organism or animals.

RT-PCR

Numerous modifications of the standard PCR procedure have been developed since its inception, which have effectively expanded the diagnostic capabilities of PCR and have increased its utility in the clinical laboratory. Reverse transcriptase-PCR or RT-PCR has been developed and used to amplify RNA targets (mRNA, RNA viruses). In the process, RNA targets are first converted to complementary DNA (cDNA), by Reverse transcriptase enzyme and then amplified by PCR. The thermostable DNA polymease (Tth Polymerase) and its derivatives have efficient reverse transcription activity and used in detection of RNA targets without the need for a separate RT step. The higher reaction temperature increases stringency of primer hybridisation and avoids the possible RNA secondary structure, so that the reaction is more specific and efficient.

Nested PCR

Another important modification technique of PCR, which has gained importance in diagnostics is "Nested PCR", which is basically designed mainly to increase the sensitivity, uses two sets of primers. One set is used for the first round of amplification, which consists of 15-30 cycles. The amplification product of first reaction are then subjected to a second round of amplification with another set of primers, that are specific for an internal sequence that was amplified by the first primer pair. Nested PCR has extremely high sensitivity because of the dual amplification process and extensively used in diagnosis. PCR technique has been applied by different researchers for detection of WSSV, MBV in shrimp and this would be more useful in screening of samples under field condition. Besides detection of shrimp viruses, PCR has been used for detection of bacterial pathogens of public health importance in fish and fish products indicating its scope of application in food quality control. In our laboratory PCR have been applied to detect WSSV, *V.parahaemolyticus* and *V.cholerae* in culture or tissue samples and found quite effective and sensitive in detection of such pathogens. The tests are now being standardized for other pathogens.

Multiplex PCR

This is another important technique used in diagnostic laboratory. A number of pathogens can simultaneously be detected using the process of PCR amplification called "Multiplex PCR". In this method two or more sets of primer pairs specific for different targets are introduced in the same tube. Thus, more than one unique target DNA sequence in a specimen can be amplified and detected at the same time. Primers used in multiplex PCR reactions must be carefully designed to have similar annealing temperatures, which often requires extensive empirical testing. This co-amplification of multiple targets can be used in various purposes. For diagnostics use, multiplex PCR can be set up to detect internal controls or to detect multiple pathogens from a single specimen. Once standardized, this technique can be popularly used for detection of multiple pathogens in sample at a time, which not only reduce the analysis time, more cost effective but the results of screening trial can be easily interpreted.

Real-time PCR

Another latest and important development in PCR technology is "Real-time PCR". This technique is the most practical, because it does not require time-consuming post-PCR manipulation and processing of the reaction with slab gel and capillary electrophoresis, hybridization to immobilized oligonucleotides, or mass spectrometry. Real-time PCR can be accomplished with the fluorogenic 5′-nuclease assay called TaqMan and a spectrofluorometric thermal cycler. TaqMan is a homogenous PCR test that uses a fluorescence resonance energy transfer (FRET) probe typically consisting of a green fluorescent "reporter" dye at the 5′-end and an orange "quencher" dye at the 3′-end. When the probe anneals to a complementary strand of an amplicon during PCR, Taq polymerase cleaves the probe during extension of one of the primers, and the dye molecules are displaced and separated. The electronically excited reporter dye is no longer suppressed by the quencher dye, and the significant increase in green emission can be monitored by a fluorescence detector. The intensity of the green fluorescence directly correlates with the concentration of PCR product in the reaction. Durand and Lightner, (2002) applied quantitative real time PCR for the measurement of WSSV in shrimp. The TaqMan probe was synthesized and labelled with fluorescent dyes 5-carboxyfluorescein (FAM) on the 5' end and N,N,N',N;-tetramethyl-6-carboxyrhodamine (TAMRA) on the 3'end. Recently a silicon chip-based spectrofluorometric thermal cycler called Advanced Nucleic Acid Analyzer (ANAA) has been developed which is handy, more sensitive and can be used in the field and offers real-time monitoring. Such techniques are not only highly sensitive, requiring only few minutes, compared to days as required by other methods, but can also be applied in cases where other methods fail to detect the pathogen. Hence these techniques have wide scope of application in disease diagnosis and quarantine programme.

IMMUNODIAGNOSTIC TESTS

Because of the speed, versatility, economic, simplicity and reasonably good sensitivity based on use of monoclonal/ monospecific-polyclonal antibodies, these tests will be potentially very useful as routine diagnostic tests even in the most modestly equipped diagnostic laboratories (Lightner & Redman, 1998). A variety of immunological tests like agglutination test, Enzyme linked immunosorbnt assay

(ELISA), Nitrocellulose Enzyme immunoassay (NC-EIA) also called Dot immunoassay (DIA), Western blotting techniques, latex agglutination test etc. have been developed and used for detection of a variety of pathogens and disease conditions. ELISA based on monoclonal antibodies(MAb) to *V.vulnificus* and *V. harveyi* have been used. While considerable research and development efforts have been made to develop polyclonal (PAb) or MAb to penaeid viruses like BMNV, Rhabdoviruses of penaeid shrimp (RPS), WSSV, Baculovirus penaei (BP), WSSV, IHHNV, HPV, YHV, etc. the specificity of such tests has still to be standardized.

GENOTYPING TECHNIQUES

A major breakthrough in pathogen identification and characterization has been achieved with introduction of molecular methods like Randomly Amplified Polymorphic DNA (RAPD), Restriction fragment Length Polymorphism (RFLP), Pulsefiield gel electrophoresis (PFGE), Ribotyping, Plasmid profiling techniques etc.

RANDOMLY AMPLIFIED POLYMORPHIC DNA (RAPD) TECHNIQUE

RAPD based on PCR amplification technique (RAPD-PCR) also referred to as Arbitrary primed PCR (AP-PCR) is increasingly being used in identification, classification and differentiation of strains of animals, plants , fungi and bacteria. RAPD fingerprinting allows detection of DNA polymorphism by randomly amplifying multiple regions of the genome through PCR using arbitrary primers designed independently of the target DNA sequence. RAPD analysis also helps to assess paternity and kingship relationship in large offspring samples, to analyze mixed genome samples and generating novel genomic or species specific probes for use as diagnostic RAPD marker.

RIBOTYPING

Ribotyping assays have been used to differentiate bacterial strains in different serotypes and to determine the serotypes most frequently involved in outbreaks. This technique is especially useful in epidemiological studies for organisms with multiple ribosomal operons, such as the members of the family of Enterobacteriaceae. Ribotyping simplifies the microrestriction patterns by rendering visible only the DNA fragments containing part or all of the ribosomal genes. The technique is less helpful when bacterial species under investigation contains only one or two bands, which limits its utility for epidemiological studies. However, both these techniques have wide scope of application in fishery and aquatic microbiology for pathotyping analysis, microbial biodiversity, ecological and evolutionary studies.

GENETIC IMPROVEMENT AND TRANSGENESIS

Application of basic molecular biology techniques and methodologies to aquaculture genetics will be important as means for acceleration of genetic improvement in aquaculture. The commercial potential of transgenic fish lies in developing transgenic brood stock lines. Once these fish strains have been generated, these would be very cheap source of brood stock and these could transmit their genes to the offspring. This require combining transgenic technology with traditional selective breeding programme to produce superior strains of fish.

APPLICATION OF PROBIOTICS IN FISH CULTURE

One of the most significant technologies that has been evolved is "Probiotics" to control potential pathogens. Probiotic is as a mono- or mixed cultures of live microorganisms that, applied to animal and man, affect beneficially the host by improving the properties of the indigenous microflora. Addition of these harmless or beneficial bacteria to competitively exclude potential pathogens from larval culture media has been suggested. They have been accepted as better, cheaper and more effective agents in promoting animal health than antibiotics. In fish culture, their use has been significant. Probiotics may also enhance larval nutrition by supplying essential nutrients, improving digestion through supply of essential enzymes, mediating direct uptake of dissolved organic material and producing substances which may inhibit the growth of opportunistic pathogens. Several bacteria like *V.alginolyticus*, *V.harveyi*, *V.pelagius*, *Bacillus* sp., *Lactobacillus* spp., *Altermonas* sp., *Aeromonas* spp., *Pseudomonas* spp., etc. have been used in the larval culture of aquatic organisms either delivered directly into water or via live carriers such as *Artemia* nauplii or rotifers. When probiotic bacteria like Bacillus strains are added to the water sufficiently, they can make an impact. They compete with the normal microflora naturally present for the available organic matter (excess feed, fecal matter etc.). The result is less accumulation of slime or organic matter on the pond bottom, better penetration of oxygen into the sediment and a better environment for farmed stock in general. As because shrimp are not stressed by probiotic application, its natural resistance can fight off diseases.

DEVELOPMENTS IN VACCINES AND IMMUNOSTIMULANTS

The immunostimulatory effects of glucan, chitin, lactoferin and levamisol for fish and shrimp have also been reported and nutritional factors such as vitaminc B and C, growth hormone and prolactin have also shown to be immunostimulators (Sakai, 1999). These immunostimulants mainly facilitate the function of phagocytic cells and increase their bactericidal activities. An increasing body of evidence indicate that non-specific stimulation of fish and shrimp immune system with glucans, peptidoglycans or lipopolysaccharides can improve resistance against pathogenic bacteria.

CONCLUSION

The future success of fish and shrimp farming will depend upon increasing supplies of healthy, high quality seed for stocking with a application of health management practices and application of biotechnological tools will have a major role in this regard. Improved hygiene and biosecurity, development of diagnostic methods, application of probiotics and immunostimulants and improvement of artificial feeds promise better post-larval fitness. The development of healthy, genetically improved shrimp stock represents a tremendous economic opportunity while improving the outlook for sustainability of fish farming. These methods combined with practice of "good on-farm management" would contribute strongly to a new, more productive aquaculture.

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CONSERVATION OF FISH GERMPLASM RESOURCES IN OPEN WATERS IN INDIA.

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INTRODUCTION

Fisheries Research in India spearheaded tremendous impact oriented effort for the development of capture and culture fisheries in the country during last five decades. India has unique fish fauna with huge area of open water bodies such as rivers, canals, Reservoirs, lakes, beels, oxbow lakes and derelict waters. The Indian ichthyofauna enlists about 2144 species, one of the richest resources consisting 11% of the world fish germplasm. However, many species are reported to be declined in the areas of their natural abundance and some are even at the verge of extinction. This may be attributed to habitat destruction, over exploitation and other anthropogenic stresses. There is a strong necessity to evolve suitable conservation measures to check this declining trend.

PRESENT SCENARIO OF AQUATIC RESOURCES - PRODUCTION, PRODUCTIVITY AND AVAILABILITY

The river system of the country has a total length of about 45,000 km, comprising 14 major, 44 medium and innumerable small rivers and desert streams. The major river system on the basis of drainage can be divided broadly into two categories, (1) Himalayan river system and (2) Peninsular river system. India is the seventh largest country in the world with regard to area coverage, accounts for 15% of global population and shares 2.5% of the world's area. It has a frontier of 15,200 km and a coastline of 8,219 km including Lakshadweep, Andaman and Nicobar Islands. India is a land of many rivers and mountains its geographical area of about 329 million hectare (m.ha) is criss – crossed by a large number of small and big rivers, some of them figuring amongst the mighty rivers of the world. As many as 12 of them are classified as major rivers whose total catchment area is 252.8 m.ha. Of the major rivers, the Ganga – Brahmaputra Meghana system is the biggest with catchment area of about 110 m.ha., which is more than 43% of the catchment area of all the major rivers in the country. Other than rivers and canals, total water bodies cover an area of about 7 m.ha. In totality.

India is the seventh largest producer of fish in the world and, perhaps, second in inland fish production. Fishery sector plays a vital role in sustaining a fairly large proportion of population along the 8,219 kms. long coastline. The contribution of fisheries to the net domestic product has increased from Rs.1479 crore in 1984-85 to Rs.9826 crore in 1994-95 at current prices showing about six and a half times increase in ten years. The Indian fisheries sector, which 50 years ago produced only 0.75 m mt of fish, today produces 5.65 m mt (2000-2001), including 2.0m mt from Inland sector. Although the yield from marine fisheries has stagnated, freshwater aquaculture is growing at a healthy 6 percent a year.

CONSERVATION - STATUS

As per IUCN red data book, 510 species have been listed under threatened categories, of these, 2 species have been listed from India namely *Schistira sijuensis and Horaglanis krishnai*. Besides IUCN many countries have brought out their own list of threatened or rare fish like Nepal, South Africa, Australia, UK and USA. In India, the listing of threatened fishes is being actively persued by NBFGR. Because of vast area and large number of species make the task of listing threatened species very difficult. Based on the study carried out by NBFGR the first list of threatened species has been prepared through prioritization.

