ECOLOGY AND FISHERIES OF BEELS IN WEST BENGAL

CENTRAL INLAND CAPTURE FISHERIES RESEARCH INSTITUTE, BARRACKPORE

Ecology and Fisheries of Beels in West Bengal

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Foreword

Floodplain wetlands *(beels)* constitute a major aquatic resource of West Bengal contributing significantly to the State's inland fish production. During the last two decades, fish yield of West Bengal *beels* has registered substantial increase by adopting culture-based fisheries and other forms of enhancement. This form of fishery management facilitates substantial increase in fish yield and production with minimal monetary inputs and environmental damage. Development of *beel* fisheries on the basis of culture-based fisheries is also significant from a socio-economic point of view. Most of them are common property resources managed under cooperative fold. Thus, benefits accrued from the increased productivity is equitably distributed among the fishers.

The Central Inland Capture Fisheries Research Institute has been conducting research on ecology and fisheries of *beels* in West Bengal during the last two decades. Finally, we have been able to come out with useful guidelines for fishery management of this important resource. This bulletin is the first ever attempt in India to provide advice on fishery management of floodplain wetlands based on scientific principles. Even though it is not possible to develop technology packages for fishery management of beels due to many reasons, the formative guidelines evolved by CIFRI are good enough to achieve substantial increase in yield and production from beels.

The team of scientists under the leadership of Dr. V.V. Sugunan has done a commendable job in analyzing the voluminous data collected over the years and developing the guidelines for fishery management of *beels*. I am glad to put on record that the pen culture method developed as a part of the management strategy has been adapted in the State of West Bengal. Pen culture of giant freshwater prawn has become popular in many *beels* in the State especially in the districts of 24-Parganas. I trust this bulletin, apart from being a very useful reference material for the *beel* managers, will go a long way in increasing the inland fish production in the State.

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INTRODUCTION

India has extensive floodplain wetlands, defined as low-lying areas bordering large rivers, which are seasonally inundated by the overspill from the main river channel. These wetlands are an integral component of the Ganga and the Brahmaputra river basins, covering an area of 0.2 million hectares. They also exist in Manipur and Tripura as well as in the foothills of Arunachal Pradesh and Meghalaya. They can be typical ox-bow lakes (*i. e.* cut off portions of river meander bends), sloughs, meander scroll depressions, back swamps, residual channels or tectonic depressions, though it is often difficult to establish their identity due to natural and man-made modifications to the environment. These water bodies are locally known as *beels* (Assam, West Bengal, Arunachal Pradesh, Meghalaya and Tripura) *maun, chaurs* and *dhars* (Bihar), *pats* (Manipur*), charhas* and *boars* (northern and south-eastern West Bengal respectively). Floodplain wetlands form an important fishery resource in these states and thousands of poor fishermen are dependent on these water bodies for their livelihood. The magnitude of their distribution and potential as a fishery resource in different states can be seen from Table 1.

The beels are considered as biologically sensitive habitats as they play a vital role in the recruitment of fish populations in the riverine ecosystems and provide nursery grounds for commercially important fishes. They form an important fishery resource in the northern and northeastern states of the country. The beels vary widely in size, shape, extent of riverine connection, etc. and offer tremendous scope for expanding both capture and culture fisheries. They are extremely rich in plant nutrients (as reflected by rich organic carbon and high levels of available nitrogen and phosphorus in the soil), therefore, have high biological productivity. However, in many beels the nutrients are usually locked up in the form of large aquatic plants like water hyacinth, and do not contribute significantly to fish production.

Importance of beels

If managed along scientific lines, fish production in beels can be increased significantly. For example, studies conducted by the CIFRI for the past fifteen years have shown that the fish yields from West Bengal beels can be raised to 1,000-1500 kg/ha/yr from its present level of only 100-150 kg/ha with scientific management. Besides, many of the closed beels (which are cut-off from the river course) are in a transient phase of their evolution into marshlands. Such water bodies, apart from attracting migratory and resident waterfowls, support a rich faunistic diversity in the form of plankton, macrophytes, benthic organisms, insects and other macrophyte associated fauna as well as a rich variety of air-breathing and small sized fishes, some of which are threatened ones. Thus, conservation of these dynamic and productive habitats has become necessary for *in situ* conservation of threatened aquatic species including fishes and waterfowls. In addition, the beels also regulate the water regime and nutrient exchange and act as natural filters. However, a combination of the processes of river bed evolution and the effects of extensive flood control and irrigation works have reduced the fish production of many beels through siltation, habitat destruction, macrophyte infestation and isolation from the seasonal floods restricting entry of riverine fish stocks. The floodplains with their associated lentic water bodies are essentially a continuum of the rivers. Indiscriminate killing of brood and juvenile fishes of commercial species during the breeding and recruitment seasons badly hampers the production in the lake as well as in the rivers. Thus, there is an urgent need to formulate sound management norms for sustainable development and optimal utilization of the beels keeping in view the conservation of the productive and dynamic ecosystems while increasing their fish production to optimal levels.

Table 1. Distribution of floodplain wetlands in India.

STATE	DISTRIBUTION (district-wise)	RIVER BASINS	LOCAL NAME	AREA (ha)
Arunachal Pradesh	East Kameng, Lower Subansiri, East Siang, Dobang valley, Lohit, Changlang & Tirap	Kameng, Subansiri, Dibang, Lohit Dihing & Tirap	Beel	2,500
Assam	Brahmaputra & Barak valley districts	Brahmaputra & Barak	Beel	1,00,000
Bihar	Saran, Champaran, Saharsa, Muzaffarpur, Darbhanga, Monghyr & Purnea	Gandak & Kosi	Maun, Chaur & Dhar	40,000
Manipur	Imphal, Thoubal & Bishnupur	Iral, Imphal & Thoubal	Pat	16,500
Meghalaya	West Khasi hills and West Garo hills	Someshwari & Jinjiram	Beel	213
Tripura	North, South & West Tripura districts	Gumti	Beel	500
West Bengal	24-Parganas North & South, Hooghly Nadia, Murshidabad, Maldah,, Cooch Behar, Burdwan, North & South Dinajpore and Midnapore	Hooghly, Ichhamati, Bhagirathi, Churni, Kalindi, Dharub, Dharala, Pagla, Jalangi, Behula, Torsa and Mahananda	Beel Charha & Baor	42,500
Total				**202,213**

BASIC CONCEPTS/DEFINITIONS

Floodplains

The floodplains are either permanent or temporary water bodies associated with rivers that constantly shift their beds especially in the potamon regimes. The frequency with which a river changes its course depends on a number of variables like flow velocity, sediment transportation rate, slope, channel pattern, water and sediment yield, amount and duration of precipitation over the catchment area, texture and lithology of soil, tectonic status, and so on.

According to Leopold *et al* (1964), a typical floodplain wil! include the following:

i) The river channel
ii) Ox-bows or ox-bow lakes: *they represent the cut-off portion of meander bends of a river. These are usually serpentine or horse-shoe shaped.*
iii) Point bars: *These are loci of deposition on the convex side of curves in the channel.*
iv) Meander scrolls: *Depressions and rises on the convex sides of bends formed as the channel migrates laterally down valley by the erosion of the concave bend.*
v) Sloughs: *Area of dead water formed both in the meander scroll depressions and along the valley walls as flood flows more directly down valley scouring adjacent to the valley walls.*
vi) Natural levees: *Raised berns or crests above the floodplain surface adjacent to the channel, usually containing coarser materials deposited as floods flow over the top of the channel banks. These are most frequently found at the concave bank and are submerged annually. They may be absent or imperceptible where most of the silt load in transit is fine grained.*
vii) Back swamp deposits: *Over bank deposits of finer sediments deposited in slack water ponded between the natural levees and the wall or terrace riser. These are submerged for long periods of the year.*
viii) Sand splays : *Deposits of flood debris usually coarser sand particles in the form of splays or scattered debris :*

According to flow of water, the floodplains can be divided into two groups

The plain (lotic component) : Includes the river channel (s), the levee region that more or less follows the river channel course and the flats extending from the levees to the terrace or plateau delimiting the plain. While the main channel (s) of the river usually retain water (not necessarily flowing water) throughout the year, the levee regions and the flats are seasonally inundated but remains dry for at least some parts of the year.

The standing water (lentic component): Receding floods leave permanent or semi-permanent standing waters in the form of sloughs, meander scroll depression, back swamps or the residual channel (ox-bow lakes). These water bodies expand or contract in area according to annual flood cycle and tend to merge into a continuous sheet or water covering the whole plain during the highest floods.

Wetlands

The Ramsar convention (1971) defined wetlands as *Areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water which is static or flowing, fresh, brackish or salt including areas of marine waters, the depth of which at low tide does not exceed nine metres.* Thus, wetlands embrace a broad category of water bodies, which include riverine floodplains, swamps, marshes, estuaries, backwaters, lagoons, and so on.

The beel or floodplain wetlands usually represent the lentic component of floodplains *viz.,* ox-bow lakes, sloughs, meander scroll depressions, residual channels and the back swamps and excludes the lotic component (the main river channels, the levee region and the flats). In addition, tectonic depressions located in river basins are also included under beels. Thus, all the wetland formations located at the floodplains can be termed as beels. They are either shallow depressions or dead riverbeds generally connected to the principal rivers and/or receive backflow water from the rivers during floods or from the huge catchment area following monsoon rains.

DESCRIPTION OF BEEL RESOURCES OF INDIA

Geomorphology

The floodplain wetlands are an integral component of the Ganga and the Brahmaputra basins. The Indo-Gangetic Plains are situated between the southern peninsula (oldest land mass in the Indian sub-continent) and the extra-peninsular Himalayas in the north. The Himalayan mountains are comparatively of recent (tertiary) origin and are disturbed by earth movement, as evident from the rocks being folded, faulted, over thrust and even carried over some distance as thrust sheets. The plains occupy the depression in the earth's crust between these two elevated regions. Here, the sediments are of recent origin and largely consist of silt which can be easily eroded. The Indo-Gangetic alluvial tracts, especially in the northeast, are also geologically unstable and experience earthquakes of varying intensities from time to time. Two devastating earthquakes occurred in the northeast during 1897 and 1950.

Origin of floodplain wetlands

The litholol gy, geological structure, tectonic status, seasonal variation in river discharge and flow characteristics, largely determine the formation of the floodplain wetlands. The beels of the country owe their origin either to the often changing course of rivers in the potamonic stretches or to tectonic adjustment.

In the northern part of Bihar and West Bengal as also in Assam, the rivers emerging from the central and eastern Himalayas suddenly debouch into the plains and ultimately flow down as the river Ganga, Brahmaputra and Barak. These rivers carry heavy loads of silt and detritus from the Himalayas and overflow during the southwest monsoon season submerging huge tracts of lands every year. These rivers change their course very often creating numerous floodplain lakes and braided channels, mainly in the form of ox-bow lakes. In deltaic West Bengal, due to low gradient and high riverine discharge during the monsoon season, rechannelisation of rivers occurs at the slightest obstruction to flow, resulting in creation of beels of varied types. In the northeast (Assam, foothills of Arunachal Pradesh and Meghalaya), frequent earthquakes coupled with heavy rainfall and cutting action of river meanders have resulted in the formation of typical ox-bow lakes, lake-like beels or true tectonic depressions. The *pat*s of Manipur owe their origin mainly to the cutting action of the stream meanders.

Classification of floodplain wetlands/beels

Since the floodplain wetlands include low-lying water bodies of diverse origin, size, shape, depth, inundation pattern, ecological characteristics, *etc.* many attempts have been made to classify them according to these criteria. Some of these classifications are given below :

Classification based on morphometry

Ox-bow lakes : these are cut of portion of river meanders. The basins are relatively narrow, long, deep and have either bent or straight shapes. They derive the name from their shape, which is usually horse-shoe shaped, crescent shaped or serpentine. They receive water from the parent river through the old channel or neighboring catchment areas (Haripur, Bhomra, Akaipur, Garapota beels in West Bengal).

Lake-like wetland: these are wide and shallow with irregular contours. They may be connected to the river through channels or receive water from it during floods. During the monsoon season, the entire neighboring area gets flooded, turning the beel into a vast sheet of water whereas during non-monsoon seasons the water spread area shrinks to the basin proper (Baloon and Bansdaha beels in West Bengal).

True tectonic depressions : these are created by tectonic activities like earthquakes and usually resemble natural lakes with regular contours. Normally, they are not connected to rivers through connecting channels but may receive water from the latter during floods. Such tectonic wetlands are common in the northeastern region (Chanddubi beel in Assam)

Meteorite lake: these are created by the impact of fall of a meteorite on earth. Such beels have regular, nearly oval shape and abnormally high banks on all sides, which, according to geologists, can be created when the left over portion of a large meteorite hits the earth. The morphometric features of the beels are similar to those of volcanic lakes, except for the fact that they are located in the plains and are very shallow (Sarasanka in Midnapore district of West Bengal).

Classification based on water retentivity

Seasonal beels: these are shallow floodplain wetlands, which periodically get inundated by monsoon rains and floods but completely dry up during summer months.

Perennial beels: Deeper and permanent beels, which retain water round the year.

Classification based on depth

Shallow beels: Beels having maximum depth up to 5 metres.
Medium deep beels : Beels which have maximum water in the range of 5 to 10 metres.
Deep beels : Beels having maximum depth of over 10 metres.

Classification based on size

Small beels : Effective area less than 100 hectares
Medium beels : Effective area 100 to 500 hectares
Large beel : Effective area more than 500 hectares

Classification based on shape

Ox-bow shaped, crescent shaped, serpentine, oval, irregular braided channels, etc.

Ecological classification

Investigations on floodplain wetlands of West Bengal carried out by CIFRI for the last decade and a half indicate that water residence and renewal time as well as the extent 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. While this adversely affects the biological productivity of the ecosystem, it helps in delaying eutrophication process. Rapid water renewal also helps in breaking the thermal stratification, if any, in deep beels, which is beneficial for nutrient recycling and gaseous exchange. At the same time, continuous water flow does not allow the plankton species to stabilize, resulting in lower plankton density and primary production rates in such beels. Similarly, aquatic macrophytes use up large chunks of plant nutrients, thus making them unavailable for the growth of phytoplankton (Phytoplankton is a better primary producer than macrophytes in beels for efficient conversion of energy). The aquatic weeds also render operation of fishing gears difficult. Thus, the following two ecological classifications using these two characteristics are much more relevant from the ecological and fisheries point of view than the previously discussed ones and will be largely followed in this treatise.

Classification based on riverine connection

Open beels : These beels retain continuity with the parent rivers either for the whole year or at least during the rainy season. Such beels have continuous exchange of water as well as fish fauna with the parent river (Kol beel).

Closed beels : These beels are completely cut-off from the nearby rivers and receive water mostly from their catchment areas following monsoon rains or during high flood. In recent years, riverine embankments constructed to prevent floods have converted many open beels into closed ones by blocking the riverine connections.

Classification based on the extent of macrophyte infestation

Weed choked beels: A beel can be considered as weed choked when more than 50% of the total water spread area is covered by aquatic macrophytes (Bhomra and Baloon beels in West Bengal).

Moderately weed infested beels: A beel can be considered as moderately weed infested when less than 50% of the total water spread area is covered by aquatic macrophytes (Bhandardaha and Kulia beels in West Bengal).