Table. 1 : Conservation status of fresh water fishes of India

Conservation status	Species
Endangered (En)	**98**
Vulnerable (V)	**82**
Critically Endangered (Ce)	**47**
Extinct (Ex)	**2**
Data Deficit (Dd)	**18**
Lower risk least concern (Lr)	**13**
Lower risk near threatened (Lrnt)	**67**

TOTAL NO. OF FRESHWATER FISHES: + 600, CONSERVATION STATUS ASSESSMENT: - 327

WORK ON CONSERVATION

Tata Electric Company, Lonavala has done commendable work in conservation and restoration of Deccan mahseer or Khudree mahseer. *Tor khudree* has been artificially bred at Lonavala Lake where ripe and oozing spwaners congregate at the outfall of streams during middle of July to the end of August. National research center on cold-water fisheries, Bhimtal has standardized a technique of mass scale seed production and raising of fingerlings of endangered *Tor putitora* at Bhimtal. The programme for ranching of artificially bred mahseer fingerlings in the Kumoan Rivers in collaboration of NRC on CWF, U.P. State Fisheries Department; G.B.Pant University with NBFGR has been initiated.

Further, NBFGR has standardized the long-term cryo-preservation of milt of endangered *Tor putitora* and *Tor khudree* (*ex-situ* conservation), which are being maintained at the Mini gene Bank of the institute since 1997, besides other commercially cultured species.

In recent times, certain NGO's have come forward to protect cold water fish stocks in the Himalayas. There is only one association to protect exotic rainbow trout - Munnar High Range Angling Association, Kerala. Some of well-known associations, which have taken responsibility of protecting Mahaseer, are:

(i) Wildlife Association of South India, Bangalore which has taken a stretch of river Cauveri on lease to conserve *Tor Khudree*;

(ii) Himachal Pradesh Angling Association, Palampur looking after conservation of *T.putitora* in the Beas between Sari Molag and Confluence of the Beas with Pong reservoir

(iii) Assam (Bhorelli) Angling & Conservation Association, Tezpur taking care of stretch of river Bhorelli, near Assam-Arunachal border traverses with in the limits of Nameri National Park.

CONSERVATION MEASURES

Holistic approach for conserving fish germplam

In order to conserve the threatened species, the strategies envisaged are: (i) *in-situ* conservation, (ii) *ex-situ* conservation.

1. Restoration of germplasm resources through in-situ conservation

The major advantages of *in-situ* conservation are: (i) continued co-evaluation wherein the wild species may continue to lost in *ex-situ* conservation, and (ii) National parks and Biosphere reserves may provide less expensive protection for the wild relatives than *ex-situ* measures. Other methods of *in-situ* are: -

(i) Restitution through Ranching

Fish stock enhancement programme of endangered species that culture and release of juvenile fish in depleted natural water bodies is ranching. In either way whether it is auto stocking or artificial introduction improvement of natural habitat is necessary.

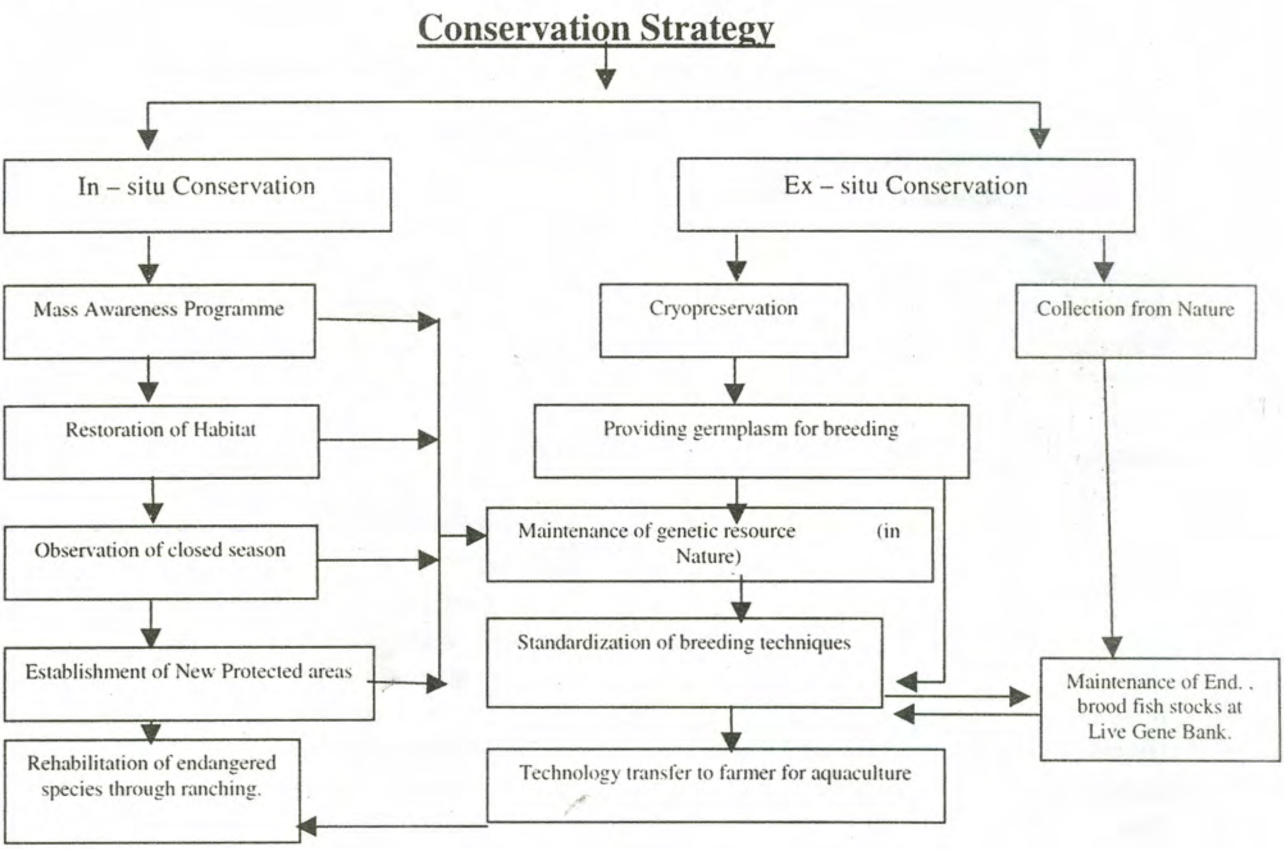
(ii) Mass awareness

(a) Arranging Kisan Goshthi,
(b) By audio- video aids,
(c) Distribution of stickers and pamphlets
(d) Constituting conservation committees
(e) By media and Doordarshan Karyakram.

(iii)Restoration of habitat

The rapid deforestation along the catchment of the streams and river facilitates soil erosion, which ultimately erodes the natural feeding and breeding grounds of the fish and also causes mass mortality. Immediate ban on the deforestation to save the erosion of soil, which decreases the water level of rivers. Immediate stopping of the extraction of stones and sand from the riverbed also leads to alteration of habitat, which reduces the breeding and nursery ground of fishes. The deforestation activities along the catchment need be immediately closed. The destructed land should be covered with polyculture of the earlier existing plant species.

Fig : 1



2. Refurbishment of Germplasm Resources through ex-situ Conservation

In these measures, the threatened species are conserved outside their natural habitats. The two main pillars of *ex-situ* conservation programme are (i) Live Gene Bank by maintaining live species and (ii) Cryo-preservation of Gamete/Embryo. In a Live Gene Bank, the endangered species are reared in captivity, bred therein and genetically managed avoiding inbreeding depression, domestication and unintended selection. In Gamete/Embryo Bank, adequate sample representative of the natural genetic variations of endangered species are kept in suspended state of animation under extra low temperature (-196^{0}C) in liquid nitrogen.

PRIORITIZED ACTION POINTS FOR RESTORATION

Establishment of Live Gene Bank

The NBFGR established a live gene bank facility to conserve and enhanced the production of endangered fishes. Preliminary work on collection of Fish Germplasm has already started with stocking of *Chitala chitala, Channa marulius, T. putitora, L. bata, L. dyocheilus* and *L. calbasu.* Stocks of Indian major carps *Labeo rohita, Catla catla, Cirrhinus mrigala* and exotic carps *Hypopthalmichthys molitrix, Ctenopharyngodon idella* and *Cyprinus carpio* are also being built up to carry out experiment on polyculture of new candidate species along with traditional species. These are expected to yield developing new culture practices along with building up a live repository. Simultaneously NBFGR has been initiated a work on establishing a regional live gene bank (Agro climatic zone wise) for NER at Guwahati.

Genetic Upgradation

Out of many modern techniques of boosting fish production in aquaculture, genetic manipulations can play decisive role in enhancing genetic worth of stocks. Some successful attempts have also been undertaken to produce *gynogenetic, androgenetic* and *polyploidy* populations of Indian and *exotic* carps. The application of biotechnology can improve yield in aquaculture using hybridization, selective breeding and use of hormone for enhancement of growth or to induce *sex reversal* in species like trout and tilapia. So far more than 40 interspecific hybrids have been produced, of these *Rohu x Catla, Rohu x Mrigal, Rohu x Calbasu, Catla x Fimbriatus, Catla x Silver carp* and *Grass carp x Silver carp* crosses and their reciprocal crosses have shown promise.

ROLE OF BIOCHEMICAL GENETICS IN CONSERVATION OF FISH GERMPLASM

The existences of complex population genetic structure with varying degree of genetic divergence have been documented in many species. For endangered species, information on population genetics is very essential to take appropriate decisions. There is a need to know the total genetic variance within the species and its distribution among population inhabiting particular areas and population within each region and within local populations.

(i) **Selection of base population** – Genetic considerations require that the chosen population for gene banking should be genetically heterogeneous. When it is not possible to maintain all population in captivity or in the gene bank, preference should be given for those exhibiting maximum genetic variation.

(ii) **Monitoring introduced stocks**- Monitoring of allele frequencies it has been possible to observe life history differences between native and transplanted rainbow trout populations and to confirm the retention or original run timing and allele frequencies in transplanted chum salmon. Allele frequencies of allozyme loci have been effectively used to study the success of introduced chum salmon into natural populations. These studies have been shown that the return of spawn in the introduced rivers were much lower than the return of native fish and in succeeding generation the introduced fish disappeared from spawning run.

PROMOTION OF AQUACULTURE

In fifties the scenario of fish seed production changed with the development of induced breeding by administering carp Pituitary Gland Extract. It is essential to go for hatchery production of seeds of new candidate species including threatened and endangered fish species, which will be helpful to interlinking aquaculture with conservation. In this way following measures are essential (a) Stock improvement through selection and breeding. (b) Maintenance of puriline reverine genetic stocks. (c) Selective breeding of non targeted threatened and endangered species.

In view of its crucial role, the fish conservation programme planning development also has to include the extension component as an integral part.

LEGAL STATUS

In India, several laws have been passed and sanctuaries and national parks have been established for protection of the dwindling wildlife. The Wild Birds and Animals Protection Act was passed in 1887 and repealed in 1972. Indian Board for Wild Life was established in 1952 and this was followed by setting up of Wild Life Boards in different State in India. It was only in 1972 that a unified national act came into being.

Although the Wildlife Protection Act of India (1972) provides legal protection to terrestrial and some of the aquatic animals only, but very little emphasis is given on freshwater **fish** genetic resources. While in Forest Act ***Section 26*** **(i) Reserved forests, Section 32 (j) Protected forests speaks Prohibition of shooting, fishing and poisoning water, setting of traps and snares.** The Indian Board of Wild Life, which is responsible for the management, preservation and development of wild fauna and flora, has defined four areas where wildlife receives some kind of protection (Protection Act, 1972). Thus the creation of fish sanctuaries, parks and listing of endangered fish species in the list of wild life protection Act is required urgently for their conservation.

Need to study the water bodies in Sanctuaries/ National Park
The study on selected water bodies of the protected areas will help in formulating and managing freshwater aquatic sanctuary on scientific angles. As per the biographic classification of India at province level prepared by Wild life Institute of India, whole North East part of India comes under 9A and 9B that contributes 2% of the total geographic area of India. This study will help in developing representative network of aquatic conservation zones geographically well distributed on such biographic classification system for better planning and management

CREATION OF AQUATIC SANCTUARIES

The protection of wild freshwater aquatic resources is necessary and for this one of the best option is creation of aquatic sanctuary in the potential reverine/streams and other wetlands areas. The protection of these resources is needed establishing National Fish Parks, Sanctuary, and protected areas of wetlands including Rivers.

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APPLICATION OF REMOTE SENSING IN WETLAND MANAGEMENT

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INTRODUCTION

Resource management requires rapid and accurate methods for interpreting data for development and management of natural resources. Monitoring and surveying are the two main factors for management of wetland resource. Surveying and monitoring of wetland resource i.e. land use / land cover, vegetation water quality, primary producers, sediment, salinity etc. could be performed by remote sensing technique.

Remote sensing is a multi disciplinary science of deriving information about an object from measurement made at distance far from the object without coming in contact with it. Remote sensing refers to the identification of earth features by detecting the characteristics electromagnetic radiation that is reflected / emitted by earth surface. Every object reflects / scatters a portion of the electromagnetic radiation depending upon its physical properties in addition, objects also emit electromagnetic radiation depending upon their temperature and emmissivity. Reflectance emittance pattern at different wavelengths for each object is different, this enables identification and discrimination of objects.

Presently, the commercial availability of remotely sensed satellite data of Indian as well as foreign satellites, which have high spatial, spectral, radiometric and temporal resolution, eases the monitoring and surveying of the wetland resources. The spatial resolution of Indian satellite varies from 5.8 m to 350 m, spectral resolution varies from 1 band to 8 bands and temporal resolution varies from 2 days to 25 days.

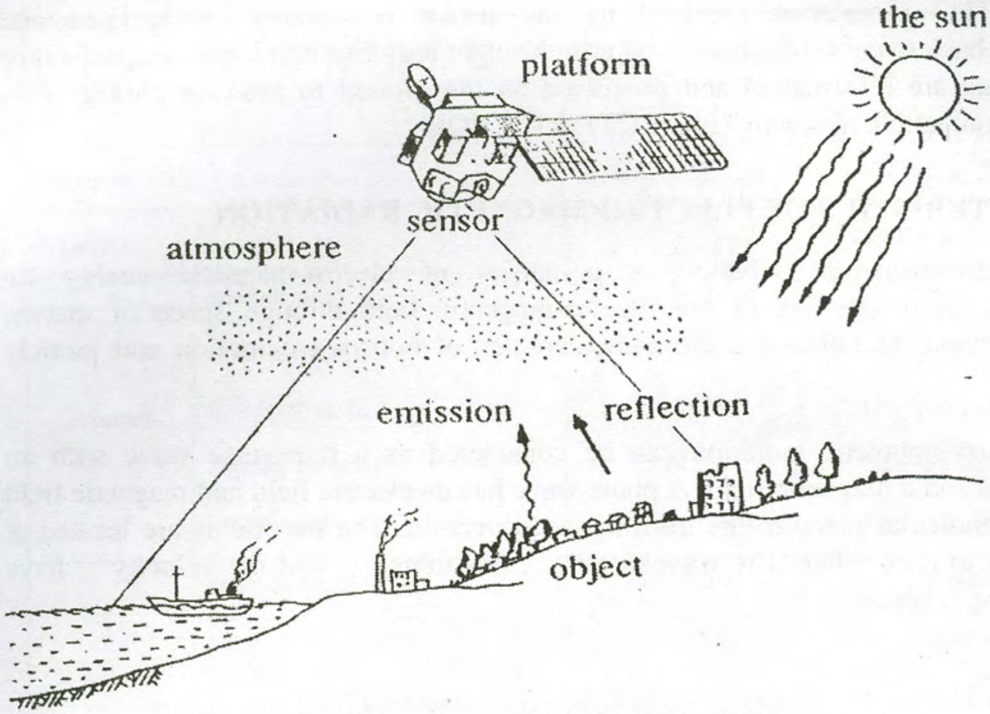
Mapping of water body and classification can be done using digital satellite data or FCC (False colour composition). Variation of water spread area can be monitored by multi date data i.e. pre monsoon, monsoon and post monsoon. The water quality can also be assessed by the colour, tone and texture of digital data. Wetland with aquatic vegetation can be identified as well as the area of vegetation can be measured. Fishery managers can utilize the remote sensing data for inventory of wetlands, water quality assessment (few parameters), weed infestation, aquatic vegetation and land use / land cover of wetlands surroundings.

PRINCIPLE OF REMOTE SENSING

Remote sensing is not a new concept. Visual perception of human eye is a best example of remote sensing. The human eye (sensor) captures light (visible radiation) from a candle (objects), placed at a distance (remote). Different objects return different amount and kind of energy in different band (range) of the EM spectrum incident upon it. This unique property depends on the property of material (structural, chemical, and physical), surface roughness, angle of incidence, intensity and wavelength of radiant energy.

The remote sensing is a science, which includes a combination of various disciplines such as optics, spectroscopy, photography, computer, electronics, telecommunication, satellite launching etc. All these technologies are integrated to act as one complete system in itself, known as remote sensing.

There are number of stages in a Remote Sensing System, working as links in complete, and each of them is important for successful operation.



Data collection by remote sensing

Stages in Remote Sensing

1. Origin of electromagnetic energy (Sun, transmitter carried by the sensor).
2. Transmission of energy from the source to the surface of earth and its interaction with the intervening atmosphere
3. Interaction of energy with the earth surface (reflection/ absorption/ transmission) or self-emission.
4. Transmission of the reflected / emitted energy to the remote sensor placed on a suitable platform.
5. Detection of energy by the sensor converting into photographic image or electrical output.
6. Transmission / recording of the sensor output.
7. Pre-Processing of the data for generation of the data product.
8. Data processing and interpretation.

Thus the remote sensing system consists of a sensor to collect the radiation and a platform which can be satellite, rocket, aircraft and balloon on which sensor can be mounted. The information received by the sensor is suitably manipulated and transported back to earth may be telemeter or brought back through films, magnetic tape etc. The data are reformatted and processed on the ground to produce photographs, computer compatible magnetic tape (CCT) or CD ROM.

CHARACTERISTICS OF ELECTRO-MAGNETIC RADIATION

Electro-magnetic radiation is a carrier of electro-magnetic energy by transmitting the oscillation of the Electro-magnetic field through space or matter. Electro-magnetic radiation has the characteristics of both wave motion and particle motion.

Electro-magnetic radiation can be considered as a transverse wave with an electric field and a magnetic field. A plane wave has its electric field and magnetic field in the perpendicular plane to the transmission direction. The two fields are located at right angles to each other. The **wavelength** [illegible], **frequency** [illegible] and the **velocity** [illegible] have the following relation.

[illegible]

Electro-magnetic radiation is transmitted in a vacuum of free space with the velocity of light c, (= 2.998 x 108 m/sec) and in the atmosphere with a reduced but similar velocity to that in a vacuum. The frequency n is expressed as a unit of hertz (Hz), that is the number of waves, which are transmitted in a second.

INTERACTIONS BETWEEN MATTER AND ELECTRO-MAGNETIC RADIATION

All matter reflects, absorbs, penetrates and emits Electro-magnetic (EM) radiation in a unique way. These spectral characteristics, if ingeniously exploited, can be used to distinguish one thing from other, or to obtain information of shape, size and other physical and chemical properties.

Wavelength regions of EM radiation have different names ranging from [illegible] ray, X-ray, ultraviolet (UV), visible light, infrared (IR) to radio wave, in order from the shorter wavelengths. The shorter the wavelength is, the more the Electro-magnetic radiation is characterized as particle motion with more linearity and directivity.

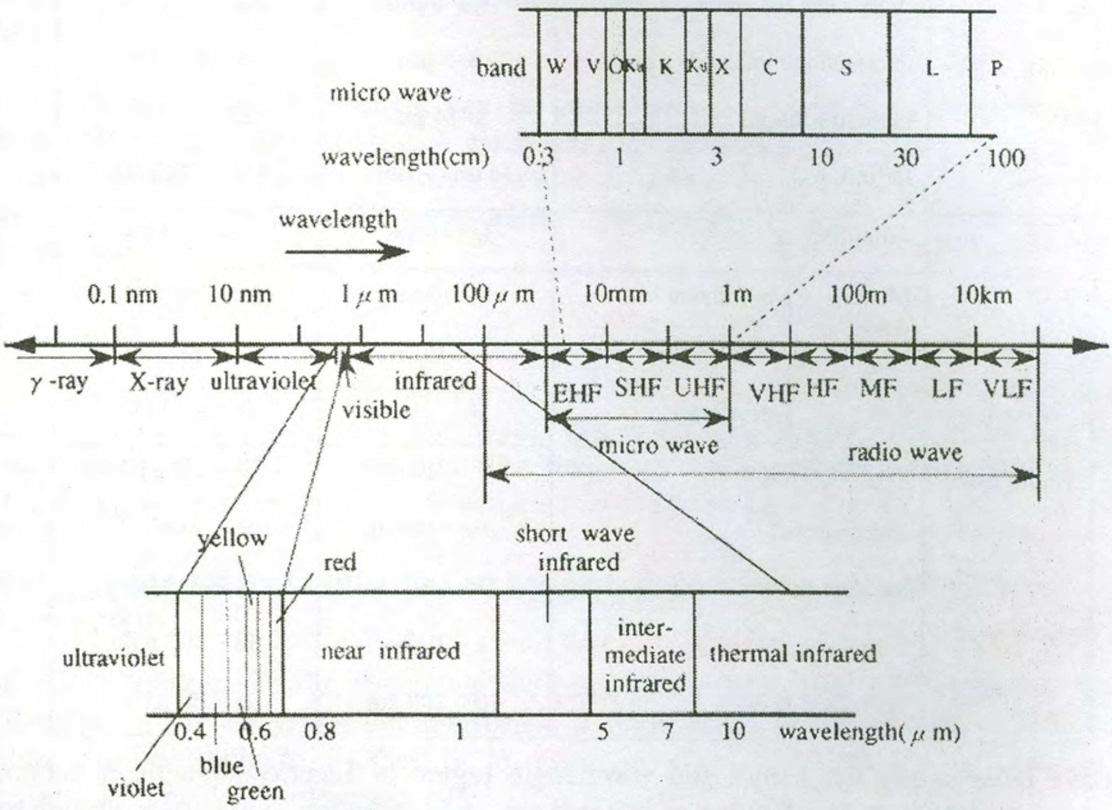
Table 1. Classification of electro magnetic raditions				
Class			wavelength	frequency
Ultraviolet			100Å ~ 0.4 μm	750 ~ 3,000 THz
Visible			0.4~-0.7 μm	430 ~ 750 THz
infrared	near infrared		0.7~1.3 μm	230 ~ 430 THz
infrared	short wave infrared		1.3~3 μm	100 ~ 230 THz
infrared	intermediate infrared		3~8 μm	38 ~ 100 THz
infrared	thermal infrared		8~14 μm	22 ~ 38 THz
infrared	far infrared		14 μm ~1mm	0.3 ~ 22 THz
Radio wave	submilimeter		0.1~1mm	0.3 ~ 3 THz
Radio wave	Micro wave	millimeter	1 ~ 10 mm	30 ~ 300 GHz
Radio wave	Micro wave	Centimeter	1 ~ 10 cm	3 ~ 30 GHz
Radio wave	Micro wave	decimeter	0.1 ~ 1m	0.3 ~ 3 GHz
Radio wave	very short wave		1 ~ 10 m	30 ~ 300 MHz
Radio wave	short wave		10 ~ 100 m	3 ~ 30 MHz
Radio wave	medium wave		0.1 ~ 1 km	0.3 ~ 3 MHz
Radio wave	long wave		1 ~ 10 km	30 ~ 300 KHz
Radio wave	very long wave		10 ~ 100 km	3 ~ 30 KHz

Above table shows the names and wavelength region of Electro-magnetic radiation. One has to note that classification of infrared and radio radiation may vary according to the scientific discipline. The table shows an example which is generally used in remote sensing.

The Electro-magnetic radiation regions used in remote sensing are near UV(ultra-violet) (0.3-0.4 _m), visible light(0.4-0.7 _m), reflected infrared (0.7-3.0 _m), thermal infrared (3.0 to 5.0 _m and 8.0 to 14.0 _m) and micro wave (1 mm - 1 m).

The following figure shows the spectral bands used in remote sensing. The spectral range of near IR and short wave infrared is sometimes called the reflective infrared (0.7-3 μm) because the range is more influenced by solar reflection rather than the emission from the ground surface. In the thermal infrared region, emission from the ground's surface dominates the radiant energy with little influence from solar reflection.

Visible light corresponds to the spectral colors. They are, in order from the longer wavelengths in the visible region, the so called rainbow colors; red, orange, yellow, green, blue, indigo and violet are located with respect to the wavelength.



The bands used in remote sensing

Short wave infrared has more recently been used for geological classification of rock types. Thermal infrared is primarily used for temperature measurement, while micro wave is utilized for radar and micro wave radiometry.

Remote sensing is classified into three types with respect to the wavelength regions;

1. Visible and Reflective Infrared Remote Sensing,

2. Thermal Infrared Remote Sensing and

3. Microwave Remote Sensing. .

SPECTRAL SIGNATURE

Spectral signature is the ratio of reflected energy to incident energy as a function of wavelength. Various materials of the earth, surface has different spectral reflectance characteristics. Spectral reflectance is responsible for the color or tone in a photographic image of an object.