Distribution of beels in West Bengal

Gangetic West Bengal represents the deltaic reaches of the river Ganga, its tributaries and distributaries, where the river course passes through alluvial plains of a very low gradient, resulting in extensive changes in floodplain configuration. Changing river courses create many ox-bow lakes, sloughs, meander scroll depressions, back swamps and residual channels. The State has more than 150 beels covering an area of 42,000 hectares and constituting 22% of the total freshwater area of the State. Thus the beels are an important natural resource playing a vital role in the fisheries, rural economy and environment of the State.

The beels of West Bengal are situated along the rivers Bhagirathi, Hooghly, Ichhamati, Jalangi, Churni, Kalindi, Dharub, Dharala, Pagla, Behula, Torsa, Puranabhaba, *etc.* Nearly half of the beels are located in the districts of 24 Parganas, Murshidabad, Cooch Behar and Nadia of which Murshidabad and Nadia have the maximum numbers, the districts of Maldah, Hooghly, West Dinajpur have comparatively lesser number of beels, while Midnapore, Birbhum, Bankura and Purulia bordering Bihar and Orissa have very few beels (Fig.1 & Table 2.)

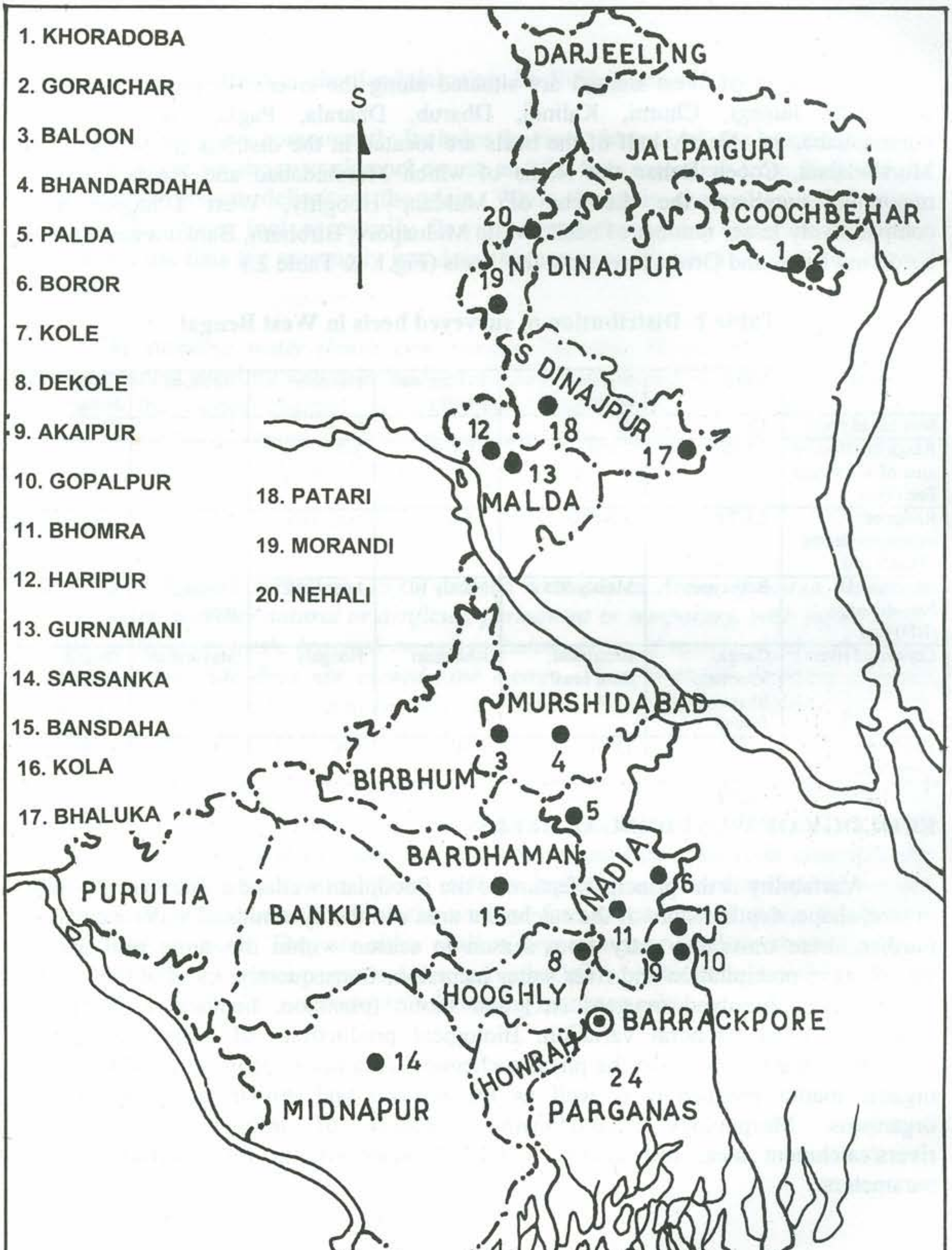
Table 2. Distribution of surveyed beels in West Bengal

Parameters	Nadia	Murshi-dabad	24 Parganas (North)	Hooghly	Birbhum	Cooch Behar
Number of beels	42	45	24	6	1	28
Range of effective area of individual beels (ha)	2-130	7-210	12-600	3-7.5	100	-
Range of maximum depths of beels (m)	2.5-7.0	3.0-17.0	3.5-8.5	1.85-3.60	2.5	1.0-6.8
Drainage (D) Non-drainage (ND) type	Both types	Mainly ND	Mainly ND	Mainly ND	Drainage type	Mainly ND
Connected rivers	Ganga, Ichamati, Bhagirathi, Jalangi	Bhagirathi, Sone canal	Ichhamati	Hooghly	Mayurakshi	Dharub Dharala
Total water spread area (ha)	15,982	13,161	1,742	174	100	3,000

ECOLOGY OF WEST BENGAL BEELS

Variability is the principal feature of the floodplain wetlands. They vary widely in size, shape, depth, nature of the catchment area and the dynamics of water exchange. Further, these traits also vary from season to season within the same beel due to variations in precipitation and river water incursion. Consequently, most of the abiotic (temperature, dissolved oxygen, *etc.*) and biotic (plankton, benthos, *etc.*) factors undergo marked temporal variation. Biological productivity of a beel ecosystem depends on the suitability of the physico-chemical parameters of its soil and water for organic matter production as well as for survival and growth of living aquatic organisms. Morphology, hydrodynamics, quality of inflowing water from rivers/catchment area, soil quality, depth of water *etc*, in turn, influence these parameters.

Fig. 1. Beels of West Bengal studied by CIFRI



Morpho-ecology

Morphology

In a floodplain wetland, the mean depth, wind action and water exchange are important factors. They control its thermal behaviour, which, in turn, influences many physico-chemical and biological parameters. Various important morphometric characteristics of 20 beels of West Bengal studied by CIFRI during 1984-95 are presented in Table 3.

Table 3. 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
	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 choked	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

Table 3. (Contd…..)

Distr.	Beel	Area (ha)	Depth (m)	Type of beel	Macrophyte infestation Level	Fish yield (kg/ha/yr)	Fishery information
Hoo-ghly	Dekole	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
Mur-shida-bad	Baloon	200.0	1.6-1.9	Closed; lake-like	Weed choked	24	Capture fishery, Indigenous spp., IMC
	Bhandar-daha	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
Bardha-man	Bansdaha	26	1.7-6.5	Closed (R. Bhagirathi), oxbow lake	Moderate	1100	Stocking, IMC, *G. chapra*
Midna-pore	Sarasanka	24.0	0.2-1.8	Closed, lake-like (oval meteorite lake)	Weed choked	250-292	Stocking, IMC
24 Par-ganas	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
Mal-dah	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*

A typical beel of West Bengal with marginal vegetation

Marginal areas of beel infested with reeds and littoral vegetation

Most of the beels studied (65%) were shallow (maximum depth <5 m) and only two beels (10%) *viz.,* Bhandardaha and Berir baor (Gopalpur) were deep (>10M). In shallow beels, the whole water body gets heated up rapidly, thereby increasing the speed of chemical and biochemical reactions. Shallow beels also facilitate dense growth of rooted aquatic macrophytes, which compete for nutrients and space with phytoplankton and are not part of the autotrophic food chain. As evident from Table 3, nearly half of the shallow beels are weed choked. In addition, shallow beels are likely to be isothermal while medium deep and deep ones may develop stable summer stratification. For example, isothermal condition was observed in Padma beel (shallow) while Garapota beel (medium deep) exhibited summer thermocline during 1990-91.

Most of the beels investigated (70%) were small (<100 ha) and rest belonged to the medium (100-500 ha) category. Large surface area facilitated higher wind-induced mixing. This is particularly beneficial in breaking the possible summer thermoclines in deep and medium deep beels.

Hydrodynamics and water balance

As mentioned in the previous chapter, water renewal and residence time play a vital role in the ecology of the floodplain wetlands. The beels gain water either directly from precipitation, through surface run-off, regeneration or from nearby rivers. Inflow of flood water into these water bodies is estimated to be equivalent to a quarter of the water volume. Thus, a complete exchange of water in a beel is possible every four years. Many of the open beels have permanent channels, measuring several kilometers in length, connecting them to the main river. This channel helps in water exchange with the river throughout the year acting as a "spillway" to limit retention of excess water from storage. The main period of water exchange is during the southwest monsoon season (June-September) when the beels are flooded. Flood water is the main water source even for many closed beels that are isolated for most of the year (*e.g.* Bansdaha beel). In closed beels like Talbona (defunct R. Kalindi, Maldah Dt.) which do not usually receive flood water due to the construction of embankments, rainfall (directly on water surface or indirectly as surface run-off or seepage water) is the major source of water.

The loss of water from the beels is mainly due to evaporation and seepage to ground water. The open beels with connecting channels also lose water as outflow into the rivers. Thus, these beels have an open drainage basin. Beels infested with floating, marginal and emergent macrophytes also lose a certain amount of water through transpiration. In some beels (Bhomra) water abstraction for crop irrigation puts an additional stress on the water budget especially during summer months (March-May).

Most of the water gain in Indian beels occurs during the southwest monsoon months resulting in rapid increase in water volume and level. They gradually shrink in water spread area as well as volume during the post-monsoon months reaching the lowest levels during the summer months. Thus, the beels undergo considerable fluctuations in water levels between the monsoon and summer season. The annual fluctuations in West Bengal beels ranged from as low as 0.85 m in Dekole beel (closed and shallow) to as high as 11.5 m in Bhandardaha beel (open and deep). In general, the range of annual water level changes were lower in closed beels (0.85-8.13 m) compared to that in the open beels (2.05-11.75 m).

Ecological implications of hydrodynamics

Water level

Changes in water level (both seasonal and long-term annual changes) affect the ecology of the beel ecosystem in many ways.

Change in thermal behaviour: Thermal behaviour in a beel is influenced by depth, wind action and water renewal. When there is a rapid water exchange, the existing thermal stratification of the beel is broken. This leads to mixing of water layers and bringing up of colder, nutrient-rich bottom waters resulting in subsequent spurt in primary production.

Change in nutrient balance: Changes in water exchange between the beel and the connected river naturally affects the nutrient-input-output ratio in open beels. This, in turn, affects the productive potential of the ecosystem. In case of closed beels there is little outflow of nutrient rich water, except where water is abstracted for crop irrigation or where seepage loss is considerable resulting in gradual nutrient accumulation and eutrophication.

Impact on biotic communities: Rapid water exchange in the open beels does not allow plankton species to colonise/stabilise. That is why plankton abundance and primary production is low in open beels in comparison to closed ones resulting in lower fish yields in them. In addition, rapid increase in water levels during the monsoon months causes death and decay of submerged and marginal macrophytes in all the beels, which is beneficial for recycling of nutrients locked up as macrophyte biomass.

Pollution

Plant nutrients and pesticides used in agricultural lands are regularly washed into nearby beel by surface run-off or flood waters. Pesticides cause severe pollution problems by outright fish kills or by entering into the food chain, while nutrients cause eutrophication over a period of time. Continuous flushing helps in removing plant nutrients and other pollutants in open beels thereby reducing the severity of pollution problems.

To summarise, continuous flushing of water helps in removing harmful pollutants and breaking the thermocline in deep beels, therefore, is beneficial for the health of the beels. At the same time, water flow also reduces productivity and fish yield. This partly explains as to why open beels are usually in good condition eventhough they are less productive than closed ones.

Water quality

All the characteristics of water, which influences the growth, reproduction, and production of fishes are collectively termed as water quality. To obtain good fish production from a water body, its water should be suitable for fishes and other aquatic organisms living there. Various physical, chemical and biological factors affect the biological productivity of a water body. Thus, assessing the quality of water of the floodplain wetlands is essential in order to assess their production potential.

Quality of water in a floodplain wetland is influenced by the soil quality (nutrient content) and the atmosphere (i.e., temperature and dissolution of atmospheric gases). In addition, these are also influenced to a great extent by the metabolic processes of the plants and animals living within the water body particularly the luxuriant growth of aquatic macrophytes. The water quality also varies from season to season owing to the large volumes of water inflow from the connecting rivers of catchment area especially during the southwest monsoon season (June-September).

Important parameters of water quality of selected beels of West Bengal are given in Table 4. All the beels had more or less alkaline waters (pH range 6.8-9.8) barring Sarasanka (6.05-6.75) beel, which is optimal both for fishes and for availability of plant nutrients. Similarly total alkalinity (42.0-33.0 mg/l) and total hardness (56.4-372.2 mg/l) of the beels were also within the range conducive for primary production except in Sarasanka beel (7.8-27.3mg/l and 16.0-33.5 mg/l respectively.) Water temperature of the beels varied widely (17.5-35.5 °C). It has been established that water temperatures in the range of 25 to 32 °C is optimal for the growth of carps. The rate of fish growth is known to decline during winter months (December to February) when water becomes cooler than 25 °C. Similarly water temperature of 35 °C or more is beyond the tolerance limit of most of the fishes. When this happens, mainly during summer months (March to May) the aquatic organisms migrate to deeper waters. Secchi disc visibility of water varied from 0.13 to 2.32 m. Water was turbid (<30 cm) in five beels. In general the beel water was turbid during the monsoon months, which is due to inflow of flood or run-off waters carrying silt and organic debris. Turbidity gradually decreased during post-monsoon (October-November) and winter months. Blooms of phytoplankton contributed to increased turbidity during summer months in many beels. Churning of the bottom due to fishing activities is a major contributing factor for increased turbidity during non-monsoon months in most shallow beels. It is interesting to note that among the closed beels weed-choked ones had marginally lower turbidity (0.14-2.00 m) than the moderately weed infested beels (0.13-1.53 m) which may be due to lesser wave action as well as higher rate of production of organic acids by the macrophytes.

Dissolved oxygen content of water was within the optimal range for fishes (4.20-12.53 mg/l) in most beels. Oxygen level lower than the critical limit (4 mg/l) was recorded in Sarasanka and Bansdaha beels in a couple of instances. While Sarasanka beel is a virtual swamp having heavy macrophyte infestation and organic matter, oxygen depletion of Bansdaha beel was due to higher BOD load following large-scale jute retting in marginal areas. Free carbon dioxide levels in all the beels (Nil-16.0 mg/l) were within the optimal range.