SENSORS

Sensor is a device that gathers energy (EMR or other), converts it into a signal and presents it in a form suitable for obtaining information about the target under investigations. These may be active or passive depending on the source of energy.

Sensors used for remote sensing can be broadly classified as those operating in optical infrared (OIR) region and those operating in the microwave region. OIR and microwave sensors can further be subdivided into passive and active.

Active sensors use their own source of energy. Earth surface is illuminated through energy emitted by its own source, a part of it reflected by the surface in the direction of the sensors is received to gather the information, and passive sensors receive solar Electro-magnetic energy reflected from the surface of energy emitted by the surface itself. These sensors do not have their own source of energy and can not be used at night time, except thermal sensors. Again sensors (active or passive) could either be imaging, like camera, or sensor which acquires images of the area and non imaging types like non scanning radiometer or atmospheric sounders.

RESOLUTION

Resolution is defined as the ability of the system to render the information at the smallest discreetly separable quantity in terms of distance (spatial), wavelength band of the EMR (spectral), time (temporal) and/ or radiation quantity (radiometric).

MAPPING OF WETLANDS/WATER BODY

There are various steps involved in mapping of wetlands starting from geo referencing, base map development, image processing to tabulation. Following are the basic steps involved in water body mapping.

ACQUISITION OF REMOTE SENSING IMAGE

For any remote sensing related study it is very important to select the sensor, satellite and passing date of the satellite. Sensors should be selected on the basis of objective of the study. For the mapping of water body, it is required to select sensor which works in the visible range (0.4-0.7 μm). There are various sensors of Indian and other country's satellites, which work in visible range i.e. Pan, LISS-3, WiFS TM and OCM. For mapping bigger water body LISS-3 sensor and for smaller PAN is better. For any remote sensing study the image should be cloud free. The remote sensing digital data of NRSA is pre-processed that includes radiometric and geometric correction.

GEO REFERENCING OF REMOTE SENSING IMAGE

Geo referencing is the process which creates and store control information that relates raster cells or vector information to a coordinate system and map projection. The geo referencing of image can be done by various techniques. In the simple geo referencing, the coordinate system cell size and coordinate for corner or central cell location is known from reference materials supplied by the source of raster objects. The precise geo referencing can be possible with the help of topographic sheet (i.e. Survey of India topographic sheets).

DATA ANALYSIS

There are two methods of data analysis for extracting resource related information from data products, either independently or in some combination with other collateral information.

1. Digital image processing techniques and

2. Visual interpretation technique

Digital Image processing

In a digital image processing, the computer analyses the spectral signature so as to associate each pixel with a particular feature of imagery.

The digital classification techniques can broadly categorized into two

1. Supervised classification and
2. Unsupervised classification

Supervised classification

Supervised classification can be defined normally as the process of samples of known identify to classify pixels of unknown identity. Samples of known identity are those pixels located with in the training area. Pixels located with in these areas term the training samples used to guide the classification algorithm to assigning specific spectral values to appropriate information class.

Unsupervised classification

This system of classification does not utilize training data as the basis for classification. This family of classification involves algorithms that examine the unknown pixels in an image and aggregate them into number of classes based on the natural groupings or cluster present in the image values.

Visual Technique

Traditionally, visual interpretation methods have been followed for extracting information on various natural resources

OTHER APPLICATION OF REMOTE SENSING RELATED TO WETLAND.

After water spread area water quality is most important factor for wetland management. And for the fish production, planktons (i.e. chlorophyll) along with others are considered as an essential factor for the fish production.

Water quality

Remote sensing applications are limited to measuring those substances or conditions with influence and change optical and / or thermal characteristics of surface water properties/ water quality. Suspended sediments, chlorophylls, dissolved organic matter and temperature are water quality indicator that can change the spectral and thermal properties of surface water are most readily measured by remote sensing techniques.(Ritchie. et al. 1994).

Suspended solids in water produce visible change in the surface of water and in the reflected solar radiation, such changes in the spectral signal from surface water, captured by the satellite. (Richie.1990). There are significant relationship between total suspended sediment and the reflectance of Landsat TM digital data. Reservoir trophic state and Carlson trophic state index were measured in Te-Chi Reservoir in central Taiwan with the help of Landsat TM (TM1~TM4). (Cheng, 1998)

Plankton (Chlorophyll)

Plankton contains a pigment that strongly absorbs red and blue light. As plankton concentration increase, there is a corresponding rise in spectral radiances, peaking in the green. Upwelling masses of water (usually associated with thermal convection) containing phytoplankton take on green hues in contrast to the deep water with few nutrients. Remote sensing can be used to measure the chlorophyll concentration and patterns in water bodies. While measuring chlorophyll by remote sensing technique is possible, studies have also shown that the broad wavelength spectral data available on current satellites do not permit discrimination between chlorophyll and suspended sediments when suspended sediment concentrations are high due to the dominance of the spectral signal from suspended sediment (Ritchie *et al.* 1994). Recent research shows the relationship between chlorophyll-a and the narrow band spectral details at the red edge of the visible spectrum (Gitelson *et al.* 1994). Data have shown a linear relationship between chlorophyll-a and the difference between the emergent energy in the primarily algal scattering range (700-705 nm) and the primarily chlorophyll-a absorption range (675-680 nm). Laboratory and field studies using hyperspectral data have been used to develop algorithm to estimate green and blue green algae (Dekker *et al.* 1995). Hyperspectral data now available from several satellite platforms, should allow better discrimination between pigments thus allowing the identification of broad algal groups.

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INSTITUTIONAL ARRANGEMENTS IN MANAGEMENT OF BEEL FISHERIES

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INTRODUCTION

Floodplain wetlands are important fishery resources and contribute significantly to the Indian inland fisheries. These resources are primarily distributed in the states of Assam, Bihar, West Bengal and Manipur and locally known as *mauns, chaurs, beels, jheels, and pats.* (Sugunan, 1995)

The outcome of any production system depends largely on its production efficiency, administrative acumen and the environment in which it operates.

The present topic concentrated more on the subjective aspects of the institutional arrangements and management regulations.

CLASSIFICATION OF INSTITUTIONAL ARRANGEMENTS

The institutional arrangements in beel fisheries may be classified into two broad categories: (a) arrangements which aim at increasing the efficiency of fishery and of overall economy through removing impediments to growth, and, (b) arrangements for redistributing income and reducing socio-economic disparities.

CRITERIA FOR SELECTION OF APPROPRIATE INSTITUTIONAL ARRANGEMENTS

A number of criteria may be used to select an appropriate form of institutional arrangements. The criteria as well as selection of institutional arrangement depend primarily on the government policy, objectives and prevailing circumstances. The major criteria are discussed briefly in the following paragraphs.

It should help, not hurt the fishers

It should focus on factors of production, which may be beyond the purchasing power of the fishers

It should rank high in terms of cost-effectiveness

Direction of institutional arrangements under resource constraint

Direction of institutional arrangements under no resource constraint

MANAGEMENT REGULATIONS

The choice of management alternatives depends largely on the specific features and circumstances of the fishery concerned and the objectives of the management authority. Yet, this choice should be based on a set of criteria, which include:

Acceptance by the fishers

Gradual implementation

Flexibility

Encouragement of efficiency and innovation

Full cognizance of regulation and enforcement costs

Due attention to employment and distributional implications

THE REGIMES FOR IMPLEMENTATION OF INSTITUTIONAL ARRANGEMENTS

The classification and criteria for selection of institutional arrangements and management regulations for culture-based fisheries are briefly described in aforementioned text. But equally important is the environment in which these are implemented i.e. the property and management regimes. These are only touched upon in following paragraphs.

PROPERTY REGIME

The property regime is generally concerned with the ownership or right to use a natural or manmade water resource. Property regimes have direct bearing on outcome of any production process and performance of institutional arrangements. The property regime may be classified as:

Open access

Under open access property regime, everyone has equal right of fishing in any water body. As a result number of active fishers is large in this regime due to free entry. This type of fishing regime may be irrational, as there is no control on fishing effort, fishing method and area of fishing. The implementation of institutional arrangements and management regulations becomes difficult under this property regime.

Common property regime

Sometimes common property regime is confused with open access. The only difference between them is that the former is open access for the local or limited users only, not for everyone from anywhere. Comparatively, these waters can be managed better than open access. In this case implementation of institutional arrangements and management regulations is comparatively easier, due to monitoring and control on fisheries operations.

Private property regime

The private property is said to be exclusive because the owner can exclude others from appropriating the property and /or benefits from it. In this sense, private property is commonly conceived as individual property. The property owned by other entities like a co-operative or company is also a private property. This regime provided a congenial atmosphere for implementation of institutional arrangements and management regulations and the chances of their success are better.

Multiple user ownership

Aforementioned property regimes are explained in the context of single type of users. The resource is utilised only for one production activity. But, in case of natural or manmade waters it is very rare.

MANAGEMENT REGIME

The property regimes are concerned with the right to use any resource, but the problem "how to use the resource" falls under the purview of management. After having the fisheries management rights, the fish production process is managed by different management systems or regimes, under given property regime. The management regime may be i) individual, ii) group(s) of individuals, or iii) organisation. These are responsible for implementation of fish production practices, institutional arrangements and management regulations. Therefore, outcome and efficiency of fish production process, and performance of institutional arrangements and success of management regulations largely depends upon the management regime.

Stakeholders and management of the beels

There is large number of stakeholders directly and indirectly associated with beels. These are fishers, lessee, state governments, informal groups *etc.* Each one of them are operating at different level of management. At ecosystem level, state government is associated through resource use polices for production and protection. At the resource level, lessee or managers are responsible for management; and at the fishing level individual or group of fishers are managing the resources.

Importance of institutions in beel fisheries management

Low adoption of technology is the prime reason for such low productivity realization. The low adoption of technology is due to lack of incentives as well as support, which are constrained by inappropriate institutional set up and support. Therefore, The institutional framework is the critical determinant of the management and management outcomes of the beel fisheries. The institutional framework governs the relationship between resources and stakeholders, and among the stakeholders (Table 1).

INSTITUTIONAL ARRANGEMENT ANALYSIS FOR BEEL RESOURCE MANAGEMENT

Research framework

The purpose of institutional analysis is to separate the underlying rules (institutions) from the strategy of the players (organisations).

The framework, of which a graphical representation is given in figure 1, enables the following institutional arrangements analysis

Table 1. Relationships and interactions among institutions/stakeholders involved in beel fisheries management

The relationships	Determinants (rules, policies, institutions)
Beels and managers	Leasing policy Property regimes Traditional rights
Managers and fishers	Sharing arrangements Terms of entry
Fishers and fishers	Formal and Informal group Community group Social reciprocity
Fishers and middleman	Previous commitments Backward integration of middleman Market structure Multiple functions like credit supply, wholesale, auctioning etc.
State and Fishers	Policies to promote fishers welfare
State and managers	Social security Policies to develop group action Mesh size regulation Human resource development
Research organizations and others	Technology development Technology transfer Human resource development

(a) Biological, physical and technological attributes

Problems and constraints over resource use most often originate in the biological and physical attributes of the resource and in the harvesting technology used. The nature of interactions among fishers are commonly structured by the biophysical and technological environment of the fishery. To understand the actions fishers have taken and the institutions that they have developed requires an understanding of the fishing grounds, fish stocks, fishing activity, boundary conditions and fishing technology.

(b) Market (supply and demand) attributes

Resource problems are often market-based. Market attributes (price, structure, stability) can effect the incentives for resource use activities, effort levels and compliance with rules. Market attributes include those related to the operation and function of the market and those related to fisher and fish trader relationships.

(c) Socio-economic and socio-cultural attributes of fishing community

Community attributes include religious beliefs and practices, traditions and customs, sources of livelihood, the degree of social, cultural, economic and locational heterogeneity or homogeneity, asset ownership, level of community integration into the economy and polity, and others.

(d) Institutional and organizational arrangements at community level

Institutional arrangements concern the rights and rules which applies to and regulate the fisheries in which community members take part. The research focus is on power structures at the local level, decision making arrangements, participation of fishers and stakeholders, legitimacy, mechanisms for enforcement and compliance with rules. Important issues are representation, decision-making procedures, implementation of decisions in the field, and interface with other related fora (dealing with other resources than fish, e.g. tourism).

(e) External institutional and organisational arrangements

Institutional and organisational arrangements at higher levels than the community level most often affect the institutional and organisational arrangements at the community level. The relations can vary widely.

Organisational arrangements at the community level may have been developed and designed at a higher level to meet higher level needs and fit into a multiple layer, nested structure.

(f) Exogenous (macroeconomic, social, political, natural) attributes

A variety of factors exogenous to the fishery resource, fisher and community have an impact on fisher or community institutional arrangements. These are factors which are beyond the control of the fishers and community, and at times also higher level entities. These are surprises or shocks to the community or management system, brought about by macroeconomic, social, political or natural occurrences or interventions which affect the survival of the institutional arrangements. These factors can provide an indication of how well the institutional arrangements are functioning and surviving through their capacity or resiliency to accommodate sudden change.

CASE STUDIES

Bihar

In Bihar, most of the lakes are public property barring few with private ownership (Sinha and Jha, 1997). The government had classified them under two category i) lakes with "Makhana" and lotus; and ii) lakes without "Makhana" and lotus. The fishing right in both the types of lakes vests with department of fisheries, although, for the former category of lakes, it is with revenue department. These are auctioned annually by the fisheries department to local fisher co-operatives. The recent upsurge in number of fake co-operatives tends to increase rivalry and litigation.

The short term leasing policy of fisheries department also affects the fisheries of these lakes (Jha, 1997). Due to short period of lease the lessees are not interested in investment for fisheries development in the lakes.

Sewage fed fisheries in West Bengal

The land of all the bheries was privately owned with multiple ownership. The number of landowners varied from 150 to 300. The bheries were leased out through open auction. The lease amount varied between Rs 8250 to 60000 per ha. The amount of lease varied according to the productivity and type of production system followed i.e. paddy cum fish culture and fish culture or tank fisheries. The bheries with tank fisheries alone were leased out at a higher amount as compared to those having paddy cum fish culture. The lease period varied between 1 to 3 years.

The lessee was bound to sell their catch to particular wholesaler as the wholesaler had paid a sizeable amount as advance. The per kg price received by the lessee for *P. monodon* ranged between Rs 350 to Rs 500.

Assam

There are about 1392 listed beels in Assam (Table 2).

Table 2. Registered and unregistered beels in Assam

Category	Number	Area (ha)	Condition		
			Good	Semi-derelict	Derelict
Registered	423	40,000	10,000	15,000	35,000
Unregistered	969	60,000	Nil	10,000	30,000
Total	1,329	1,00,000	10,000	25,000	65,000

PROPERTY RELATIONSHIP AND FISHING RIGHTS

The property rights wide and varied across the state. It varies from highly controlled exclusive private properties to the open access beels.

The beels with greater expanse (300 to 1000 ha, stretch of 2 to 10 kilometers) are under open access.

In most of the beels, customary rights of the tribals and other indigenous ethnic group are preserved legally (Anon, 2001). These rights are species, gear and purpose specific. The use of small gears like scoop net, dip net, hook and lines, and other small nets are free from any control. These rights are for the purpose of fishing of unstocked and trash fishes. These rights are limited to the self- consumption only. The fishing after main harvest season is also open to every one. in The marginal areas of beels are also recognised as open access after harvesting season and women fishers fish in these areas.

Ownership and control

The contributions of the natural resources in the beel fisheries system are higher. Political and legal processes largely determine the ownership and control. The owners gain the benefits in the form of lease amount as rent. Such rent varies from 20 to 30% of the fisheries output.

More than 67% of the beels are under state ownership. These beels are most productive. Three state departments viz., Assam Fisheries Development Corporation (AFDC), Revenue Department and Forest department have the ownership of beels.

The non-government agencies like community, autonomous tribal bodies, Panchayat, school *etc* control about 33% of the beels.

There is a shift in property regimes towards exclusivity over the years, in beels of Assam,. A transition phase of shift of open access fishing to ownership and control of a group and further to exclusive right holder like lessee has been observed. This shift has benefited the government to a large extent. Government is being able to earn a higher amount of rents even at the cost of implications on social equity.

Leasing policy

The leasing policy determines the access and the allocation of the beels. It has an important role in beel fisheries management as large proportion of the beels is under control of the state.

According to the policy, fisheries co-operative are preferred for leasing out the beels. The number of beels, which can be leased out to the co-operative society should not exceed 60%. In absence of the co-operative, lease is preferred for members from the fisherman community, or backward classes. The lease period varies from 3 to 5 year.

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LIVELIHOOD SYSTEMS IN THE BEEL FISHERIES OF ASSAM

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FISHERS IN BEEL FISHERIES OF ASSAM

Fishery is the economic utilization of the aquatic organisms and related activities. Floodplain wetlands (beel) constitute a very significant resource of Assam.. They cover an area of 1,00,000 ha constituting 28.9 % of the total fisheries resources (347,000 ha). This is considered as one of the highly productive ecosystem in terms of its biomass and fisheries production potential. (CIFRI, 2000). About 95% of 266 lakh (2001) population are fish eaters. However, present annual fish production from all the sources is about 1.6 lakh tones against the present demand of about 2.78 lakh tones calculated on the basis of minimum nutritional requirement of 11 kg per capita. During 1999-2000 the percentage share of agriculture to total NSDP was 46.26% and that of fisheries was 2.10 % at constant price of 1993-94 (Economic survey, GoA, 2002) in addition, it provides livelihood to the 4.7 lakh people along with other indirect employment. The gross value of the fish production in the state has been estimated to be around Rs 640 crores (1999-2000). The contributions of beel fisheries to the total fish share are about 16% (DoF, Government of Assam, 2001) of the states annual fish production owing to approximately 100 crores per annum.

RELEVANCE, MEANING AND DEFINITION OF LIVELIHOOD

Food and nutrition security is the primary concern of fishers as large proportions of their efforts are invested in fetching them. The livelihoods are the means of attaining them. Therefore, food and nutrition security is achievable when livelihood is secured. (Farrington, 1991). The study of livelihoods deals with the complex interaction of the their resources, endowments, capabilities, assets, strategies etc.(Scoones, 1998) .

A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base (Chambers and Conway,1992) The definition provides the basis for analyzing the livelihoods of fishers.

COMPONENTS OF LIVELIHOOD SYSTEMS:

While the definition act as guidelines, the specific issues, concerns and nature of livelihoods of fishers are different from others. In order to devolve livelihoods, it needs to disintegrate into its well-defined components. These components are as follows.

1. Priorities of fishers

Secured access to food: The household priorities in of the fishers in Assam are predominantly securing food for the their family.

Coping with seasonality; The fishing activities are seasonal in the beels. The fishing is confined to 3 to 9 months with the average of 5 months.

Reducing uncertainties: Capture fisheries are uncertain so also catch from beels. The return per effort form the basis of livelihoods. Therefore, fishers tempt to reduce the uncertainties.

Increasing income: The fishes have the motivations to increase income though additional catch, increase in value and reduction of the cost.

Control over fishing: Greater control over the fishing reduces uncertainties as well provide secured access to fishing. The greater control over fishing is achieved by increased accumulation of assets like fishing gears and craft.

2.Strategies to pursuit their priories

Fishing in the beels

The fishing activities in the beels varies from 3 to 12 month in a year depending upon the size and nature of beels. The open beels with areas of more than 100 hectares are harvested through out the season with the selective gears. The small meshed nets (masuri jal) are confined to the end of the fishing seasons and for the period of 4 to 6 weeks in the years, whereas the major fishing through katal and dragnets are spread over 2 to 4 months. The fishing through gill nets and cast nets are for the 9 to 12 months. The smaller gears like dip nets, scoop nets etc are generally for the whole year depending upon the availability of the fish. the catch per efforts in terms of money varies from 20 to 200 rupees per day. In certain period of the years they don't get any fish for the whole day. the share of the fishing to the to the consumer rupees is around 10 to 15%. In other word, only 10 to 15 rupees goes to each fisher fishing in the beels from 100 rupees of fish consumed from it.

Accumulation of assets

Fishing communities have interest in accumulation of assets required for fishing. The assets are nets of diverse characteristics used in the various conditions. The nets like cast nets, dragnets, scoop nets of various shape and size are used. The accumulation of assets is the means of achieving the household priorities.

Diversification of resources

The peculiar characteristics of the livelihood systems of the fishermen are that they have limited options outside the fisheries. However, in order to diversify their source of livelihood and cope with the seasonality and uncertainty, they diversify across the practices and resources of fisheries. They use drag nets, small meshed net, *katal* net (kind of FAD) in the main fishing season, cast net, gill net in other seasons. They also use small and big scoop net in the running water in rainy season. They also diversify to fish in the ponds, rivers and streams in other seasons other than main fishing seasons of the beels.

Diversification is also observed across other activities like duckery, goat rearing and cattle rearing in the limited scale. The larger part of the responsibilities of these activities are shared by the woman folk. Each of household maintains about 5 to 10 ducks, 2-5 goats and 1-2 cows. However, a very small proportion of the community also has interest in the agriculture. But average land holding is 3 to 5 bighas per household. The migrating fishermen have limited diversification in these activities.

Wage labours are important source of livelihoods in the off fishing seasons. The average wage is 45 to 50 rupees per day. But the opportunities are not available for all the seasons

A small proportion of the fisherman have shifted from fishing to fish marketing activities related activities like fish transportations, auctioning, selling in market, retailing etc. but the proportion are very small.

Networking with beel managers

The access to fishing and achievement of it among the competitors is determined by the relationship between the fishers and the beel managers. The relationships with many beel managers help them plan their fishing activity and get the access to better fishing grounds.

Networking with other fishers

The relationships among the fishers within and across the communities are part of the social process. It has both social as well as economic functions. The social capitals of trust, sharing and reciprocity are primarily dependent upon these relationships. The economic functions are served by flow of information across the communities on the productivity, preferences, opportunities and limitations for fishing in the beels. These information are vital to plan their livelihood and choose the better alternatives.

Storage of food

The main fishing is seasonal in nature confined to the months of October to January. Fishers purchase the food materials in this season for the rest of the period of the year. The food materials constitute rice. In this season the cost of rice is also less as it coincide with the harvesting season of rice.

Coping and adaptations strategies

These are the strategic plans to cope with the diminishing and increasing income respectively. The strategies to cope with the falling income, seasonal distress or shocks like major disease, accidents, death, social functions are important to their living. The first important coping mechanisms to cope with seasonality is storage of food for the whole year in the major fishing seasons. The other strategies they adopt are selling of assets like ducks, goats or cattle at the time of needs. In order to incur the expenses towards bigger events like social functions, medical expenses; the fishers are primarily dependent upon the loan from beel managers and then money lenders. In the extreme case the fishers go for the selling of fishing assets like boats and nets. They also adjust to the distress by reduction of consumption pattern.

Adaptations strategies are the approach towards positive directions. The adaptation strategies are purchase of nets that are costly but return from the catch is higher.

3.The institutions, policies and organizations

Institutions

The institutions are the structures determining incentives and disincentives for action in general sense. In the context of livelihoods, the institutions determines fishers access to resources, capitals, share in distributions, and return they can achieve from their efforts. Here the relevant institutions can be as follows.

Sharing arrangements

The arrangement is the agreement between the lessee and fishing group on sharing of catch. The contract involves catching as well as selling in the market. The sharing arrangement varies between 30 to 70% for the fisherman depending upon the availability of fish, ease of catch, type of catch, prevailing practices, provision of craft and gear, membership in groups etc. (Barik and Katiha,2003)

Sharing arrangement in beels of Assam for fishing		
Condition of beel	**Managers**	**Fishers**
Fishers cooperative managing beels	40	60
fish is not abundantly available the share is	50	50
availability of the fish is more	60	40
fish is quite high and easy to catch	70	30
fish is moderately available and beel is weed choked	40	60
difficulty to catch, low availability of fish and highly weed choked	30	70
Extreme difficult condition and catch by small nets like gill nets, scoop net	10	90

The above arrangement is followed when the boat and net is provided by the fishers. Manager takes 20 percent more when boats and nets are provided by him.

Property relationship

The property rights - The property rights have multiple dimensions like ownership, control, regulation, access etc.

Ownership and leasing

The non-state players like community, autonomous tribal bodies, school *etc* control about 33% of the beels. These beels are leased out to the individuals and the group. But they follow their own procedure of leasing. The lease amount or the rent is generally used for common utility creations like school management, road building, and contributions religious institutions *etc.* sometimes these money are used for providing assistance to the poor within community, or for social functions like marriage, funerals *etc*

Most of the beels are leased out to individuals or groups for the purpose of fisheries. The mechanisms and modalities of leasing outs are different and relative to the owners.

The lease period varies from 3 to 5 year in the revenue department administered beels and it is 7 years in case of the AFDC. The beels are leased out in return for the specified amount as lease value or rent. Such rent varies from 5 to 30% of the fisheries output.

In certain cases the lessee subleases the beels to some others for fishing of the whole stock or specifies stock. For the fishing of the larger fishes like IMC, cat fishes, the lease are proportion to the catch which varies from 10 to 70% of the catch.