Specific conductivity of the beel waters (55.0-3016.0 μ mhos/cm) was generally high indicating good concentration of anions and cations. This is corroborated by the fairly high concentrations of calcium (3.2-248.2 mg/l) and magnesium (2.5-204.7 mg/l) ions. Among the plant nutrients, nitrate-nitrogen (traces-1.57 mg/l), phosphate-phosphorus (traces-0.63 mg/l) and silicate (1.64-12.0 mg/l) recorded moderate to high concentrations. Concentration of these nutrients depends on allochthonous inputs during

Table 4. Physico-chemical characteristics of beel water in West Bengal

Parameters	1 Dekole	2 Baloon	3 Bhomra	4 Talbona	5 Sarasanka	6 Khorar-doba	7 Mogra
Water temp. (^oC)	19.0-31.5	21.0-35.5	24.5-31.0	21.0-29.5	22-31	17.51	-
Sechi disc depth (m)	1.00-1.02	0.55-1.65	1.26-2.00	0.26-0.62	0.14-0.78	0.60	0.34-1.50
PH	7.7-8.5	8.3-9.0	8.28-9.01	7.82-8.36	6.05-6.75	9.35	7.3-9.7
D.O. (mg/l)	4.29-9.90	5.47-6.48	4.6-11.8	10.00-11.48	3.24-6.08	9.0	6.4-22.1
Total alkalinity (mg/l)	84.0-151.2	115.2-177.6	108-192	96-108	7.8-27.3	60.0	50-128
Free CO_2 (mg/l)	Nil-16.0	Nil	Nil-6.0	Nil	4.0-10.0	5.0	-
Total hardness	86.5-171.0	79.0-124.4	108-172	82-92	16.0-33.5	56.4	-
Sp. Conductivity (μmhos)	295.8-899.0	232.0-562.6	320-440	180-280	90.0-275.0	191.4	-
Nitrate-N(mg/l)	0.05-0.10	0.02-0.05	T-0.09	T-0.34	T-0.28	0.02	0.33-1.57
Phosphate-P(mg/l)	0.04-0.06	0.03-0.08	T-0.08	T	0.01-0.08	0.63	T-0.02
Silicate (mg/l)	2.35	1.64-2.18	3.6-7.0	3.4-4.0	2.5-5.5	1.97	-
Chloride (mg/l)	30.3-34.2	20.4-30.6	5.32-31.24	4.26-11.36	10.55-65.32	26.5	-
Calcium (mg/l)	30.3-34.2	20.4-30.6	5.32-31.24	4.26-11.36	10.55-65.32	26.5	-
Magnesium (mg/l)	54.0-78.0	72.36	9.19-21.36	10.21-10.67	2.5-20.0	-	-

Table 4. contd….

Parameters	8	9	10	11	12
	Baror	Akaipur	Berir baor	Bansdaha	Kulia
Water temp. (^{o}C)	26.2-34.1	21.5-32.5	25.8-28.0	19.0-35.5	-
Sechi disc depth (m)	0.63-1.09	0.13-0.61	0.66-0.78	0.90-1.53	-
PH	7.77-8.20	7.73-8.06	7.7-8.2	6.8-8.31	7.2-8.0
D.O. (mg/l)	7.14-7.62	4.80-8.68	4.20-7.26	1.2-9.0	6.60-7.78
Total alkalinity (mg/l)	115.0-174.4	83.2-142.9	172.9-188.3	42.0-165.8	106.7-212.0
Free CO_2 (mg/l)	Nil-3.13	Nil-11.9	Nil-1.0	Nil-14.0	2.0-8.5
Total hardness	124.7-177.0	57.0-158.7	334.8-372.2	74.0-119.5	-
Sp. Conductivity (μmhos)	417.6-438.9	55.0-370.3	1693.6-3016.0	200.0-326.7	467.8-1100.0
Nitrate-N(mg/l)	0.01-0.07	0.04-0.19	T-0.07	T-0.21	0.12-0.56
Phosphate-P(mg/l)	0.02-0.03	0.03-0.14	0.03-0.45	T-0.04	0.02-0.07
Silicate (mg/l)	2.32-2.70	2.20-4.38	2.05-2.69	2.00-3.27	-
Chloride (mg/l)	23.7-26.0	13.44-34.27	4986.6-550.5	5.68-30.08	-
Calcium (mg/l)	59.0-99.0	22.0-84.9	127.4-248.2	8.82-803.00	-
Magnesium (mg/l)	25.7-92.2	12.0-73.8	124.1-204.7	10.66-26.67	-

Table 4. contd….

Parameters	13 Palda	14 Kole	15 Gorai-chara	16 Garapota	17 Bhan-daradaha	18 Haripur	19 Ghur-namani
Water temp. (^{o}C)	26.2-34.1	20.5-33.5	17.5	-	20.5-31.5	20.5-31.5	19-32
Sechi disc depth (m)	0.47	0.16-1.00	2.00	0.65-1.45	1.10-2.32	0.25-1.68	0.65-137
PH	7.7-8.2	7.35-8.30	9.05	7.5-8.7	8.2-9.8	6.89-8.88	7.53-8.28
D.O. (mg/l)	7.1-8.0	7.4-4.4	6.65-6.75	5.6-12.2	4.61-13.0	5.20-12.53	5.85-7.60
Total alkalinity (mg/l)	124.8-174	112.0-156.8	110.9-120.0	84-282.0	129.0-220.8	84-150	172-338
Free CO_2 (mg/l)	Nil	Nil-8.0	2.0	-	Nil	Nil	2.8-8.8
Total hardness	125.0-176.7	96.0-203.6	110.9	208.7	119.0-194.4	69.5-142.0	155-209
Sp. Conductivity (μmhos)	236.6-307	208.0-478.0	292.9	347.2	526.8-637.0	100-270	240-512
Nitrate-N(mg/l)	0.05-0.16	Tr-0.05	0.02	0.22-1.01	0.05-0.07	Tr-0.15	0.03-0.05
Phosphate-P(mg/l)	0.03-0.07	T-0.03	0.08	Tr-0.10	0.04-0.07	Tr-0.08	0.04-0.07
Silicate (mg/l)	2.02-2.06	1.87-7.70	2.61	-	1.61-2.2	2.6-12.0	1.76-2.72
Chloride (mg/l)	78.3	11.36-40.60	15.4	22.8	25.1-31.3	2.84-15.36	13.44-28.80
Calcium (mg/l)	60.5-122.6	20.8-125.2	-	-	108.0-138.4	8.8-56.5	87.5-141.0
Magnesium (mg/l)	54.1-65.7	7.7-8.0	28.2	-	38.9-86.4	25.0-121.5	8.72-20.50

monsoon months and their uptake or release by phytoplankton and macrophytes, which varies from season to season. However, on the whole these parameters reflect highly productive nature of the beels under investigation.

Water quality varied widely between beels as can be seen from Table 4. Open (moderately weed infested) beels recorded the highest values of pH (6.89-9.8), DO (4.4-12.53 mg/l), total hardness (84-338 mg/l) and silicate (1.62-12.0 mg/l). It also recorded the lowest concentration of free carbon dioxide (Nil-8.8 mg/l), specific conductivity (100.0-637.0 µmhos/cm), phosphate (traces-0.10 mg/l) and calcium (8.8-141.0 mg/l). In contrast, closed weed-choked beels recorded the lowest levels of pH (6.05-97), total alkalinity (7.8-192.0 mg/l), total harness (16.0-177.0 mg/l) and magnesium (2.5-78.0 mg/l) while recording the highest concentrations of free carbon dioxide (nil-16.0 mg/l), nitrate nitrogen (traces-1.57 mg/l) and phosphate-phosphorus (traces-0.63 mg/l). These values show that the closed weed-choked beels were more productive but at the same time had poorer water quality. The open beels had better quality and less productive waters whereas the closed moderately weed infested beels had waters of moderate quality and moderate nutrient content.

Soil quality

Soils of floodplain wetlands differ considerably from those of surrounding catchment areas since they receive additional inputs in terms of organic matter, soil particles, plant nutrients, etc. every year especially during the rainy season. Decomposition of marginal and submerged macrophytes, growing profusely in most of the closed and shallow beels, upon submersion by flood waters, also plays an important role in their nutrient dynamics. Consequently, the soil quality of the beels changes from year to year leading to nutrient enrichment over the years mainly because of the large volume of allochthonous and autochthonous sediments deposited at the bottom. Since the bottom is built up every year due to siltation, nutrients present in settled sediments gets locked permanently. Thus, soils of beels should be analyzed every year to determine its quality in that year.

Soil quality of the selected beels of West Bengal is presented in Table 5. The soil had near neutral pH (6.7-7.83), which is in the ideal range for supporting good fish production (both for regulating life process and nutrient availability). They had sandy loamy soils except Bhandardaha beel, which has loamy soil containing all three soil

Table 5. Soil quality of some West Bengal beels

Parameters	Bhomra	Talbona	Sarasanka	Dekole	Khorar-doba	Baloon
PH	7.52-7.68 (7.6)	7.83	4.1-7.35	5.9	5.9	6.28-7.00
Soil composition Sand (%)	86.90 (87.5)	78	75.55-84.0	93	74	74-77.34
Silt (%)	3.5	11	3-6	3	14	7.4-7.53
Clay (%)	6-8	11	12-20	4	12	15.13-19.00
Sp. Cond. (mhos)	530-7	42	220-370	986	374	1100
Organic carbon (%)	3.92-7.85	2.43	2.58-4.44	0.31	0.24	0.10-1.46
Total N (%)	0.09-0.63	0.20	0.110-0.12	-	-	-
Available P (mg/100 g)	86.56-78.96	47.6	28.37-63.86	-	-	-
Available P (mg/100 g)	T-1.20	T	T-0.50	3.18	0.53	1.21
C/N Ratio	11.75-18.60 (14.44)	9.7-12.8 (11.65)	11.9-12.8 (12.35)	-	-	-
Parameters	**Palda**	**Gorai-chara**	**Kole**	**Haripur**	**Ghurna-mani**	**Bhan-dardaha**
PH	6.93	5.9	7.54-8.56	7.5-7.9	7.4-7.8	6.7-7.3
Soil composition Sand (%)	74	64	62.77	62.93	64.77	39-79
Silt (%)	12	18	6-13	3-26	13-18	12-37
Clay (%)	14	18	6.5-25	4-26	11-18	9-24
Sp. Cond. (mhos)	2417	162	240-444	220-960	460-127	1624
Organic carbon (%)	0.31	0.10	0.09-0.55	0.26-1.94	0.54-0.85	1.27-2.31
Total N (%)	-	-	0.40-0.5	0.3-0.16	-	-
Available P (mg/100 g)	-	-	11.20-20.72	3.09-46.48	3.53-14.0	-
Available P (mg/100 g)	4.07	6.00	T-2.83	T-10.08	0.32-0.45	5.90
C/N Ratio	-	-	8.00-11.67 (10.12)	8.13-13.83 (10.81)	-	-

particles in nearly equal proportion. Though sandy -loam soil helps in gaseous exchange and nutrient movement through the soil phase to the solution phase, loamy soils are more suitable since they are less porous and more productive ones.

Sediments of the beels were quite rich in plant nutrients as reflected by high values of specific conductivity (162-2455 µmhos /cm),organic carbon (0.10-7.85 %), total nitrogen (0.04 -0.63%),available nitrogen (2.35-83.44 mg/100g) and available phosphorus (Traces -10.08 mg/100g). Similarly the average C:N ratio (10.12-14.44) were within most productive range. Thus the nutrient parameters indicate that the beel investigated are productive ones.

Soil quality varied widely between beels, and between seasons and segments within the same beels. Generally, higher organic carbon contents (0.10-7.85%) were recorded in the closed and weed choked beels indicating high organic production in the water bodies. Closed but moderately weed infested beels had comparatively lower organic carbon contents (0.12-5.99 %), while open (moderately weed infested) beels recorded still lower values (0.10-2.31%). Closed beels had comparatively higher total nitrogen (0.09-0.63 %)and available nitrogen (2.35-84.44 mg/100g) compared to open ones(0.04-0.16% and 3.09-46.48 mg/100g respectively) supporting the hypothesis that closed beels are more productive but susceptible to eutrophication. This view is also corroborated by comparatively higher average C:N ratio (9.7-20.3) recorded in closed beel than those of open ones (8.00-13.83). A case in point is that of Haripur and Talbona beels near Ratua in Maldah district, which separated out of the same river, meander due to construction of two earthen embankments around 1975-76. Construction of the dykes have converted Talbona beel into a closed one which is now shallower than Haripur (open) beel and is weed choked. After nearly two decades of separation, Talbona beel has significantly higher organic carbon (2.43%), total nitrogen (0.195)) and C:N ratio (11.65%) compared to Haripur (0.26- 1.94%, 0.03- 0.16% and 10.81 respectively).

In contrast to other nutrient parameters, available phosphorus values were lowest in closed and weed choked beels (traces-3.18 mg/100 g), higher in closed but moderately weed infested beels (traces-7.6 mg/100 g) and highest in open (moderately weed infested) ones (traces-10.08 mg/100 g). Phosphorus being the limiting nutrient for plant growth, aquatic macrophytes specially rooted ones might have used up most of the available phosphorus in weed choked beels resulting in such reverse trends.

Among the beels, Bhomra recorded the highest values of organic carbon (3.72-7.85%), total nitrogen (0.09-0.63%) and C:N ratio (14.44). It also had very high available nitrogen (56.56-78.96 mg/100 g) content. This strengthens the assumption that this closed and weed choked beel is in transient phase of swampification.

Biotic communities

Since the floodplain wetlands are highly productive ecosystems and present diverse ecological conditions ranging from lotic to lentic water bodies and from deep lakes having summer thermoclines (e.g., Bhandardaha and Haripur beels) to shallow swamps (*e.g.,* Sarasanka dighi), they support a rich variety of biotic communities like plankton, macrophytes, benthos, insects and other weed associated fauna, periphyton, etc. The relative abundance and dominance of these groups vary from beel to beel depending on their hydrodynamics and morpho-ecological conditions. They also vary from season to season within the same beel. However, one characteristic biological feature common to all West Bengal beels is the moderate to heavy infestation of aquatic weeds.

Plankton

The term plankton includes generally microscopic aquatic flora (phytoplankton) and fauna (zooplankton) having limited power of locomotion and drifted by water currents. Phytoplankters are primary producers which form the base of the autotrophic food chain. Zooplankters convert plant and organic matter into animal matter and form an important link in both the autotrophic and heterotrophic food chains. Thus, plankton sustains planktophagous and predatory fish populations in beel ecosystem either directly or indirectly.

Generally, population of phyto and zooplankton in the floodplain wetlands is low during the southwest monsoon season and increases thereafter when the environment becomes stable and the plankton population establishes utilizing inorganic nutrients and organic matter brought in by the incoming flood or run-off waters. Thus, the plankton population recorded during winter (25 to 4658 u/l) were manyfold higher than those enumerated during summer months (281 to 40.836 u/l). The only exception to this trend was observed in Kol and Gurnamani beels due to their unstable environment even during nonmonsoon months since both of these are open beels.