Control and regulations

The control over the fishing is transferred to the lessee through the leasing arrangements. The lessee becomes de-facto controller of the beels. The fishermen have limited role to play in the control and regulation functions of the beels. This situation positions them at low bargaining ability and limited access to the return earn through control of the beels. this arrangement also put the fishermen's access to the beels at the mercy of the lessee.

4. Capital and access to capital

The livelihood framework encompasses wide range of the capitals that have significant influence on the life of the people. Such capitals are social, human, physical, financial and natural capital. The identities like *Muslim, Assamese, Bengali* etc are binding principle of fishers community. The supporting each other at the distress can be generalized.

The capital possession are mostly confined to fisheries assets like boats, nets, etc. However, the fishers with limted surplus, purchase duck, goats or cow as capital. Therefore, the land-based activities are limited to the fishers of Assam.

Natural capitals like rivers, other derelict water bodies are the basis for their primary livelihoods. The fishers tend to prefer other well managed fisheries like ponds, beels as the return to efforts from the open access fisheries are lower. But access to the manged fisheries resources is determined by the transactions and negotiations with the lessee or owners.

5. Context of living

The contexts are the larger issues or factors that are externals to the people and resources but affects the livelihoods. These variables include external trends (economic, technological, demographic, etc), shocks (natural and man-made) and seasonality (Scoones, 1998). The significant contextual variables for livelihoods can be described as follows.

Shrinking of beel resources: the wetlands all over the world are threatened resource by virtue of its ecological process and multiple uses. In Assam, The beels are subjected through destructive practices like diversion of the land for agricultural and industrial purposes, extraction of water for irrigation purpose, manipulations of the habitat by cross bunds, siltation etc. these factors contributes to gradual shrinking of the resource in extent and quality.

Increase in populations: there is considerable pressure of population on the beels in the recent times. The increase population has made increased number of people dependent upon the beels for their livelihoods and consequently share of each of the fishers has reduced.

Degradation of resources: degradation is the reduction of the quality of the beels in fisheries perspective. The lack of management in many of the beels led to excessive growth of weed, gradual drying and silting of the beels. Many of the beels are getting silted up and the channels are severed from the parent rivers and that lead to reduced auto stocking. These processes contribute towards reduction of the productivity.

Exclusivity of property regimes: In the recent times many of the open access beels are converted into exclusive right regimes by leasing. Besides, there are increased practices of pricing of other wise free services like grasses, catching of small fishes, collection of other aquatic organisms. The fishers are excluded from accessing these resources.

CONCLUSION

The issues of livelihoods are much larger the issues of income and employment alone. For a considerable part of the year, the fishing activities are stopped in the beels and fishers are to depend on other sources like fishing in rivers, streams, open access water bodies. besides fishing, the fishers are also dependent upon the other sources of livelihoods like duckery, piggery, goatary etc. these assets are used as buffer to maintain consumption level at the period of shortages. Therefore, the livelihoods systems of fishers associated with the beels are complex, diverse and intricately associated with the many issues outside beels fisheries management systems.

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POSSIBILITIES OF STOCK IMPROVEMENT FOR FLOODPLAIN WETLANDS

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INTRODUCTION

The green and white revolutions in India, as is known, became possible on account of deep understanding of the plant and animal genetic principles and through application of specific genetic manipulations. Similarly, a sustainable blue revolution will be possible through application of genetics for improvement in the quality of fishes used for aquaculture, in addition to the effort of fish husbandry improvement. It is heartening to note that the work in this direction has already been initiated in the country in several universities and research institutions.

GENETIC CHARACTERISATION

Genetic characterization is being done through cytogenetic, biochemical-genetic and the most sophisticated molecular genetic techniques.

When the DNA in chromosomes is coiled and condensed, the chromosomes in different species take characteristic shapes which are studied under cytogenetics. In addition to Karyotyping, Cytogenetic study is now done by C,G,R,Q, and NOR banding techniques and restriction Endonucleases are also being used.
Biochemical-genetic investigations, use electrophoretic techniques which enable identification of genetically variable polymorphic enzymes. Sophisticated devices like ultra thin isoelectric focussing of eye lens proteins and gradient SDS polyacrylamide gel electrophoresis are used in the investigations.

All the genetic information of an individual are contained in DNA. With the rest of the world, in molecular genetics, we also use genomic and DNA for studies through RFLP and the latest DNA fingerprinting techniques.

With the background of some genetic information and knowledge of genetic techniques, genetic manipulations for upgradation of fish stocks with the aim of higher fish production have been initiated.

HYDRIDISATION

Hydridisation aims at flow of genes resulting in heterosis introgression due to overdominance and heterozygosity at many loci. Though crosses between different species and genera were successful, so far no viable superior hybrid with the exception of the catla-rohu hybrid with intermediate characters, could be produced in India.Some intraspecies trout hybrids abroad are disease resistant but show lower percentage of survival. In India cross breeding of trouts of north and southern parts could yield some results in a collaborative research by NBFGR and Himachal Pradesh Fisheries Department.

SEX REVERSAL

Sex reversal aims at aquaculture upgradation using only a single sex which grows faster or with sterile fish in case of prolific breeders. Artificial reversal of phenotypic sex from male to female and vice versa without changing the genotype is possible in most of fishes owing to lack of distinctive heteromorphic sex chromosome pair. It has been possible to reverse the sex in some Indian species also with not much of genetic gain so far. A report indicates a production increase of a specific fish by 100 -200% through mono-sex culture of sex reversed seed in Malaysia. In view of about 100% higher growth rate of male *M. rosenbergii* than the female, its all male culture in India can automatically increase the yield and also avoid cannibalism in the pond.

GENE BANKING

Successful freezing of fish gametes and storing them for indefinite periods without deterioration and loss of genetic properties are of considerable importance in aquaculture. While the work on cryopreservation of eggs and embryos are pursued world over, it has been successful only in respect of sperms/milt in India and abroad. There is a milt bank at the NBFGR at Lucknow. Some stock is available at CIFA

Dhauli as well. Milt gene bank facilitates availability of male gametes of good quality all the year round for early or late breeding if females are available. It can also cut down the need for brood fish transportation, and help in selective breeding and hydridization programme, maintenance of genetic diversity in hatcheries and in the conservation of fish biodiversity in the country in years to come.

SELECTION FOR FASTER GROWTH

There are some traits such as growth rate, food conversion, disease resistance, fecundity etc., which are influenced by unknown but sizeable number of genes which are additive in nature. Selection of such additive will have the effect of increasing frequencies of favourable genes for the characters in question for stepping up heterozygosity and the number of favourable gene combinations which can be utilized through cross breeding after studying heritability.

High yielding wheat, rice, broiler chicken, milch cow etc., are the benefits of adopting such a selection. Response to selection in the form of genetic gain in fishes has been at 5% in salmonids in 3 generations, 33% in channel catfish in 3 generations and 30% in coho salmon in 4 generations. In Norway, the Atlantic salmon *(Salmo salar)* stock used in aquaculture is through selective breeding, improving about 2% per year in terms of production. In India, predicted response was 8% in *Etroplus suratensis* in one generation. Likewise there was 13% gain in one generation selection in *Labeo rohita.* These can be taken as bright indications of possible genetic gain through selection.

GENETIC ENGINEERING

Chromosome in a normal individual is in a pair of two. During the cell division, manipulation in chromosome number has become feasible. Changes in the number of chromosome sets may be brought about by the simple destruction of one set or by disruption of metaphase spindle. The production of viable progeny with all maternal or paternal inheritance alone and increasing the ploidy of individuals to triploidy (3n) or tetraploidy (4n) are results of genetic engineering at different stages, as explained hereunder.

Gynogenesis: It involves stimulation of parthenogenetic development of an egg by a genetically inactivated spermatozoa. The diploidy of the haploid egg is restored by the retention of second polar body normally through a temperature shock at an appropriate time after fertilization. In other words, the DNA in the progeny is constituted only by the maternal genome.

The high level of inbreeding achieved in the process may help in the genetic studies and also in the hybridization programme. The gynogenetic off springs, being all females, provide scope for monosex culture too.

Androgenesis: It is based on the same principle as gynogenesis. The androgenetic progeny is produced with the paternal genome alone avoiding maternal genetic contribution altogether. Androgenesis, when successful in India, would help in the conservation of fish biodiversity since it would be possible to reconstitute the endangered or extinct species from its cryopreserved milt, if present in the Genebank.

Polyploidy: This is again a manipulation of chromosome number after normal fertilization of both sexes. Triploids are produced by suppression of melotic metaphase II, normally by heat or pressure shock shortly after fertilization. In such fishes there is a set of 3 chromosomes instead of normal 2. These fishes being sterile, generally grow faster and bigger due to avoidance of gametogenesis. Production of tetraploid fishes by disruption of the first cleavage mitosis is possible. The tetraploids also may grow faster.

Transgenic fish: The most sophisticated approach to genetic manipulation is production of transgenics through gene cloning. The successful injection of a novel gene into the host organism produces a transgenic individual with better growth/disease resistance/other desired characters as the case may be. Although human insulin gene was the first gene that was successfully used to produce transgenic loach in 1985, subsequently, growth hormone gene of cattle, rat and chicken were used to produce transgenic pike, trout and medaka respectively. Recently, genes of rainbow trout, common carp, salmon, flounder and tilapia have also been used for the production of transgenics. Such an usage has been successful in prawn also. Successful transgenics grow significantly larger than their normal ones.

With the recent successful experimental production of transgenic rohu and mrigal and initiation of a collaborative programme, India has entered the race with the rest of the world. The commercial potential of transgenic fish, however, would lie in developing transgenic brood stock lines. This may require combining transgenic technology with selective breeding for producing superior strains of fish. The ecological and psychological aspects are also required to be studied side by side.

In view of the above progress, we may hopefully expect achieve a breakthrough in the application of genetics to augment aquacullure production in the country at the beginning of the 21st century.

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NEED FOR PARTICIPATORY TECHNOLOGY DEVELOPMENT

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Blue revolution in the country has been made possible through effective transfer of technology programmes. In the history of technology transfer, there have been several changes based on the knowledge and field experiences. In the 50's and 60's there was a belief that the technology is resource and scale neutral and farmer's ignorance was considered the most important reason for non-adoption of technology. During the 70's there was a shift in the level of understanding and Farm level constraints' were considered responsible for non-adoption of technologies.

It's only in the 80's when it was realized that all the technologies recommended were not appropriate under all farming situations. This has now been understood that the technologies need to be assessed and fine tuned to suit different farming situations. Therefore, there has been change in the research methodology for tailoring of technologies for different socio-economic conditions. Some important aspects are summarized in Table 1.

In response to the situation being experienced in developing world, several participatory approaches have been evolved with a view to developing relevant and viable technologies with full knowledge of their existing farming systems. Now there is emphasis on on-farm research for development of technologies for the fish farmers/fishermen for whom sustenance of the family is the main consideration for the acceptability of technology instead of yield maximisization. The fact that the technologies are highly location specific is also now fully appreciated leading to the consideration that the technologies should be tailored for different biophysical and cultural situations. The inclusion of these changes in technology generation has laid emphasis on ***On-farm research approach***.

WHAT IS ON FARM RESEARCH ?

On farm research (OFR) is an approach of adaptive research conducted on fish farmers field with their farming system perspective in view under their management and with their active participation. The farmers/fishermen should have greater say and researcher should act only as facilitator.

There is considerable confusion between the terms *On-farm research* (OFR) and on-farm testing (OFT). The trials conducted on farmers' field with pre-release technologies are called as *On-farm trials* (OFT). The objectives behind these trials are to verify the superiority of new recommendations, find out fish farmers'/fishermen's reactions, identify constraints in adoption of new technologies and provide feedback to research system about the performance of their research.

In case of *On-farm testing*, the technological solution is already known and, hence, trial is laid out for its verification under a given situation. In case of on-farm research only the local problem is known but the technological solution is yet to be evolved suiting local farming situations and resources. The *Field demonstration* is another term which is often used as synonym of OFR and OFT. The field demonstration programme which deals generally with released technologies and carried out of fish farmers'/fishermen's fields differs strikingly from OFR and OFT in terms of objectives as well as methodologies. The main objective behind a demonstration is to motivate the farmers through the concept of' 'seeing is believing', rather than establishing the merit of a new technology.

TECHNOLOGY APPLICATION GAP

The present scenario of inland fisheries sector of the country clearly shows that the fish productivity of small fish farms, and open water systems have not been influenced much during the blue revolution and there is wide '*Technology application* gap'. The experiences of 'Fish Farmers' Development Agency, IDRC Programme, National Demonstration Programme etc. show that the adoption of improved fishery technologies increased with subsidies. But after the withdrawal of subsidies, farmers slowly started reverting to the traditional practices and after sometimes only a few technologies were left with the farmers. Economic constraints were considered the important reasons for the rejection of improved technologies.