It is evident that among the three types of beels, the average numerical abundance of plankton was lower in weed-choked ones compared to that of moderately weed infested (both closed and open type) beels. However, low plankton biomass was recorded in Kol beel (moderately weed infested) which may be attributed to its continuity with the Hooghly river and associated high turbidity coupled with prevailing tidal currents.

Quality composition of plankton varied in beels. The group *Chlorophyceae* dominated the plankton population in most weed choked (closed) beels whereas *Bacillariophyceae* dominated in Bhomra (weed choked, closed) beel. It is possible that dominance of these two groups in these beels is facilitated by the rapid removal of plant nutrients by macrophytes from soil and water. This view is strengthened by the moderately high species diversity indices (1.5173-3.1660) worked out in these beels. In contrast, most moderately weed infested beels (both closed and open types) showed the dominance of *Cyanophyceae* and had widely ranging SDI values (0.8456-3.6202) indicating that due to lower rate of absorption by the macrophytes, higher nutrient concentrations are available to the phytoplankton which favours blooming of a blue-green algal species like *Anabaena* sp., *Microcystis aeruginosa*, etc. especially during the winter/summer months. Zooplankton dominated the plankton population in Sarasanka dighi (weed choked), and Goraichara (open) which points to the dominance of detritus food chain in these two beels.

The various phytoplankton species from different beels of West Bengal has been listed in Table 6. The species dominated in the South Bengal beels are *Chaetophora spp., Oscillatoria spp.* and *Mougeotia spp.* However, in case of North Bengal beels they were *Microcystis spp., Spirulina*, *Spirogyra* and *Ankistrodesmus spp.*

Seventyfour species of phytoplankton have been recorded in West Bengal beels (Table 6), which include twentythree diatoms, twenty green algae, seven blue green algae and four others. *Synedra ulna* and *Melosira granulosa* (diatoms) constituted the bulk of the winter peak plankton population while the blue-green algae species *Microcystis aeruginosa* dominated the summer peak population in Bhandardaha beel. *Microspora, Eudorina*, *Volvox* and *Pleodorina* were commonly observed green algae whereas the groups *Eugleninae* and dinoflagellates were represented by *Phacus* and *Ceratium* respectively.

Table 6. Phytoplankton species recorded in West Bengal *beels*

Group	Taxa
MYXOPHYCEAE (Blue green algae):	*Anabaena* sp., *Chlorococcus* spp., *Gomphosphaeria* spp., *Lyngbya* spp., *Microcystis aeruginosa, Nostoc* spp., *Oscillatoria* spp., *Phormidium* spp., *Spirulina* spp.
CHLOROPHYCEAE (Green algae):	*Actinastrum* spp., *Ankistrodesmus* spp., *Botryococcus* spp., *Chlamydomonas* spp., *Chlorella* spp., *Closterium spp., Coelastrum* spp., *Cosmarium* spp., *Eudorina spp., Gloeotaenium* spp., *Microspora* spp., *Oedogonium spp., Pandorina* spp., *Pediastrum* spp., *Planktospaeria* spp., *Pleodorina spp., Protococcus* spp., *Sirogonium spp., Spirogyra* spp., *Tribonema* spp., *Ulothrix* spp., *Volvox* spp., *Zygnema* spp., *Zygnemospis* spp.
BACILLARIOPHYCEAE (Diatoms) :	*Amphora* spp., *Amphipleura* spp., *Anomoeoneis* spp., *Cocconeis* spp., *Coscinodiscus* spp., *Cyclotella* spp., *Cylindrotheca sp., Cymbella* spp., *Diatoma* spp., *Diatomella* spp., *Denticula* spp., *Fragilaria* spp., *Gyrosigma* spp., *Melosira* spp., *Navicula* spp., *Nitzchia* spp., *Pinnularia* spp., *Rhizosolenia* spp., *Skeletonema* spp., *Stephanodiscus* spp., *Surirella* spp., *Synedra* spp.
CHARAPHYCEAE	*Chara spp.*
CHRYSOPHYCEAE	*Dinobryon* spp.
DINOPHYCEAE (Dinoflagellates)	*Ceratium* spp.
EUGLENINAE	*Phacus* spp.
MASTIGOPHORA	*Gonium* spp.

In general, availability of phytoplankters in the West Bengal beels ranged from 396-14987 u/lit (mean value: 1188-11,203 u/lit). The diversity index (H) varied between 2.209 to 4.069 (Table 7). *Brachionus, Keratella* and *Moina* dominated in South Bengal beels, whereas nauplius, *Diaptomus* and *Cyclops* in the North Bengal beels. Seven species of zooplankters, which were found in the South Bengal beels were absent in the North Bengal beels. Similarly, nine species of zooplankters were found only in the North Bengal beels. Zooplankton counts of beels were in the range of 104- 2,317 u/l.

Altogether 27 species of zootoplankton have been recorded in West Bengal beels (Table 8), which include two protozoans, sixteen rotifers, three copepods, five cladocerans, and one ostracod. Among rotifers, *Brachionus* spp., *Trichocerca, Keratella* and *Filinia* were commonly observed. Diversity indices in respect of zooplankters in different beels of South and North Bengal have shown many variations, especially in species richness index (Table 9).

Table 7. Species diversity indices in respect of phytoplankton

Beel	Number of species	Varity index (d)	Concen-tration of dominance (C)	Shanon Weaner Index (H)	Evennesss index (J)
Bhomra	29	26.852	0.142	3.288	7.472
Bansdaha	38	32.873	0.126	3.351	7.051
Kole	27	25.210	0.134	3.547	8.234
Kola	22	21.511	0.160	3.009	7.448
Bhaluka	28	28.020	0.670	4.062	9.327
Patari	12	12.324	0.194	4.069	12.527
Nehali	33	28.926	0.453	2.209	4.834
Moranadi	22	17.229	0.177	2.867	7.121

Table 8. Zooplankton species recorded in West Bengal beels

Groups	Taxa
PROTOZOA	*Condonella, Euplotes*
ROTIFERA	*Asplanchna, Brachionus, B. angularis, B. forficula, B. havenaensis, B. plicatillis,* *Chromogaster, C. ovalis, Conochilus, Euchlanis, Filinia, Keratella, Polyarthra, Synchaeta, Testudinella, Triochocerca*
COPEPODA	*Cyclops, Diaptomus,* Nauplius
CLADOCERA	*Bosmina, Ceriodaphnia, Daphnia galeata, D. longiuris, Moina*
OSTRACODA	Cypris

Table 9. Species diversity indices in respect of zooplankton

Beel	Number of species	Variety index (d)	Concentration of dominance (C)	Shannon Weaver Index (H)	Evennesss index (J)
Bhomra	10	11.530	0.181	2.670	8.872
Bansdaha	11	10.881	0.259	2.368	7.556
Kole	10	9.082	0.199	2.591	8.607
Kola	11	11.349	0.149	2.893	9.233
Bhaluka	5	5.441	0.304	1.923	9.154
Patari	6	6.754	0.224	2.295	9.799
Nehali	13	13.943	0.149	2.644	7.891
Moranadi	13	14.952	0.184	2.773	8.276

Macrophytes

All the beels in West Bengal under study were infested by aquatic macrophytes with varying extent of infestation. All the open beels (*e.g.* Palda, Kol, etc.) were only moderately weed infested (average < 50% of water area covered by macrophytes). A majority (8 out of 30) of the closed beels were weed choked (rate of infestation > 50% of water area) while rest were moderately weed infested. Most of the closed beels facilitate dense growth of aquatic macrophytes since they provide a more stable environment besides acting as a sink for inorganic and organic plant nutrient from the catchment areas.

The aquatic macrophytes have profound influence on the ecology and fisheries of the floodplain wetlands. As already discussed, water of weed choked beels tend to have lower pH, turbidity and nutrient concentrations as well as high diurnal variation of dissolved oxygen and carbon dioxide . The macrophytes compete for plant nutrients and space with phytoplankton. As a result, low phytoplankton biomass is observed on weed infested beels. In general, macrophytes are not consumed by fishes with the exception of grass carp which feeds on a few soft submerged plants like *Hydrilla*, *Ceratophyllum*, *etc*. Thus, most of the solar energy fixed by the macrophytes are converted to fish flesh only through the weed-detritus food chain. However, the macrophytes harbour aquatic insects and molluscs which form food for some fishes.

Aquatic plants contribute considerably to the bottom detritus, thereby encouraging fast colonisation of benthic organisms. Heavy weed infestation has many harmful effects on the fisheries of the beels since it renders the operation of fishing gear difficult. It also leads to the predominance of air breathing and carnivorous fishes instead of planktivorous ones thereby reducing the efficiency of conversion of solar energy into fish biomass. Because of their harmful effects, the macrophytes are also termed as aquatic weeds, especially when they grow in excessive quantities. However, the growth of certain amount of aquatic macrophytes along the margins can be considered desirable as it can reduce the wave action on the banks and prevent occurrence of algal bloom. Opinions differ as to how much macrophytes can be allowed to grow in a beel. Studies in West Bengal showed that when the weeds cover more than half of the total water area, the ecology and fisheries of the beels are adversely affected. Though a number of physical and chemical methods of weed control are available, these are either uneconomical, or harmful to the fishes or are ineffective in a large water body. Grass carp is an effective biological agent for controlling many soft macrophytes. But stocking of this exotic fish in beels is not permitted as it can escape into the natural open waters during floods.

The biomass of macrophytes varied from 18.44 g/m^2 (dry wt.) in Bhandardaha to 726.67 g/m^2 in Bhomra beel. There is a marked seasonal variation in the growth of macrophytes. Generally the beels have lower macrophyte infestation during the South West monsoon season. Their biomass gradually increases after monsoon when the water body becomes stable and reaches very high level during winter and summer months.

A rich variety of macrophytes grow in the beels of West Bengal (Table 10) since they present a wide variety of favourable environments. Submerged plants are found to grow profusely, even up to a depth of about 5 m. Eleven species of submerged plants have been recorded in West Bengal beels; of these *Hydrilla verticillata, Ceratophyllum demersum, Vallisneria spiralis, Ottelia alismoides* and *Najas* sp. were dominant species in most (twelve) beels. The free-floating weed, *Eichhornia crassipes* dominated macrophyte biomass in four beels. In all, nine free-floating and ten rooted floating macrophytes were recorded from West Bengal beels. Thirteen erect and seven prostrate floating emergent macphytes were found to grow in the beels. The emergent types dominated macrophyte population in two beels.

Table 10. Common macrophytes of West Bengal beels

Type	Species
SUBMERGED	*Hydrilla verticillata, Vallisneria spiralis, Ceratophyllum demersum, Najas indica, N. minor, Ottelia alismoides, Potamogeton crispus, Blyxa oclandra, Nechamandra alternifolia.*
FLOATING	
Free floating	*Eichhornia crassipes, Trapa spinosa, Lemna perpusilla, Pistia stratiotis, Spirodela polyrrhiza, Azolla pinnata, Utricularia stellaris, U. aurea.*
Rooted	*Nymphaea nouchali, N. pubscens, Nelumbo nucifera, Nymphoides cristatum, N. indicum, Myriophyllum tetrandrum, M. tuberculatum, Limnophila indica, Potamogeton nodosus, Aponogeton natans.*
EMERGENT	
Erect	*Cyperus procerus, C. exalatus, Eleolcharis dulcis, Monochoria hastata, Scirpus squamosus, S. articulatus, Typha angustata, Polygonum barbatum, Aeschynomene indica, A. aspera.*
Prostrate	*Ludwigia adscendens, Alternanthera sessilis, A. philoxeroides, Ipomoea aquatica, Commelina longifolia, Pasopalum paspaloides*

Weed associated fauna

The aquatic macrophytes promote growth of a number of macro-invertebrate fauna by providing them food and shelter. The abundance of this weed associated fauna ranged from as low as 53 numbers/m^2 in (Kol beel) to as high as 2832 numbers/m^2 (Akaipur baor). Insects and molluscs formed the bulk of this community followed by gastropods and annelids. The molluscs comprised mainly gastropods followed by bivalves. The groups gastropods and insects dominated the population of weed associated fauna in six beels each. The Shannon-Weaver species diversity index (H) in respect of weed-associated fauna ranged from 0.824 (Khorardoba beel) to 1.325 in the six insect dominated beels and from 1.018 to 4.993 (Bhandardaha beel) in gastropod dominated ones.

Table 11. Common weed associated fauna of West Bengal beels

Group	Taxa
MOLLUSCS	
Gastropods	*Gyraulus convexiusculus, Gabia orcula, Bellamya bengalensis, B, folioris, Indoplanorbis exustus, Lymnaea acuminata, Thiara tuberculata, Pila globosa.*
Bivalves	*Lammellidens marginalis, Parreysia corrugata, Piscidium* sp., *Corbicula* sp.
INSECTS	*Diplonychus allulatum, Ranatra filiformes, Laceotrephes ruper, Lethocerus indicus, Gerris nitida, G. spinolae, Mircronectaproba, M. merope, Plea sp., Anisops sp., Canthydrus morschbachi, C. laetadilis, Hydrocoptus subvittulus, Hydrobatlus confertus, H. bonvoulor, Regimbertia attenuata, Perosus indicus, Helocharis sp., Pachydiplax rambur, Chironomus sp., Stratiomys sp., Ceratopogon sp., Tabanus sp., Caenis sp.,Beatis sp., Nymphula sp.*
ANNELIDS	
Oligochaetes	*Branchiura sowerbyi, Aelosoma sp., Dero sp., Chaetogaster cristallinus.*
Leeches	*Placobdella sp., Helobdella sp., Hirudo sp.*

The gastropod species commonly associated with macrophytes were *Gyraulus convexisculatus, Gabia orcula, Bellamya bengalensis, B. variatus, Indoplanorbis exustus, Lymnaea acuminata, Thiara tuberculata, Pila globosa, etc.* Among the bivalves, *Lamellidens marginalis, Parreysia corrugata* and *Piscidium sp.* were commonly encountered (Table 11). The aquatic insects belong to the groups Hemiptera, Coleoptera, Odonata, Diptera, Ephemeroptera, Lepidoptera and Trichoptera were recorded. Common insect species observed were *Diplonychus allulatun, Ranatra filiformes, Laceotrephes ruper, Lethocerus indicus, Gerris nitida* and *G. spinolae*. The annelids were less in number, mostly represented by oligochaetes (*Branchiura sowerbyi, Aelosoma* sp., *Dero* sp.) and a few parasitic annelids mainly leeches (*Placobdella* sp., *Helobdella* sp.) Epheroptera, Odonata and Zygoptera were common to all the beels studied.

Benthos

The benthic communities include animals and plants either crawling on, burrowing into or attached to the bottom or a stratum, of these, the assemblage organisms attached to the submerged substrates are termed as periphyton. Thus, the benthos comprise both primary producer (represented by phytobenthos) and consumers of different levels. The benthic community occupies a preeminent position in the floodplain wetland ecosystem, where the energy transformation takes place through the detritus food chain in a majority of instances.

In the weed-choked beels, the organic carbon is synthesized primarily by the aquatic macrophytes. In the absence of substantial fish population to consume them, the plants die and decay, contributing to bottom detritus. The constant accumulation of decaying weeds make the bottom soil of the beels rich in organic matter which, promote a dense growth of detritivorous bottom fauna. Thus, detritivorous, insectivorous and macrophygous fishes are commonly found in the beel ecosystem, especially in the weed choked ones.