CHARACTERISTICS OF RESOURCE POOR FISH FARMERS/FISHERMEN

The resource-poor fish farmers/fishermen due to peculiar conditions of their environments, function differently than the resource-rich fish farmers/fishermen. The small fish farmers/fishermen use an integrated system of fish/prawn production activities both to a subsistence and commercial nature, as well as off-farm labour and trade enterprise in order to sustain themselves.

Another important points is that most resource-poor or small- fish farmers/fishermen operate the rural economies characterized by imperfect markets. As a result, other institutions, such akin groups or tribal membership, commonly, regulate farm family's access to land, labour and capital.

SOME IMPORTANT TERMS

Recommendation: The recommendation is an information that fish farmers/fishermen can use to improve the productivity of their resources. Fish farmers/fishermen may be able to use the recommendation directly, or they may modify it somewhat to suit their own conditions and needs.

Target Group (TG):

The Target Group' (TG), is a group of fish farmers/fishermen operating the same system in fairly homogenous in local circumstances and who can be expected to have the same problems and opportunities to take up the same new technologies.

Recommendation Domain (RD):

The target groups are further divided into Recommendation Domain (RD) based on minor but important variations in local circumstances. Both target farmers and recommendation domain are identified, defined and redefined throughout the process of OFR.

TECHNOLOGY GENERATION MECHANISM

The fishery technology generation mechanism is a dynamic process which basically has two approaches, a non-formal approach, and the formal approach. All approaches available can be grouped in three main categories *viz.* Top-down Research Model Operation-Research Model, and Farmer Participatory Model.

1. Traditional Research Extension Approach – Top Down Model

In this approach highly trained and specialized scientists generate new technologies on research stations and/or in laboratories or workshops and pass them on to the extension agencies for onward transfer to farmers without considering the needs and capacities of their clients to absorb these technologies

OPERATIONAL RESEARCH APPROACH

This approach includes testing of technology on farmers' fields feed-back to researchers and the identification of constraints in the adoption of new technologies by the farmers

FARMER PARTICIPATORY RESEARCH (FPR) APPROACH

This approach takes whole farm as a system, not an individual activity. Further, the farmers and researchers are actively involved in the technology generation process. Therefore, this approach encompasses understanding of farmer's resources, both bio-physical and economic and their requirement and goals in the technology generation process.

ON-FARM RESEARCH

The following 5 requirements of OFR must be fulfilled to make this approach successful:

i. The research must address problems that are important to fish farmers/fishermen.

ii. The OFR should examine relatively few factors at a time. An on-farm experience with more than 4 variables will difficult to manage.

iii. The farmers' practices should be included as one of the treatments in the experiment because the farmers will definitely like to see for themselves such a comparison.

iv. The non-experimental variables of an experiment should reflect farmers' actual practices and management.

v. The experiment must be implemented at locations that are representative of farmers' conditions.

CORE CHARACTERS OF OFR

It is holistic,
It is farmer participatory,
It is problem solving,
It is gender sensitive,
It is interdisciplinary,
It is interactive and iterative,
It emphasizes extensive on-farm activities,
It complements on experiment at station research,
It acknowledges the location specificity of technical solutions,
It recognizes interdependencies among multiple clients,
It emphasizes feedback,

METHODOLOGY

The procedure of OFR can broadly be divided into 5 stages, among which there is considerable overlap and feedback.

STAGE 1 : DIAGNOSIS

The diagnostic stage involves collection and analysis of information in order to design OFR. The multi-disciplinary team of scientists in collaborations conducts diagnosis with farmers of the selected target group(s). Researchers while talking and working with the farmers in the field and outside, continuously enhance their understanding of the system and its limitations which helps them in exploiting local circumstances to satisfy farm family priorities.

The following steps are involved in initial diagnosis.

i. ***Study of Secondary Data:***

Study of background information with the help of secondary data, if available.

ii. and Informal survey:

This is undertaken after collection and analysis of secondary data. The scientists should mix well with the farmers and their family members and try to understand their farming situations.

STAGE 2: PLANNING

The planning process brings together two information streams; the understanding of the target group farming system gained in initial diagnosis and technical information from research by specialists. Planning is the stage at which available technical knowledge about the identified farmers' problems is collected and listed in an organized way.

STAGES 3 : EXPERIMENTATION

i. Selection of site and farmer: Clustered sites allow more efficient logistical support of the experiments and other OFR activities.

ii. Choice of farmers' practice: Special care is required to identify appropriate farmers' practice for OFR so that the comparison with new technology practice would be made in an objective manner.

iii. The experimental sequence and appropriate designs: The experimental sequence which takes the researcher from uncertainty about factor responses under local conditions to full confidence that a new practice is a superior substitute for farmers current practice.

STAGE 4 : ASSESSMENT OF THE RESULTS

There are four types of assessment of on-farm experiments.

i. ***Aqua-management Assessment:*** In exploratory experiments aqua management assessment is used to understand problem causes or the responses to new management factors.

ii. ***Statistical Assessment***: It is used to quantify the differences observed between treatments. Usually the analysis is done on data pooled over locations and years.

iii. ***Economic Assessment:*** Both aqua-management and statistical assessment of experimental results contributes to the economic assessment of experimental results. Normally economic assessment should be taken only when the earlier two assessmentss are satisfactory.

iv. ***Fish farmers' Assessment*** :As aqua-management assessment, fish farmers' assessment is a continuous process throughout the season. Fish farmers themselves will be assessing aspects important to them at appropriate points throughout the growing cycle.

RECOMMENDATION AND EXTRAPOLATION OF RESULTS

The primary use of on-farm research results including those from the experiments is to make or move towards fish farmers'/fishermen's recommendations. The intermediate use of the information increase the effectives of subsequent OFR cycles, and mobilize services for pending recommendations such intermediate uses include: improvement of the understanding of technical, economic and social aspect of the target group farming system; re-definition of target groups and sub-sets of target group conditions as recommendation domains, modification of objectives and replanting next years' experiment and other supplementary on-farm research thrusts; analysis of errors made the reorganization of implementation plants to solve problems in logistics and alerting local planners and enabling organizations and where appropriate policy makers of progress towards a recommendation and action required to mobilize the emerging technology.

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Table 1. Some dominant beliefs and modes 1950-2002

Period	Explanation of non-adoption	Prescription	Key activities	Socio-economic research focus	Methods	Label
1950s 1960s	Farmers' ignorance	Extension education	Teaching Etc	Diffusion adopters laggards	Questionnaire survey	Diffusion research
1970s 1980s	Farm-level constraints	Removal of constraints	Input supply	Constraints farming systems Research	Questionnaire surveys' of-farm	Farming systems research
1090s	In appropriate technology	Farmer participation	Facilitation	Participatory approaches and methods	Discussion, observation, diagramming by and with farmers	Farmers participatory research farmer-first PRA, etc

FLOODPLAIN WETLANDS AND NUTRITIONAL SECURITY

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INTRODUCTION

Floodplain wetlands form major source of fish for people in several parts of Eastern India. These aquatic resources have been providing employment, food and essential nutritional needs of millions of poor people particularly in Northeastern part of India (Table 1).

COMMUNITY BASED FISHERY MANAGEMENT

Understanding the social dimensions of the community is recognized as an high priority for the effective management of these resources. Such community based approaches have begun to show positive impact in many other parts of the world. In Bangladesh, community based fisheries management practices of floodplain wetlands has helped in increasing the productivity of several beels. The sale price of the fish realized by the fishers managed beels was always higher with huge difference in income from the sale of carp per unit area - Tk 10,627/ha in DOF managed beels as compared to Tk 18600 /ha in beels managed directly by the fishers (Middendorp and Balarin, 1999).

In one of the beels, through community organization, a canal was reexcavated and connection with the river system was established. This paved the way in increasing diversity of fish species as well as productivity from 2481 kg to 12222 Kg/ha. In small beels, group management resulted in the increase of productivity from 120 kg/ha to 982 kg/ha (Tripathi, et.al., 1999).

In several beel areas, women have been productively employed through aquaculture by constructing ponds in peripheral areas of beels. Although various forms of resistance were encountered from the local elites and even the fishers themselves, constant efforts made by the projects helped in changing the attitude and creating gainful employment for women through aquaculture activities (Nathan and Bala, 1999). These have demonstrated where new options and opportunities for women in Bangladesh where conservative nature of the society has been effecting involvement of women in these type of new activities.

Participatory decision making and transparency in all transactions are helping good NGOs to grow confidence and respect of fishers (Middendorp, et. al., 1999). Studies have clearly shown that in Bangladesh NGOs have been more successful in assisting fishers to improve their livelihoods.

HARNESSING THE INNOVATIVE POTENTIAL OF FISHERS

One of the best example to demonstrate the innovative potential of farmers is the invention of cage culture system by the fishers of Cambodia. The Great Lake, which is the life line of Cambodia contracts and expands by least 3-4 times. Farmers have been building pens for storage of fishes collected through harvesting using large size gears and fatten them until they are transported by cages to marketing sites. Cages that are almost in the shape of boat and as big as 3000 m^2 in area are commonly used for culture of fishes and the entire cage is towed along the river to the marketing site. Production obtained from cages vary from 30 kg to 150 kg /m^3.

NEED FOR SCALING UP RESEARCH RESULTS IN TO DEVELOPMENT PROGRAMS

In India also, CIFRI results on pen culture have been highly encouraging. Cage culture is yet to be started in a significant way in India, although preliminary results demonstrate the benefits of this technology in growing carps in cages placed in tanks and reservoirs. High market value species like freshwater prawn nursing in cages have also been found to be effective.

DEVELOPMENT OF WEED BASED AQUACULTURE SYSTEMS

Most of the large open water bodies suffer from severe infestation of weeds. In Northeast, Lok Tak lake is a good example to illustrate the extent of weed infestation. Farmers have invented a aquaculture system using these weeds, which are established in the form of a circle. Fish appear to be attracted to these weed circles area which are called *phums*, and derive good nutrition and grow rapidly. The mechanism and the extent to which fish derive nutrition from these weed based phum systems are yet to be investigated. Phum is an example for another form of periphyton based aquaculture systems, which are becoming commercial in Aquaculture.

Research in to this area on the large-scale conversion of weed in to other usable products are yet to be attempted. With the increasing popularity of organic farming, these weeds provide good opportunity in very many ways. There is necessity to get farmers involved in developing socially acceptable technical processes, through which these weeds can be turned in to productive products.

KNOWLEDGE BASED DEVELOPMENT SYSTEMS.

In India, the concept of extension still revolves around "Technology Transfer" mode, although in recent years, farming systems approach is slowly gaining popularity. Cage culture, pen culture, enhancement of stock through selective stocking have already proved to be some of the successful options in many regions. However, if these new options have to be taken up by farmers in India , it is both the economic viability as well as the social accommodation of the new activity to the existing work load are important. Unless the technique introduced is simple and economically rewarding, the speed of acceptance of the new technology and its retention may not be too high.

NEED FOR MAPPING FISH CONSUMPTION PATTERN

Although, it is generally reported that more than 95% of the population is eating fish, the level of consumption by people located in different geographical regions is lacking. A developmental approach formulated based on such an assessment should help in developing a realistic plan to meet the fish demand of all sections of the population.

CONCLUSION

The World Fish Center has launched a new program on "Fish For All" to ensure adequate supply of fish to all and also protect the interests of all those involved in capture and culture of fishes (World Fish Center, 2000). With the increasing knowledge about the health benefits of fish and the increasing urbanization, the demand for fish is bound to increase by several folds. There is an opportunity for fisheries researchers and development personnel to play proactive role to increase supply of fish to meet the increasing demand. If this global program on "Fish For All" has to become a success local actions are essential. In this direction, within the country, Northeast region has good opportunity to launch a massive program not only to ensure fish for all, but in adequate quantity at an affordable cost. As most of the people in the region consume fish, launching of a program is likely to receive support from all section of the population. In the State of Tripura, College of Fisheries, is begining a program to assess the aquaculture status and availability of fish to people and based on the information generated through such a study, it is proposed to develop policy frame work to help the State Government in developing suitable strategies. As other States in the region have large amount of floodplain wetlands, it would be useful to tryout various strategies suggested to increase productivity from such water bodies. Nearly two decades of work in Bangladesh have amply proved that community based fisheries management would be one of the best options available to increase productivity of these water bodies. Community empowerment through people centered programs are essential to have good imapct through this approach. To enable staff to undertake this new task, there is a necessity to train staff on these new approaches through experiential learning approaches.

Table 1. Fishery Resources, utilization and average production in different sates of North-Eastern hill region.