Study of benthic communities in beels helps in assessing the quantum of energy transferred through this phase and it also indicates the trophic status of the beel. The West Bengal beels under investigation supported rich growth of benthos, the average density ranging from 90 to 13,238 nos/m^2. The lowest numerical abundance was recorded in Kol beel which presented a near riverine condition whereas the maximum density was observed in Ghurnamani, which is a shallow open beel. Contrary to the general expectation, the weed choked beels did not support the rich density of benthos. The factors determining the colonizing preference of macroinvertibrates are poorly understood and vary from species to species. For example, higher concentration of calcium in water is essential for synthesis of the calcareous shells of molluscs. The interplay of various edaphic and hydrological factors are probably responsible for the growth and abundance of the benthic communities. The choice oviposition sites by the adults and availability of food may also be responsible for their population growth. In weed choked beels, the bottom soil is often blackened by a thick mat of decayed macrovegetation which stinks and create anaerobic conditions and thereby restricts the growth of bottom fauna.

The benthic community of beels is generally dominated by molluscs, insects and annelids. Molluscs dominate the macrobenthic population often accounting for 60-90% of their total biomass. The highest density of the molluscan population is found in the inshore region. The benthic molluscan species most commonly observed in West Bengal beels were *Bellamya bengalensis* and *B. variatus*, followed by *Lymnaea acuminata*, *Indoplanorbis exustus*, *Digoniostoma cerameopoma*, *Brotia costula* and *Gyraulus convexiculus*. *Lamellidens marginalis, Parreysia corrugata* and *Piscidium* sp. were the common bivalves observed.

The insects represented by their nymphs, larvae and adult population formed the next important constituent of benthic fauna. The nymphs and larvae of most of these insects feed on bottom debris, plankton and other microorganisms while they themselves form food for carnivorous fishes. Some of the insects like chironomids are found more in the offshore region whereas others are predominant in the inshore region. A large number of insect species belonging to *Hemiptera, Coleoptera, Odonata, Diptera, Ephemeroptera, Lepidoptera* and *Trichoptera* were recorded in West Bengal beels. The annelids mainly belonging to oligochaetes were usually associated with the roots of submerged weed and bottom debris in the offshore region.

The list of common benthic organisms recorded from West Bengal beels is given below :

Gyraulus convexiusculus, Gabia orcula, Indoplanorbis exustus, Lymnaea acuminata, L.luteola, L.ovalis, Thiara tuberculata, Amnicola spp., *Segmentina calathus, Bellamya bengalensis, Camptoceras terebra, Digoniostoma cerameopoma, Pila globosa, Corbicula bensonii, Pleurocera* sp., polychaetes, oligochaetes, nematods, *Helobdella* (leach), chironomids, culicoids, mosquito larvae, crabs, prawns.

FISHERY MANAGEMENT

Fish yield potential

Yield potential of the 18 beels, representing various categories, has been estimated from all over West Bengal on the basis of energy fixation by plankton and macrophytes. Primary productivity of phytoplankton (dark and white bottle method) and macrophyte biomass were estimated and 1% of the total energy fixed by the producers has been considered as the fish production potential. In general, production potential of the North Bengal beels was lesser than those of South Bengal. Open beels with fluviatile conditions also found to be less productive. Among the closed weed choked beels, Bhomra, Bansdaha, Mogra and Ghurnamani indicated production potential in the range of 84.4 to 264.6 kg/ha/yr, while it ranged from 109 to 112.5 kg/ha/yr in Baloon and Dekole beels. Under the same category, Nehali beel in the North Bengal indicated lower yield potential. Beels under closed moderately weed choked category Beror baor, Haripur and Akaipur showed production potential to the tune of 43.8 to 256 kg/ha/yr. Garapota, Sarasanka, Moranadi and Bhaluka revealed low potentials. Under closed weed-free category of beels, fish yield potential of Kola beel was within 270-320 kg/ha/yr. While Patari in North Bengal had lower values (Table 12).

Interestingly, 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. This is a very revealing finding of this study. Compared to other ecosystems such as reservoirs, beels are highly rich system where huge amount of energy is loaded at detritus stage while rate of carbon production by plants indicates the current production of carbon. In beels, the huge reserve of energy at the bottom is contributing more significantly to the fish productivity than the turnover of living plants. Thus, a new dimension is added to the energy dynamics of beel ecosystem. Thus, the conventional method of calculating fish yield potential from the rate of primary productivity is not applicable to the beels. In these unique water bodies, the total budget of detritus including accumulated detrital carbon at the bottom and the rate to detrital loading from macrophytes need to be considered. Age of the beel is also an important factor in accumulation of energy at the bottom. This finding suggests the need for more studies on the detrital dynamics in beel ecosystem.

Fish and Fisheries

A rich variety of fishes has been recorded from the floodplain wetland ecosystem. Majority of the fishes are resident fauna of the system. Few fishes recorded from the beels are found to undertake local migration between beels and adjacent river. A clear distinction is discernible in case of fish fauna of open and closed types of beels. The open type of beels are found to harbour many riverine species in addition to fishes resident of such ecosystem. The closed type of beels has its own distinctive fauna. However, many of the riverine forms have gained entry into closed beels either through introduction or due to flooding. Seasonal fishery of a few species in closed beels is the testimony of migration of their brooders (for breeding) or migration of young ones for shelter or grazing. Commonly encountered exotic carps in beels are silver carp (*Hypophthalmichthys molitrix*) and common carp (*Cyprinus carpio*).The grass carp (*Ctenopharyngodon idella*) is not commonly encouraged to be stocked in beels as it can enter the adjacent agricultural fields during monsoon and cause damage to the tender paddy.

Since most of the closed beels are now under management, there has been a drastic shift of fish fauna. Management intervention, particularly stocking, has brought in new fauna, and macrophyte removal has caused many fauna to perish or become scarce. Encroachment of beel area for agricultural purposes or conversion of beel marginals into paddy fields have destroyed the breeding ground of many resident fauna leading to failure of their recruitment. Barricading the connecting channel have prevented the to and fro movement of migratory fish resulting in their absence or drastic reduction in the faunal diversity. Barring a few, faunal composition of such beels are now dominated by major carps. In some of the beels, minor carp, *Labeo bata* occupies a prominent position in the catch. *Gudusia chapra*, a member of clupeidae sporadically dominates the catch of some closed but seasonally open beels.

Fish yield from closed beels, in comparison to open ones, has improved notably with the adoption of various management practices. The main management norms followed by the cooperative societies are stocking, liming, and clearance of macrophytes and enforcement of fishing season and mesh size regulation. Fish production from such beels ranged from as low as 300 kg/ha/yr to 1,100 kg/ha/yr. Closed beels which follow stringent management practices like stocking at regular intervals, maintaining the appropriate size of stocking material, frequent liming, strict fishing schedule, fish size regulation at capture, vigilance against poaching, flood control measures and rational fishing practices have enabled the system to become at par with some pond production system. Kola beel with a phenomenal yield of 3,262 kg/ha/yr and Akaipur beel with a yield of 1,922 kg/ha/yr are the examples.

The list of fish encountered in closed beels is given below (not exhaustive):

Family : Cyprinidae

Catla catla
Labeo rohita
Labeo bata
Labeo calbasu
Labeo gonius
Labeo fimbriatus
Cirrhinus mrigala
H. molitrix (exotic)
Cyprinus carpio (exotic)
Ctenopharyngodon mola (exotic)
Puntius javanicus (exotic)
P. sarana
P. ticto
P. sophore
Amblypharyngodon mola
Oxygaster bacaila
Esomus danricus
Garra gotyla
Rasbora daniconius

Family : Aplocheilidae
Aplocheilus panchax

Family : Ophiocephalidae

Channa marulius
C. striatus
C. punctatus
C. gachua

Family : Nandidae
Nandus nandus
Badis badis

Family : Clupeidae
Gudusia chapra

Family : Ambassidae
Chanda ranga
C. nama

Family : Mastacembelidae
Mastacembelus armatus
M. puncalus

Family : Gobiidae
Glossogobius giuris

Family : Siluridae
Wallago attu

Family : Bagridae
Mystus tengra

Family : Clariidae
Clarias batrachus

Family : Saccobranchidae
Heteropneustes fossilis

Family : Anabantidae
Anabas testudineus
Colisa fasciata

Family : Cobitidae
Lepidocephalus guntea
Botia dario

Family : Belonidae
Xenentodon cancila

Family : Symbranchidae
Amphipnous cuchia

Fishing in open beels continues throughout the year with a peak during September-November and continue till February-March. Faunistic composition of open beels generally reflects faunal diversity of parent river. During monsoon, the breeding season of fishes, the catch dominated by young ones of various fishes. The practice of catching fry and fingerlings by using fine mesh net at the entry point is a matter of concern. Such practices lead to depletion or extinction of many varieties of fishes from the system. Reduction of yield have also been felt by the fishermen. In addition to the groups of fishes recorded from the closed beels, fishes commonly encountered in the open beels are the following varieties:

Family : Notopteridae
Notopterus chitala
N. notopterus

Family : Siluridae
Ompok bimaculatus
O. pabda

Family : Schilbeidae
Eutropiichthys vacha
Ailia colia
Silondia silondia
Pangasius pangasius

Family : Bagridae
Mystus seenghala
M. tengra
M. cavasius
M. aor

Family : Sisoridae
Bagarius bagarius

There is another category of seasonally opened beels which otherwise remain closed. In this type of beels, fishes enter along with flood water 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 fish stock is removed and the fishermen remain jobless for the rest of the year. The society can prolong fishing in such system by enforcing regulatory measures like fish size regulations, quota of harvest for each fishing groups, and so on. Stocking can also be done after the recession of flood water to grow fish till the onset of next flood (monsoon).

Fishing in a beel

A rich haul of freshwater prawn raised in pen

Stocking and yield pattern of some West Bengal beels

Many of the beels are under active management practices by Cooperative Societies following the norms of culture-based fishery. These beels are being regularly stocked with both major carps, minor carps and exotic carps species (Table 13).

Table 13 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
92-93	14270	172	41647	502	2.9
93-94	8107	98	31302	377	3.9
94-95	9535	115	39158	472	4.1
95-96	5819	70	25550	308	4.4
96-97	9677	117	56275	678	5.8
97-98	8936	108	77762	937	8.7
98-99	9643	116	53688	647	5.6
Akaipur beel (32 ha)					
92-93	1895	59	20600	644	10.9
93-94	4498	141	20277	634	4.5
94-95	3940	123	31800	994	8.1
95-96	2892	90	23452	733	8.1
96-97	6114	191	39796	1244	6.5
97-98	8108	253	38181	1193	4.7
98-99	4163	130	61290	1915	14.7
Kola beel (12 ha)					
91-92	1017	85	7952	663	7.8
92-93	1289	107	6717	560	5.2
93-94	1199	100	6409	534	5.3
94-95	1970	164	10906	909	5.53
95-96	1938	165	22569	1881	11.4
96-97	3101	300	36247	3021	10.0
97-98	-	258	-	2993	11.6

Table 13. contd……					
Gopalnagar beel (35 ha)					
1990-91	6722	192	30090	860	4.5
91-92	6940	198	8334*	238	1.2
92-93	5630	161	25170	719	4.7
93-94	6459	185	45029	1286	7.0
94-95	4710	135	32650	933	6.9
95-96	6939	198	31836	910	4.6
96-97	3869	110	74361	2125	19.2
97-98	5807	166	71777	2051	12.4
98-99	9091	260	60560	1730	6.7

* *abnormal value due to flood*

Stocking density, however, does not seem to have been arrived at on any rational basis. Funds available at the disposal of the managers and seed availability generally govern the stocking density. As a result, stocking rates are highly variable. In Bhomra beel stocking density varied between 97 and 171 kg of fry/ha, in Akaipur beel, the density varied between 59 and 253 kg/ha, in Kola beel the stocking rate was 84 and 356 kg/ha and in Gopalnagar it varied between 110 and 259 kg/ha. The fish yield rate from these beels indicated differential response. Yield varied between 307 and 937 kg/ha in Bhomra, 633 and 915 kg/ha in Akaipur, 534 and 3020 kg/ha in Kola and 719 and 2124 kg/h in Gopalnagar beel.

In a culture-based fishery, growth of fish is density dependent and mortality is size dependent. Thus, it is very important to generate advice on size at stocking and stocking density. Unfortunately, no beel is maintaining sufficient data on the size and number of fishes stocked species-wise. There is no clue on the survival rate of fishes as well. The quality and amount of data available at the beels in this regard are not sufficient to make any sound scientific findings on stocking-yield relationship. However, response of stocking density on yield rate has been studied by plotting the available data on yield against stocking density. Based on these observations, optimum stocking rate has been calculated. This can at best be taken as tentative as more studies on modeling are required to arrive at definite conclusions. The figure is specific to the respective beel, however, proximity appears to be existing amongst different values obtained from each beel (Fig. 2- 4).

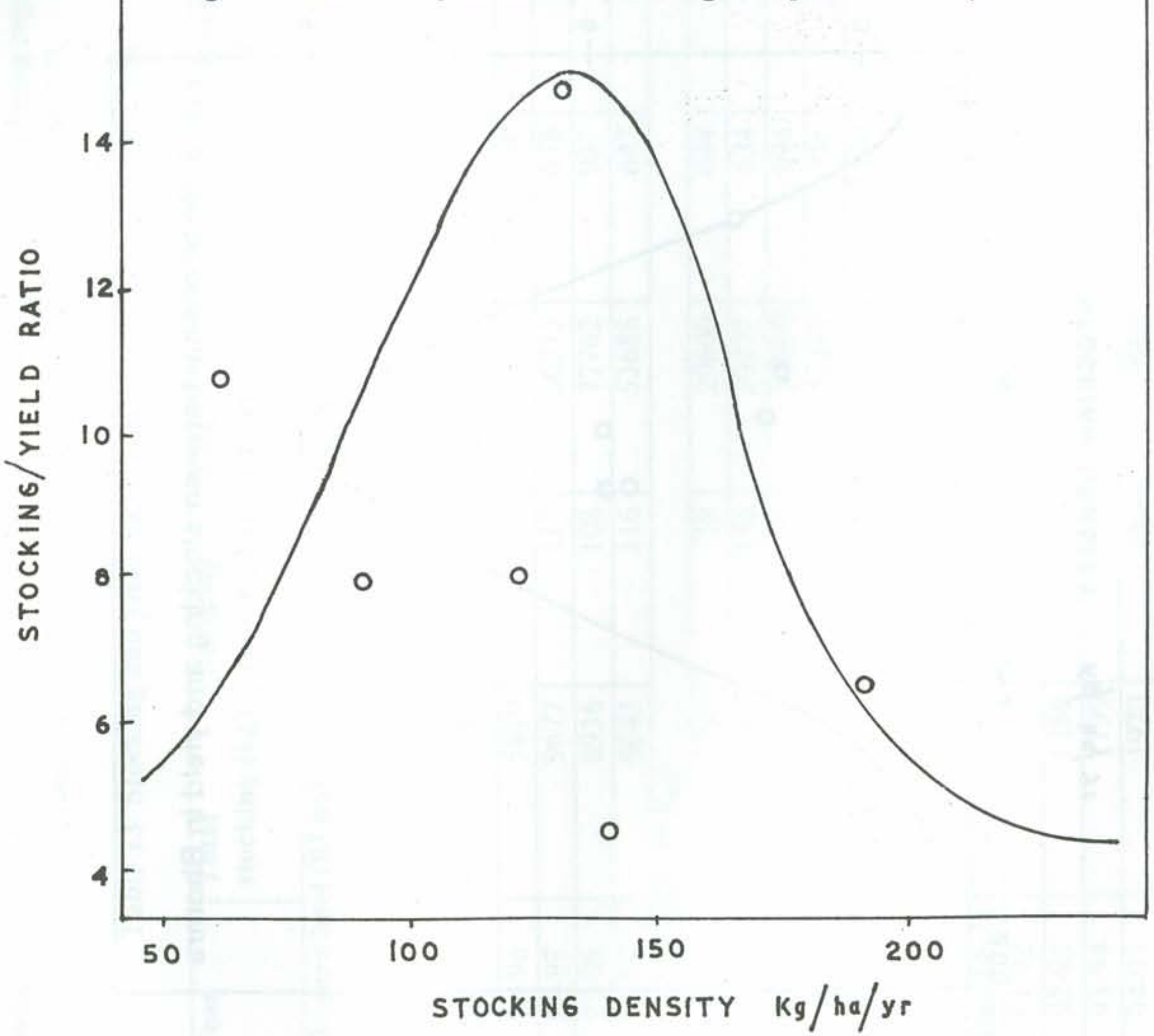
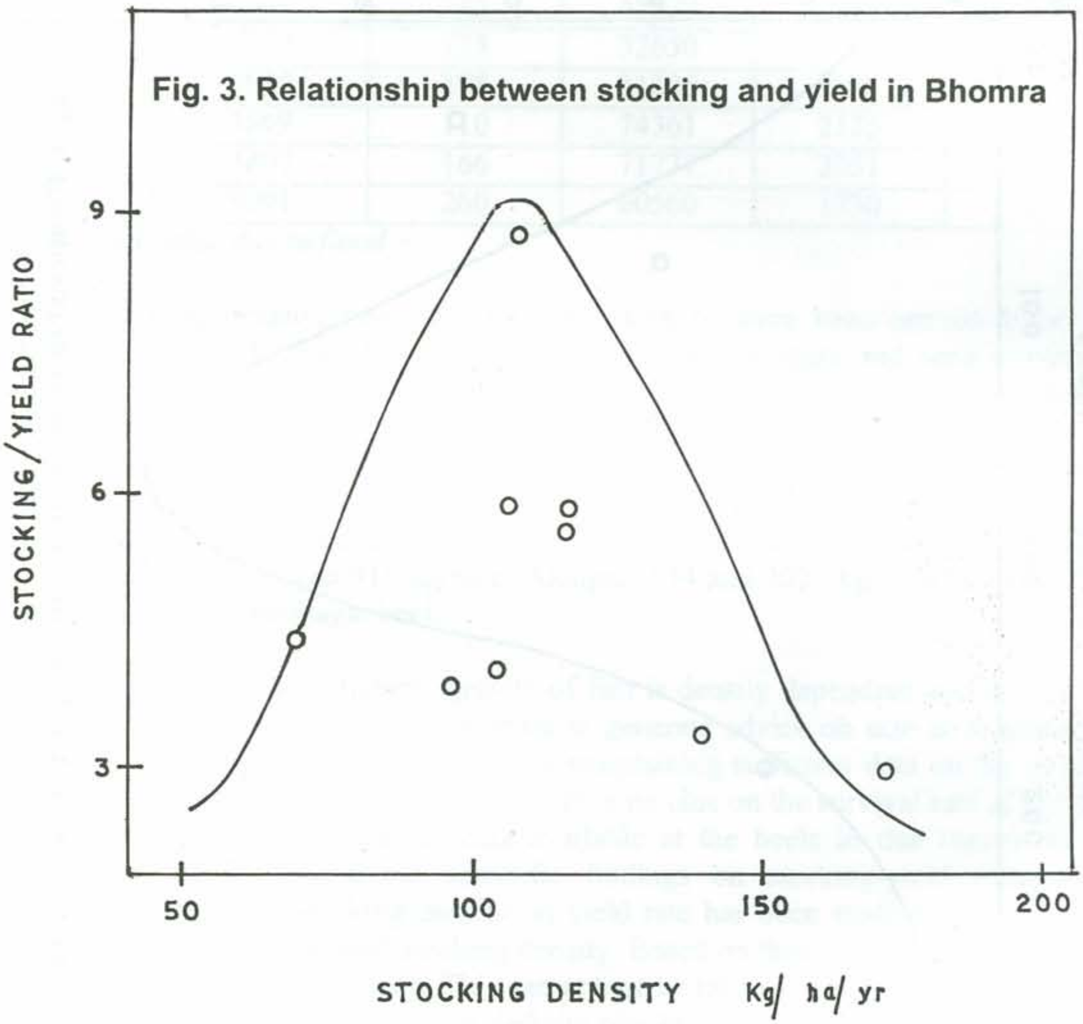


Fig. 2. Relationship between stocking and yield in Akaipur beel

Fig. 3. Relationship between stocking and yield in Bhomra



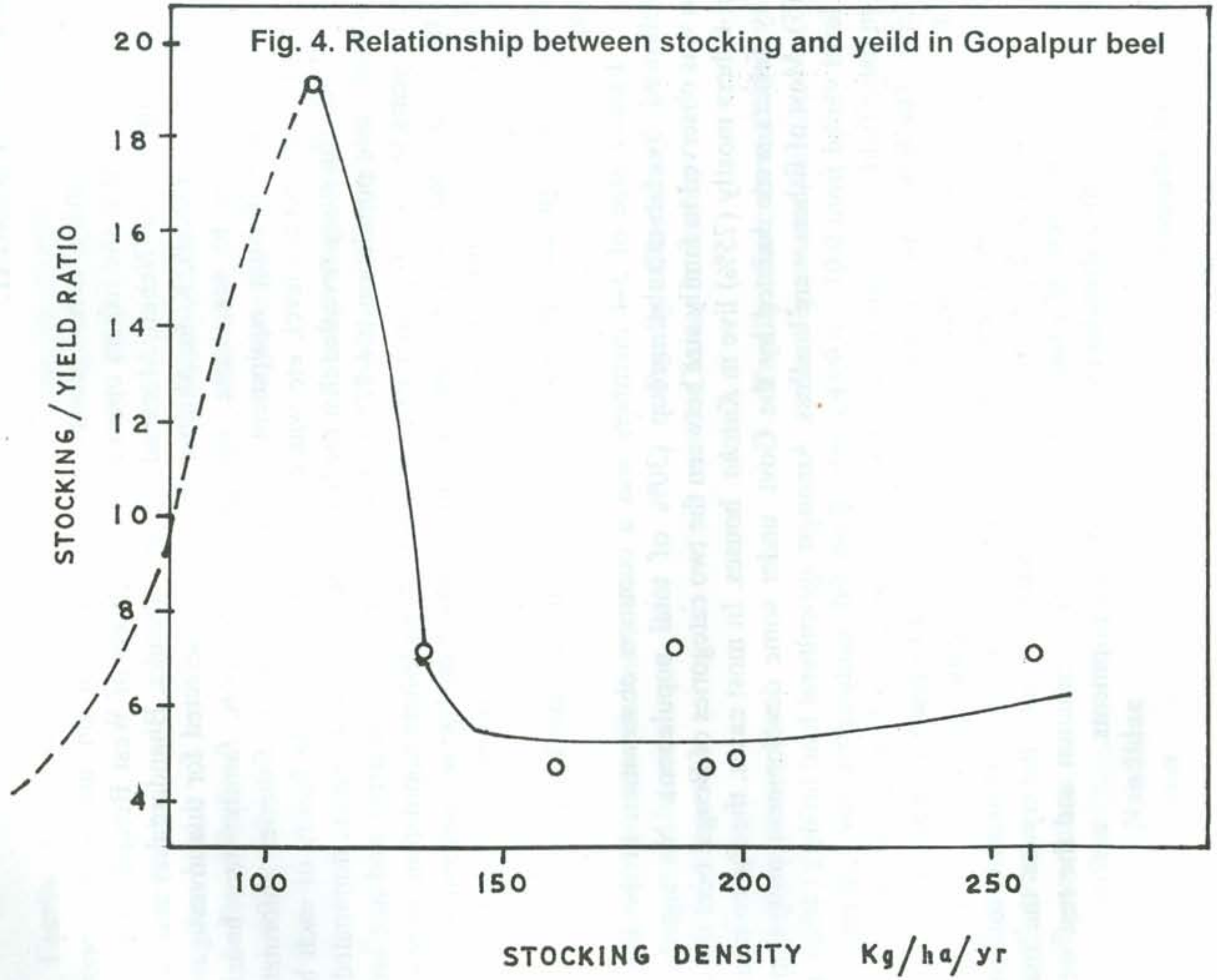


Fig. 4. Relationship between stocking and yeild in Gopalpur beel

SOCIO-ECONOMIC CONDITION OF THE FISHERS OF SOME SELECTED BEELS IN WEST BENGAL

Some preliminary investigations were carried out on the socio-economic conditions under which the fishers operate in some beels of West Bengal. Five beels each from North Bengal (Nehali, Moranadi, Patari, Bhaluka, Bhandardaha) and South Bengal (Bhomra, Bansdaha, Kole, Akaipur, Kola) were selected for this investigation. Information pertaining to sex, caste, age group, education, family size, housing, occupation, income, fishing equipment, marketing channel, fisheries information sources, fisher's awareness level, *etc* was collected from sample family of each beel during 1997-98. The study revealed that the beel fishers are mostly male, dominated by the scheduled caste population (94-97%) of which 94% were married and age group between 30 years to over 60 years formed the bulk of the fishers population. In overall most of the people were lacking basic education. However, literacy percentage (only upto primary level) was more (69%) in South Bengal as compared to North Bengal (41%). Among the literate, majority were having only primary education. Out of the total, 52% are trained in fisheries practices mostly from the State Fisheries Department (Table 14).

Family size of 3-4 members was a common observation in the Bengal beels, followed by 5-6-member group (30% of total population). No significant variation was observed in family size between the two categories of Bengal beel fishers. The beel fishers mostly (75%) live in *Kutcha* houses. In most cases, the *Pucca* houses owned by fishers were donated by the Govt. under some development programmes (Table 15). Most of fishers were landless. Amongst agricultural land holders (40%), the holding level varied from 0.01 – 0.99 ha only. Rain-fed paddy cultivation is a common practice in these fields, 2-3 crops are also taken in some areas where irrigation facilities are available. The Bengal beel fishers (72%) were found to rear live stock and poultry mainly for their own consumption and some extent to generate family income. The animal reared are cow, goat, sheep, hen, cock, ducks. No intensive method is followed in such rearing practices. Eighty per cent of population have fishery as the main occupation. Among the rest, 8% had trade as the main occupation and the rest were agriculturists. Most of the fishers had their own fishing equipments.

Fishing days and income

Annual working days of the fishers varied from 180 to 270 days *i.e.*, 6-9 months in a year. Majority of them fished for more than 9 months. During the lean fishing seasons the fishers engage themselves in agricultural practices, seasonal business, etc.

The largest single group accounting for 52% of total fishermen have annual income between Rs. 11000 to Rs. 20000, followed by the income group having Rs. 1000 to Rs. 10,000, Rs. 21,000 to Rs. 30,000 and Rs. 31,000 to Rs. 40,000. The annual income pattern of the fishers is presented in Table 16. The fishing equipment used for fishing in the surveyed beels are mainly indigenous small to medium size wooden boats and different types of gears. Gears such as drag net, gill net, cast net, dip net, scoop net are used in fishing operation. Fish traps, hooks and lines fishing are also used in some beels. Majority of the North Bengal fishers possessed fishing nets only, whereas 44% of South Bengal fishers have boats plus nets.

Table 14. Social and educational status of fishers in selected beels of West Bengal

	North Bengal		South Bengal		Total	
	No.	*%*	*No.*	*%*	*No.*	*%*
Sex						
Male	125	100	125	100	250	100
Female	-	-	-	-	-	-
Caste						
Gen	5	4	-	-	5	2
Sc	118	94	125	100	243	97
St	2	2	-	-	2	1
Religion						
Hindu	120	96	125	100	245	98
Muslim	5	4	-	-	5	2
M. status						
Married	118	94	112	90	230	92
Unmarried	7	6	13	10	20	8
Age group						
< 30	11	9	28	22	39	16
30 –60	98	78	83	66	181	72
>60	16	13	14	12	30	12
Education						
Illiterate	74	59	39	31	113	45
Primary	38	30	47	28	85	34
Secondary	2	2	8	6	10	4
Above	11	9	31	25	42	17
Training						
Fisheries	25	20	65	52	90	36
Others	1	1	-	-	-	-
Nil	99	79	60	48	35	64

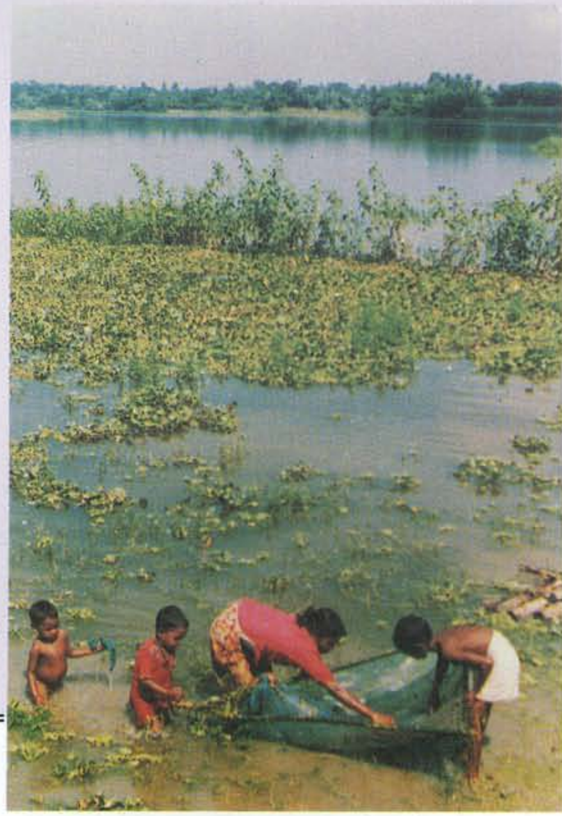
Table 15. Family size and housing

	North Bengal		South Bengal		Total	
	No.	*%*	*No.*	*%*	*No.*	*%*
Family size						
1-2	13	10	18	14	31	12
3-4	70	56	57	46	127	51
5-6	40	32	34	27	74	30
7-8	2	2	16	13	18	7
Housing						
Kuchha	108	86	79	63	187	75
Pucca	17	14	46	37	63	25
Membership to cooperatives						
Have	104	83	108	86	212	85
Hav'nt	21	17	17	14	38	15
Agricultural land holdings (ha)						
nil	77	61	71	82	148	59
0.01-0.99	47	38	53	42	100	40
1.00-2.00	1	1	1	1	2	1

Table 16. Annual income and possession of fishing equipment of beel fisher

	North Bengal		South Bengal		Total	
	No.	*%*	*No.*	*%*	*No.*	*%*
Annual working days						
Up to 180	1	1	1	1	2	1
181 – 270	8	6	11	9	19	8
271 - 365	116	93	113	90	129	91
Income per family (Rs x 1000)						
1-10	20	16	81	65	101	40
11-20	91	73	39	31	131	52
21-30	13	10	4	3	17	7
31-40	1	1	1	1	1	1
Fisher's contribution to family income						
<25	11	9	19	15	30	12
25 – 50	29	23	35	28	64	26
51 - 75	6	5	9	7	15	6
>100	79	63	62	50	141	56
Fishing equipment						
Boat only	-	-	1	1	1	-
Net only	90	72	28	22	118	47
Boat & Net	12	10	55	44	67	27
None	23	18	41	33	64	26
Fish culture practices						
Yes	14	11	8	6	22	9
No	111	89	117	94	228	91
Net income from fish culture practices (Rs x 1000 per year)						
0-5	-	-	6	42	6	21
5 - 10	9	64	-	-	9	32
11 - 15	4	28	6	42	10	36
15 - 20	1	8	1	8	2	7
>20	-	-	1	8	1	4

Women and children are often involved in fishing activities



Fish marketing channels

Five fish marketing channels were found in the beels. In all the beels surveyed, the marketing was done through co-operative societies only. The most desirable marketing channel of Fisher > Consumer accounted for most of the societies in North Bengal, whereas in the South, more protracted channels were common. The following channels were observed:

1. Fisher > Consumer
2. Fisher > Retailer > Consumer
3. Fisher > Cooperative > Consumer &
4. Fisher > Cooperative > Wholesaler > Retailer > Consumer

Awareness level

The survey revealed a dismal picture regarding awareness level of beel fishers towards beel fisheries conservation and management. About 59% to 65% of them were blissfully unaware of any need for conservation and scientific management. It was known to 21 to 23 % and well known to only 20 to 12 %. (Table 17).