Resource		Arunachal Pradesh	Manipur	Magahalaya	Mizoram	Nagaland	Tripura	Sikkim
River/Stream	EL (KM)	2000	2000	5600	1748	1600	1200	900
	EL (Kg/Km)	80	NA	40	26	31	635	NA
Reservoirs	EA (ha.)		100	1761	---	17	4500	1,20,000
	AU (ha)	--	NA	300	---	NA	4500	NA
	AP (Kg/ha)			25	---		70	
Beels/Lakes	EA (ha.)		40000	394	32	215	240	3000
	AU (ha)	2610	40000	394	NA	NA	240	NA
	AP		71	30			145	
Ponds/Tanks	EA (ha.)	1000	5000	1944	1800	2000	110398	
	AU (ha)	225	2000	560	250	500	11038	NA
	AP	600	1400	500	1600	700	2100	
Paddy fields	EA (ha.)	2800	40000	5000	1560	10000		
	AU (ha)	810	Neg	125	140	2000	NA	NA
	AP	80	NA	NA	250	70		
Other suitable water bodies.	EA (ha.)	700	10000	3000				
	AU (ha)	Neg	Neg	Neg	--	--	---	NA
	AP							

E.L= Estimated Length, EA= Estimated Area, AU= Area under Utilization, A.P.Av.= Prodn. , N.A= Not available.

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PEN AND CAGE CULTURE – EFFECTIVE MANAGEMENT OPTIONS FOR INCREASING FISH PRODUCTION FROM FLOODPLAIN WETLANDS

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INTRODUCTION

India is rich in inland fishery resources. Floodplain wetlands form an important part of it. It is spread over an area of 2,00,000 ha. in the states of West Bengal, Assam, Bihar, U. P., Manipur and Meghalaya. West Bengal contains 21% of the total floodplain wetlands resources of the country. The present fish yield rate varies from 120 to 320 kg ha^{-1} yr^{-1} against the potential production of 1000 to 1500 kg ha^{-1} yr^{-1} in these water sheds. This wide gap in production may be due to lack of proper management practices and knowledge of exploitation.

Presently the cnclosure culture system like cage and pens is gaining importance in open water fisheries through out the world for production enhancement. In India, cage culture was first attempted by Dehadrai *et al.,* (1975) in the swamps of Assam for rearing the air breathing fishes. Later Natarajan *et al.,* (1979), Sukumaran *et al.,* (1986) and Govind *et al.,* (1988) reported rearing of the Indian major carps in the floating cages from riverine and pond environment. Similarly the cage culture of the exotic species in India was also done by Kumaraih, *et al.,* (1986), Sivakami *et al.,* (1991) and Bandyhopadhyay *et at* (1991).

On the other hand, the informations on pen culture in fisheries from India is really scanty. The early attempt in this direction is the rearing of carp seed in pens since 1978 at Bhavanisagar and Tungabhadra reservoirs in India. Apart from that some works were also done on pen culture of fishes and prawns under CIFA, Bhubaneswar and CIFRI, Barrackpore during the last few years (Vinci, *et.al* 2002).

POTENTIALITY AND SCOPE

The floodplain wetlands offer immense scope for taking up cage and pen culture due to several reasons. Basically these water resources serve as the ideal sites of nursery, breeding and biodiversity of many riverine species. Now a days, due to siltation and human interferance, most of the wetlands become stagnant in nature. However, the morphometric and ecological conditions of the wetlands are favourable for cage and pen farming towards production enhancement.

Cages and pens can be used for raising stocking materials for growing endangered and economically important species, to take up monoculture of needed species, brooder rearing, to make sites of recreation and finally to conduct experimental programmes.

Selection site

The important criteria for the selection of cage and pen culture sites are as follows:

- The physicochemical condition of water (temperature, oxygen, salinity algalblooms, water current and water exchange) for healthy environment.
- The climatic and morphometric (shelter, depth, substrata) condition
- Social situation of the surrounding, easy approach to the site and market accessibility

Designing and construction

The cages and pens are usually constructed as per the species to be cultured, climatic condition and scale of operation. Cage and pen construction materials should be corrosion and fouling resistant, smooth and repairable as well as inexpensive and easily available.

The cages may be floating or fixed type. The may be rectangular, square, hexagonal, round in shapes. Though 40 to 625 m^3 size cages are used in many countries, in India they are found to be 1 to 36 m^3. The low cost cages are generally made from locally materials available like bamboo poles, bamboo mats, ropes, wires and sealed oil drums. However, the modern cage enclosures are made by using synthetic fibers (polyamide, polyester, polyethylene and polypropylene). The twines may be knotted or knotless. Apart from that rigid plastic (netlon, Velon) and PVC drums, oil drums, aluminium float and styrofoam are used. The mooring system consists of lines, ropes and anchors.

The pen is constructed with the help of bamboo or wooden poles and rigid plastic nettings supported by head and foot ropes. Pen fencing should go at least 50 to 60 cm in the bottom soil to prevent the entry of unwanted organisms inside the pen.

Culture system

The enclosure systems like cages and pens can be utilized in various ways for production enhancement in the floodplain wetlands. They are used for seed rearing, brood stock management.

In cages, spawn of the Indian major carps can be reared at a stocking density of 30,000 to 50,000 m^{-3}, where as in pens it will be 4.5 million ha^{-1}. Similarly for fry rearing, the stocking density will be 8,500 m^{-3} in cages and 0.5 million ha^{-1} in pens. While for growout fishes it will be 500 m^{-3} (intensive), 200 m^{-3} (semi-intensive) and 100/m^3 (extensive), in the cages, and 8,000 to 10,000 ha^{-1} in pens.

Inspite of huge potentiality, the cage and pen culture practices of fishes in the floodplain wetlands is really meager. This may be due to lack of awareness scientific inputs and finance. However, the rate of carp production in cages from 25 to 37.5 kg/m^3/month have been recorded in some other countries (Japan, Germany and Netherlands). In India, cage culture of *Catla catla* and *H. molitrix* recorded a production of 1.30 kg/m^3/month and 0.7 kg/m^3/month respectively.

Nutrition and feeding

The energy requirement in fry and fingerling rearing is found to be 4920 Kcal/kg to get maximum growth and 3400 to 3800 K.Cal/kg for table fish rearing. Likewise protein requirements vary from 30 to 36% with optimal value of 33%. Addition of 20 to 25% fish meal plus yeast increases the nutritive value of feed in case of fry and fingerling. The vitamins mineral mixtures are added.

In pens and cages due to non-availability of sufficient natural food, it is necessary to give supplemented feed to the fishes for proper growth and survival. As per nutritional requirements, feeds can be prepared with locally available ingredients like ground nut oil cake and rice bran in 1:1 ratio. However, to prepare a complete food it requires all the essentials nutrients (carbohydrates, proteins, fats vitamins and minerals) plus medicines, preservatives and binders.

The daily feed consumption of life history stages of the Indian major carps varied considerably. For spawn rearing it is 4 to 8 times of the total stocking materials, 75% of body weight for fry rearing and 2 to 5% of body weight for growout fish rearing. The feed should be given in two installments (morning and evening) either by broadcasting or placing in the immersed feeding tray.

Water quality management

The water quality represents the physical, chemical and biological factors present it it. It affects the production, growth, survival and management of the cultivable aquatic organisms. The important water parameters for cage and pen culture of fishes are mentioned below.

Temperature

Water temperature controls the metabolic activities as well as the reproductive cycle of the aquatic organism greatly. The fishes grew well in the water temperature range of 27 ^{0}C to 33 ^{0}C. It has been observed that the dissolved oxygen requirement of the fishes become double when the water temperature reaches 30 ^{o}C from 20 ^{o}C. Normally the catabolic activities of the fishes increase with the rise of temperature and vice-verca.

Turbidity

Turbidity due to the presence of biotic (plankton) and abiotic (suspended particles) materials, blocks the meshes of the cage and pen. As a result of which the water exchange between inside and outside of the enclosure reduces. The water transparency less than 15 cm is considered as critical. Less water transparency creates LODOS (Low dissolved oxygen syndrome) amongst the fishes.

Dissolved oxygen

It is the most critical parameter in the enclosure culture systems. When the dissolved oxygen concentration goes below 3 mgl^{-1}, it is considered to be detrimental to fishes. As this juncture the free CO_2 concentration becomes highest and creates respiratory problems to the fishes. Generally, the concentration of the dissolved oxygen is found to be least in the early morning hours and maximum in the late afternoon. Fishes do not grow well and feed properly when the dissolved O_2 concentration remains in level of 3 to 4 mgl^{-1} for a long period. It is better to start emergency aeration in the cages/pen when the dissolved O_2 concentration goes below 2-3 mgl^{-1}. The aeration will improve the water quality and increase the feed conversion efficiency.

pH

The pH indicates the acidity and alkalinity of a solution. The pH in a water increases during day and decreases at night hours. Fluctuation in the pH value is negligible in water, when total alkalinity remains high. The acidic and alkaline death points of fishes are pH 4.0 and 11.0 respectively. In lower pH value, it is necessary to control the acidification process and to rear more acid tolerant species. In the open water systems pH goes down due to accumulation of CO_2 and organic materials.

Inorganic nitrogen

All the intermediate products of the nitrogen cycle in an aquatic ecosystem are toxic to the aquatic animals. Amongst them ammonia is the most dangerous pollutant. The lethal level of NH_3 is 2.8 mgl^{-1} for most fishes. NH_4 is 7.5% to 100% less toxic than NH_3. Even NO_2 at a concentration of 0.5 mgl^{-1} is detrimental to fishes. The highest concentration of total ammonia nitrogen occurs when the phytoplankters die off. To avoid the nitrogen wastes toxicity of water, the aquatic system should not be overloaded with the organic materials like manures, feeds etc.

PROBLEMS AND CONSTRAINTS

A wide variety of problems are encountered in the cages and pens of fishes. Some of the areas where care is necessary to be taken to prevent the loss of fishes and other materials are mentioned below.

Fouling

Fouling reduces the mesh size of the net enclosure and cuts down water exchange rate. Clogging results from the clay particles settlement and growth of algae. To overcome the problems of fouling, different measures can be taken. These are regularly cleaning of the nets, application of anti fouling chemicals (orgenotin algicides and chlorine). Stocking of rohu in low densities is found to be effective in maintaining the cleanliness of the carp cages.

LODOS occurs

LODOS occurs due to cloudy weather, summer thunder storms and mass death of plankton. DO level less than 3 mgl^{-1} causes high LODOS amongst the fishes. Sometimes, huge mortality of fishes occur due to LODOS. To overcome this problem, supplementary aeration either in the form of direct air injection or by increasing the water exchange rate in the enclosures by paddle aerators have to be resorted for 2-3 days.

Fish mortality

The mortality of fishes in the enclosures occur mainly due to the stocking of unhealthy fishes, rough handling, over stocking, improper feeding, thermal variation low DO and waste products accumulation. Fishes suffering from diseases show loss of appetite, colour change, abnormal movement, and weakness. Fish disease are caused by parasites, bacteria, fungi and viruses, Some of the common fish diseases and treatment are mentioned below.

Bacterial diseases

These are tail and finrot, ulceration dropsy and eye disease. Dip treatment in 1:2000 of copper sulphate solution for 1 to 2 minutes is recommended. The badly infected fish with ulcer should be discarded. Dropsy is caused by *Aeromonas* spp. Chlorimycetin at a concentration of 60 mg in 4.5 ltr. water is found to be effective to cure dropsy.

Protozoan diseases

The white spot disease of the major carps is caused by the protozoa, *Ichthyophthirius* spp. Myxosporidians produce cysts on different regions of the body, internal tissues and organs. Worm diseases are caused by the trematodes, *Gyrodactylus* and *Dactylogyrus*.

Treatment of fishes in 2 to 3% common salt solution in 5 to 6 minutes or 1:5000 formalin solution is effective to kill the protozoan.

Crustacean diseases

Carp lice (*Argulus*) *Lernaea* and *Ergasilus* are important ecotoparrsites. They attach to the body of fish by means of suckers and draw nutrition. The infected fishes become weak. Application of lindae (y BHC) @ 8ml/10000 lt. And Diptrex 2 ppm is helpful to eradicate ectoparasites.

Poaching

It is a common problem in cage and pen farming. Fishes can be easily removed from the enclosures with hand net or cast net. So guarding arrangement for the cages and pens have to made to save the fish loss.

Predators

The predators include carnivorous fishes, turtles, crocodiles, snakes, crabs, birds and mammals. Predators like birds and mammals prefer to attack fishes at dawn and dusk, they cause mortality of the fishes as well as damage to enclosure material. This problem can be overcome through the use of antipredator nets and top covering of enclosures.

Weather

The stormy weather and wave action can damage the enclosure structures, moorings and fishes. Break waters (floating type) are often used in inland waters to resist wind and wave action. Rigid celar and sub sensible cages are also helpful to overcome this problem. UV radiation causes damage to cage collar and the netting components. So use of UV radiation resistant materials (PVC) or dyestuffs (bitumen or coal tar) can be applied.

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