Table 17. Fishers awareness level regarding beel fisheries conservation and management

	North Bengal		South Bengal		Total	
	Number	*%*	*Number*	*%*	*Number*	*%*
Ignorant	74	59	81	65	155	62
Known	26	21	29	23	55	22
Well known	25	20	15	12	40	16

GUIDELINES FOR ECOSYSTEM-ORIENTED FISHERY MANAGEMENT OF BEELS

Criteria for ecosystem-oriented management

Biological productivity of a water body depends primarily on the capacity of the system to trap solar energy and store them in the form of chemical energy. The energy conversion efficiency at trophic levels of consumers differs considerably from one water body to another, depending on the qualitative and quantitative variations in the biotic communities. Any conversion rate above 1% can be considered as good. However, recent studies conducted in West Bengal has proved beyond doubt that beels can yield much more due to accumulated carbon at the bottom. In an ideal situation, the commercial species share the ecological niches in such a way that trophic resources are utilized to the optimum. At the same time, the fishes should belong to short food chain in order to allow maximum efficiency in converting the primary food resources into harvestable materials.

Thus, the basic parameters that abet primary productivity (soil and water quality) and effect composition of community and their efficiency to transfer energy from one trophic level to the other are the primary considerations in selecting management option. These factors are again dependent on the water renewal cycle and the species spectrum of the parent rivers and the beels. Ecosystem-oriented management implies increasing productivity by utilizing the natural ecosystem processes to the maximum extent. This will be more cost effective and to do minimum damage to ecosystem and biodiversity.

Community metabolism

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 organisms 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 channelled through detritus chain. There is different detritus chains such as *macrophytes >detritus> detritivore* system, *phytoplankton > detritus > benthos > bottom feeders* system and *macrophytes > associated fauna > air breathing* fish system.

Two typical systems generally found in the closed and open beels of West Bengal are depicted in Fig 5 and 6. In both the cases, the birds are at the apex of the food chain. In Bandardaha, most of the energy are transferred through *phytoplankton > zooplankton > planktophagus > predatory fish* chain. This is more or less the case with most of the open beels. In sharp contrast, Baloon beel has a macrophytes based food chain with dominance of fish feeding on weed associated fauna or detritus. The management norms in both cases should aim at correcting the fish species spectrum with the above food chain in view.

Since it is very difficult to prescribe management norms for all possible situations, a few management options are described below:

Capture fisheries of the open beels

Some beels retain their riverine connection for a reasonably long time, which are relatively free from weed infestations. These beels are typical continuum of rivers where the management strategy is essentially akin to riverine fisheries. Thus, basic approach is to allow recruitment by conserving and protecting the brooders and juveniles. These measures have the dual advantage of conserving the natural habitat of the beels along with extending the benefits of conservation to the lotic ecosystem of the parent stream. In capture fishery management, the natural fish stock is managed. Therefore, a thorough insight of population dynamics including recruitment, growth and mortality is very much essential. In order to ensure recruitment, the following parameters are taken into consideration.

Identification and protection of breeding grounds
Allow free migration of brooders and juveniles from beel to river and vice versa.
Protection of brood stock and juveniles by conservation measures.

The growth over-fishing is prevented by taking appropriate measures for gear selection. Adjustments in quality and quantity of fishing gear is an essential component of capture fishery management. Common strategies followed are summarized as:

Fig. 5. Pathways of energy flow in detritus chain

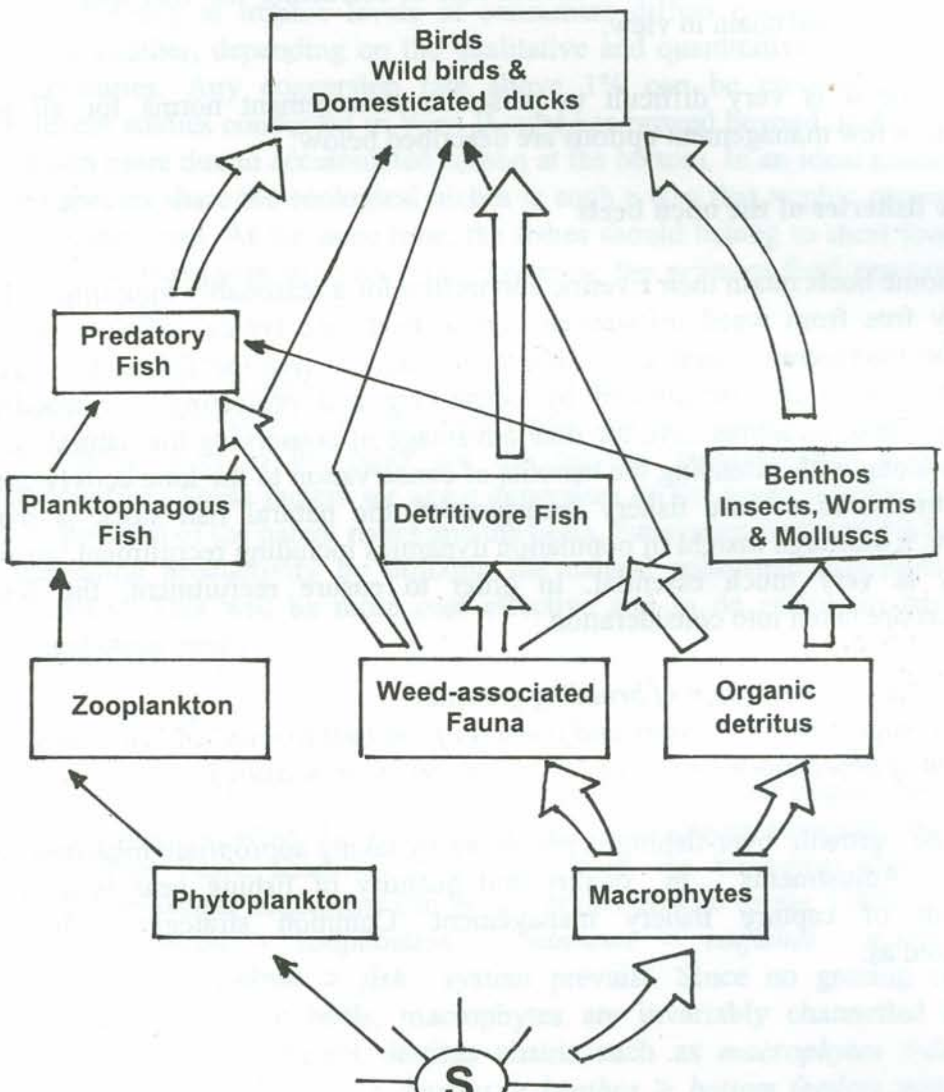
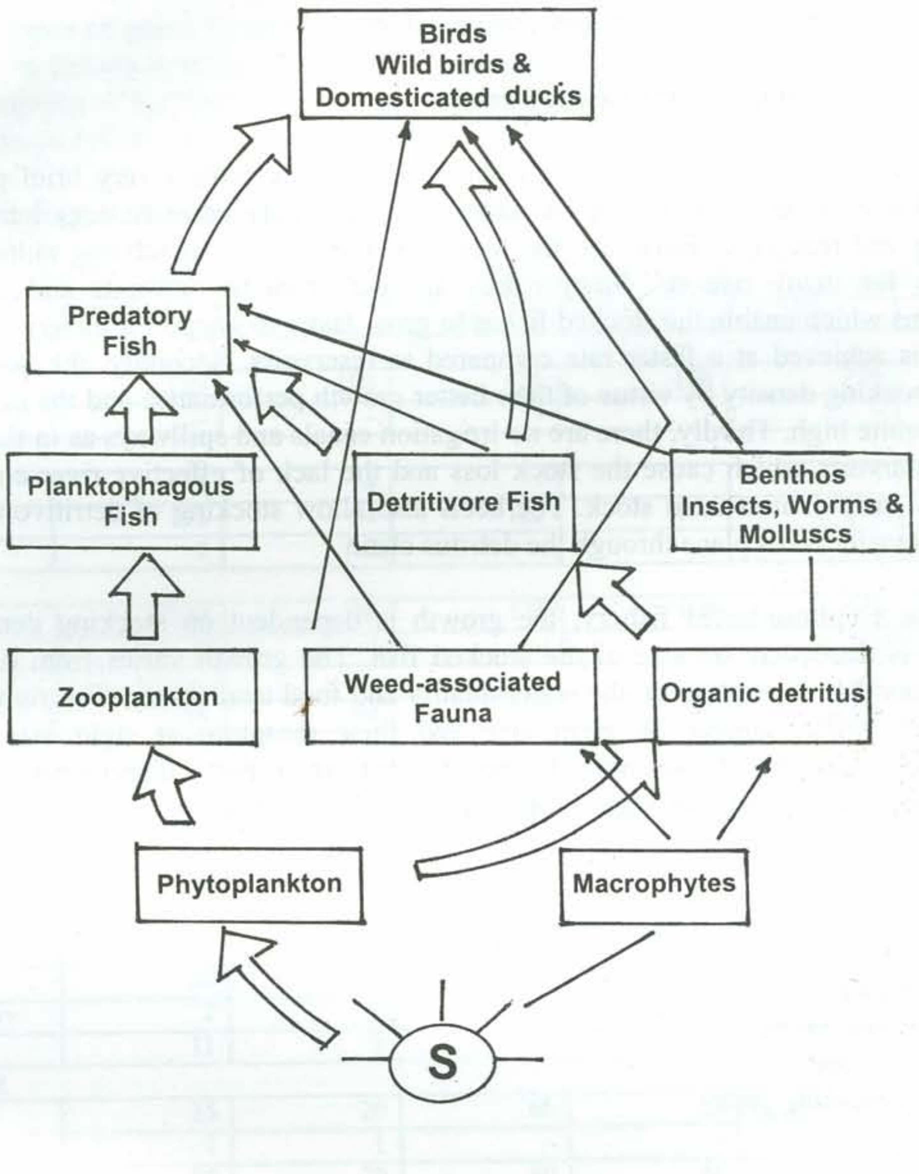


Fig. 6. Pathways energy flow in grazing chain



Increase the minimum mesh size.
Increase or decrease the fishing effort.
Observe the closed season to protect the brooders.
Strict adherence of the restriction on the minimum size at capture.
Diversity of the gear.
Selective augmentation of stock, only if unavoidable.

Culture-based fisheries 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 here will be stocking and recapture. Beels are the ideal water bodies for practising culture-based fisheries for many reasons. Firstly, they are very rich in nutrients and fish food organisms which enable the stocked fishes to grow faster to support a fishery. Thus, the growth is achieved at a faster rate compared to reservoirs. Secondly, the beels allow higher stocking density by virtue of their better growth performance and the per hectare yield is quite high. Thirdly, there are no irrigation canals and spillways as in the case of small reservoirs which cause the stock loss and the lack of effective river connection prevents entry of unwanted stock. The beels also allow stocking of detritivores as the energy transfer takes place through the detritus chain.

In a culture-based fishery, the growth is dependent on stocking density and survival is dependent on size of the stocked fish. The growth varies from one water body to another depending on the water quality and food availability. The right species stocked in right number, in right size and their recapture at right size are the determining factors. These have to be decided as a part of ecosystem-oriented management. The basic management strategies can be summarized as :

Size at stocking
Stocking density
Fishing effort
Size at capture
Species management
Species selection
Selection of fishing gear

Beels are commonly used for retting jute stem

Beels attract migratory and local birds

Culture and capture systems

There are systems which combine the norms of capture and culture fisheries. The marginal areas of beels are cordoned off for culture systems either as ponds or as pens and the central portion is left for capture fisheries (Fig. 7). This has been tried in many places of the country with certain degree of success.

Fishery options

Fishery based on Indian major carps

The beel, especially the closed ones can be developed as big ponds as their fishery solely depends on stocking with IMC. Although not done in a scientific way the beels are being stocked regularly. In the absence of natural recruitment, stocking with economically important species form the best management option.

Fishery based on indigenous fishes

In many of the beels indigenous fish form a substantial share of the catch which fetch good price also in the local market. 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 these fishes fetch. This practice will prevent the compartmentalization of beels and their conversion into ponds.

Fishery based on pen and cage culture

Many of the beels are not productive and it is not practical to fertilize the whole open water area. Therefore a manageable part of the water body can be cordoned off to stock choice species. Pen and cage culture practices are the perfect management option for the weed choked and unproductive beels. This solves the problem created by gear restriction and catchability.

Beels also can 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, West Bengal (Fig. 8) has been shown as an

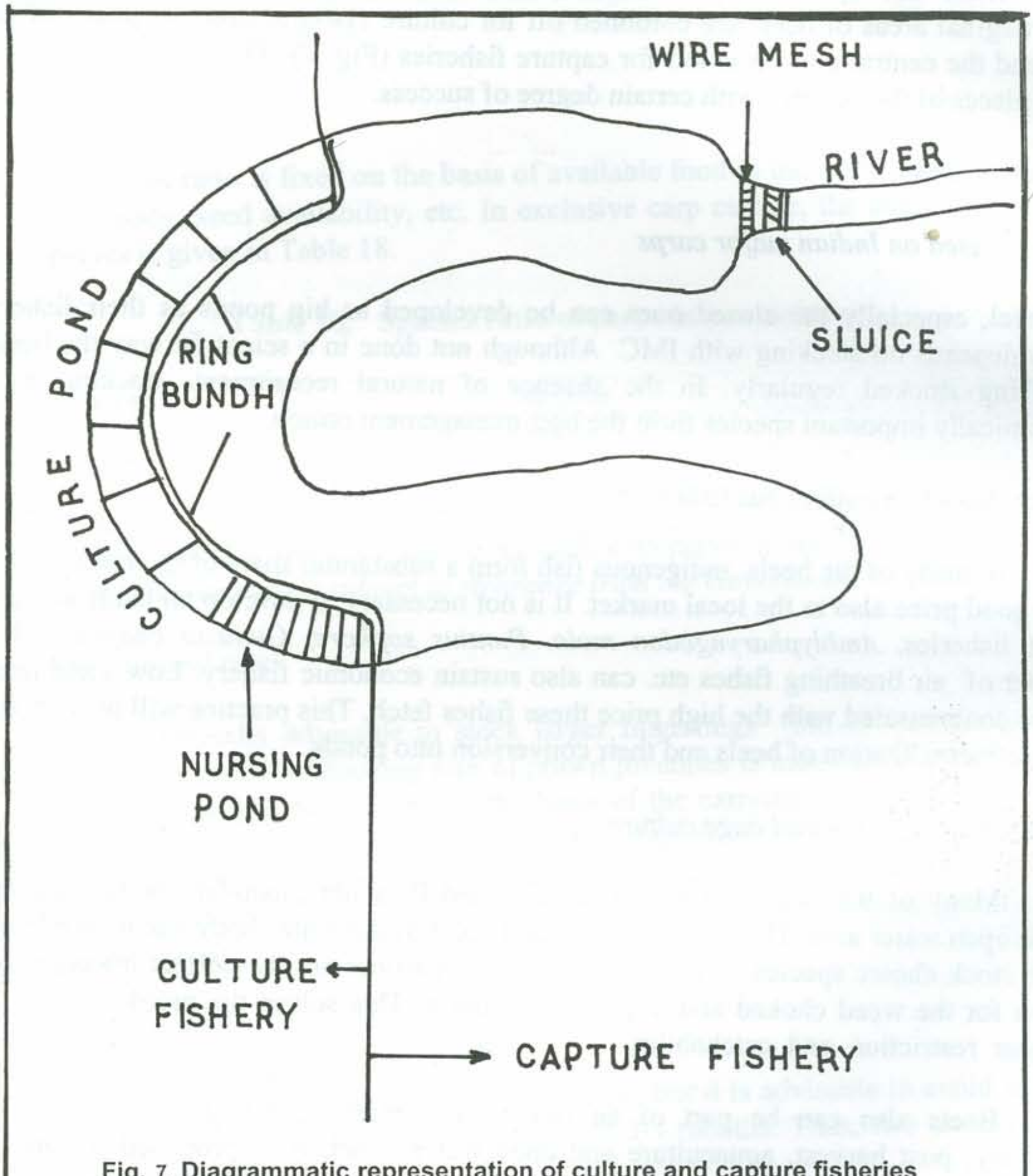
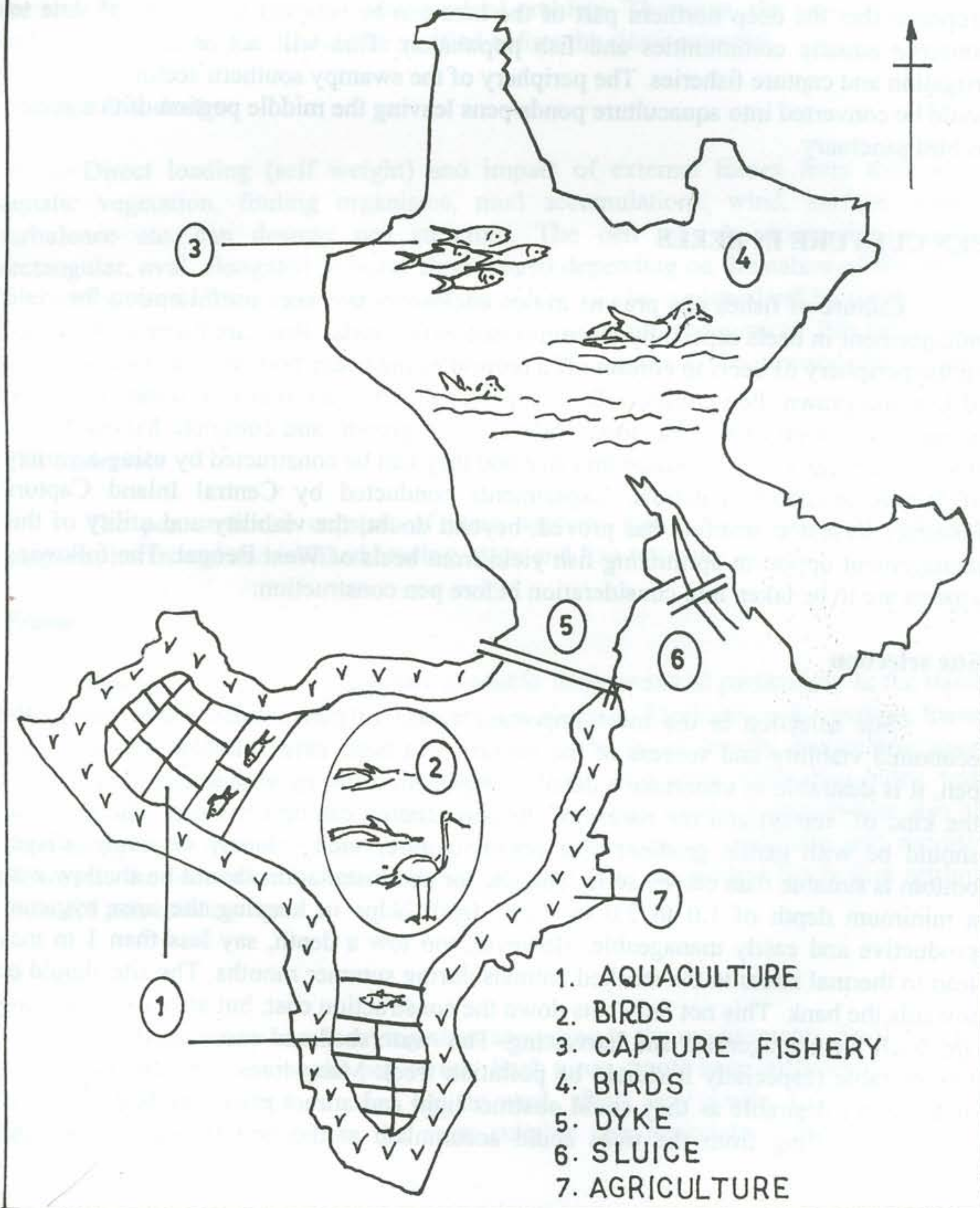


Fig. 7. Diagrammatic representation of culture and capture fisheries development in Assam

Fig 8. Integrated development of beel



example. This plan is a part of holistic development of the wetland, which can benefit the local people and help retaining the biodiversity of the beel and its environment. It is proposed that the deep northern part of the lake can be retained in its natural state to conserve aquatic communities and fish population. This will act as a reservoir for irrigation and capture fisheries. The periphery of the swampy southern sector of the beel could be converted into aquaculture ponds/pens leaving the middle portion of this sector as bird sanctuary.

PEN CULTURE IN BEELS

Culture of fishes and prawns in pen enclosures is a very useful option for yield enhancement in beels especially those infested with weeds. Pens are barricades erected on the periphery of beels to cordon off a portion of the water body to keep captive stock of fish and prawn. Pen culture offers scope for utilizing all available water resources, optimal utilization of the fish food organisms for growth and complete harvest of the stock. Pens can be of any shape and size and they can be constructed by using a variety of locally available materials. Experiments conducted by Central Inland Capture Fisheries Research Institute has proved, beyond doubt, the viability and utility of this management option in optimizing fish yield from beels of West Bengal. The following aspects are to be taken into consideration before pen construction:

Site selection

Site selection is the most important aspect of pen culture which decide the economic viability and success of the venture to a large extent. Before constructing a pen, it is desirable to undertake a detailed engineering survey with special emphasis on the kind of terrain and the nature of the surrounding catchment areas. The shoreline should be with gentle gradient. For prawn culture, sandy- loamy or sandy -clayey bottom is suitable than clayey soils. The site for pen installation should be shallow with a minimum depth of 1.0 to 2.0 m. Low depth helps in keeping the area hygienic, productive and easily manageable. However, too low a depth, say less than 1 m may lead to thermal stress to the stocked animals during summer months. The site should be towards the bank. This not only cuts down the construction cost, but also allows an easy approach for management and harvesting. The watershed and shore characters should be favorable (especially it should be pollution free). Many trees overhanging the pen area are not desirable as they could obstruct light and attract predatory birds. Besides, the leaves falling from the trees could accumulate at the bottom and release CO_2

through decomposition. Turbid water is not suitable, if prawn is cultured. Other important factors are availability of the construction materials and the accessibility to the site. Poaching is a very disturbing social problem. Therefore, the prevailing social conditions of the locality should be verified before the site is selected.

Pen size and design

Direct loading (self weight) and impact of external forces from drift logs, aquatic vegetation, fouling organisms, mud accumulations, wind, surface waves, turbulence *etc.* can destroy pen structure. The pen may be triangular, square, rectangular, oval, elongated or horse shoe shaped depending on the nature of the shore, land and water depth. Sometimes, a portion of lake can be cordoned off by a single pen wall. This type of sites if available will be very useful and economical. Pen height > 2 m needs special protection measures. For better management, the covered area should vary between 0.1 and 0.2 ha.

Pen materials

The pen structure consists of main support, frame work spanning over the supports, horizontal and inclined bracing, stays and fish retaining linings.

Frame

Bamboo is the most commonly available frame material particularly in the states like Assam, West Bengal and Bihar, where it is cheaper. The bamboo for making frame should be of 6" to 8 " in diameter and 30' or more in length. Depending upon availability, logs can be used as replacement of bamboo poles. Casuarina poles, teak wood, synthetic pipes, galvanised iron pipes or any other similar materials can also be used along with iron net, depending upon their, availability, durability and rigidity. However, the cost effectiveness of these materials is to be worked out before settling them for pen construction.

Screen

Pen screen may be of varying sizes according to the requirements. Split bamboo or cane is used for weaving the pen screen. Each piece should have sufficient length and a smooth surface. Iron mesh also can be used, albeit very costly. Considering their durability, synthetic nets are the most suitable pen materials if the pens can be protected from possible damage from various biotic agents and logs. They are very popular in countries like the Philippines, Thailand, Indonesia *etc.* Coir ropes or synthetic threads are the best fastening materials. The mesh size of screen is decided on the basis of initial size of the stocking materials.

Net lining

Provision of lining the frame with net is necessary to protect unwanted entry or exit of the organism. Nylon nets are generally used for this purpose. The nets should be cleaned periodically for facilitating water exchange and aeration inside pen area.

Pen preparation

Deweeding

Most of the floodplain wetlands are heavily infested with macrovegetation. In order to remove them and to keep off the unwanted fauna, the pen site must be cleared of aquatic vegetation. Besides consuming nutrients from the water body, excessive growth of the aquatic vegetation poses serious problems like upsetting the oxygen balance, creating obstruction for light penetration, movement of the stocked animals and in netting operations. The aquatic weed control could be done by (a) manual, (b) mechanical, (c) chemical and (d) biological means. The manual method is recommended for pen culture operations in West Bengal as it is cost-effective and convenient.

Eradication of the unwanted fauna

Complete eradication of the unwanted organisms from the pen before stocking is very important. While uneconomic species of fishes compete with the cultured ones for food, space and oxygen, predators prey upon the stocked young ones. Repeated netting is the best method for eradication of fishes from the pens. This also helps in removing other unwanted biotic communities like molluscs, insects *etc.* which could interfere with the management processes affecting production. Poisoning the pen area to eradicate the unwanted biotic communities is not advisable in pen culture.

Liming

Liming the water hastens mineralisation of organic matter and helps in maintaining the environment hygienic. Use of quick lime @ 400-500 kg/ha pen area is recommended with initial dose @ 200-300 kg/ha followed by monthly installments @ 50-75 kg/ha.

Pen management

Water

The success of pen culture is largely dependent on the productivity and ecological suitability of water. The adequate depth of water in the pen is a necessary prerequisite for better production. This depends generally on various factors like rainfall and water abstraction for irrigation. Generally, pen culture period excludes the monsoon season to avoid the problems of flood. Extreme summer is an equally bad season for pen culture as the water level recedes drastically due to high rate of evaporation and lifting of water for irrigation purposes. During summer, the temperature inside the pen shoots up and the resultant thermal stress is detrimental to the stocked fish/prawn. A water temperature range of 30 to 36^0 C is ideal for faster growth of the cultured animals. Other desirable parameters are dissolved oxygen (4-8 mg/l), CO_2 (1-2 mg/l), alkalinity (50-150 mg/l), pH (7.0-8.0) and moderate nutrient contents (N-2.0 mg/l and P- 1.5 mg/l).

Soil

The bed soil should be sandy-clayey. The detritus load between 50 and 70 g/m^2 and organic matter between 1-2% are ideal for better production. Very high organic content of bed soil results in anaerobic condition at the bottom, which is detrimental to the bottom dwellers, especially prawns.

Species selection

Species belonging to the groups planktophagous, detritivores and bottom feeders are the most suitable for pen farming. However, phytophagous species can also be introduced to keep weeds under control. In pen culture, the combination of carps with giant freshwater prawn has proved to be successful. However, from economic point of view, monoculture of giant freshwater prawn is more acceptable. The suitable species for mixed culture of carps are catla/silver carp, rohu and mrigal. Under mixed culture of carps and prawn, catla/silver carp, rohu and *M. rosenbergii* can be considered. In monoculture, the prawns grow faster with a higher survival rate, compared to their culture along with carps.

Species ratio

Species ratio is fixed on the basis of available food in the environment, depth of the water body, seed availability, etc. In exclusive carp culture, the suggested ratio of fish species is given in Table 18.

Table 18. Species ratio of carps in pen culture

Category	Species	Fraction
Surface feeder	*Catla catla*/Silver carp	35%
Column feeder	*Labeo rohita*	20%
Bottom feeder	*Cirrhinus mrigala*	45%

The bottom slot of *C. mrigala* can be replaced with prawn in the mixed culture.
**Stocking of silver carp is subject to clearance from the Government*

Stocking size and rate

It is generally advisable to stock larger fingerlings (l00-150 mm) for better survival in carp culture. Stocking size of prawn juveniles is much smaller between 65-70 mm. Rate of stocking is fixed on the basis of the carrying capacity of the pen. In monoculture of carps the recommended density ranges from 4,000 to 5,000/ha. While in mixed culture, the density of carp and prawn could be 3,000-4,000/ha and 1,000-2,000/ha respectively, in monoculture of prawn stocking density could go as high as 30,000-40,000/ha.

Culture frequency

Pen farming could be done round the year, but it is advisable to avoid monsoon months. The culture period for prawns is about 3-4 months. Thus, two crops could be raised per year per pen.

Supplementary feeding

Since the objective of pen farming is to utilize natural productivity of the water body, role of supplementary feeding is marginal except for the prawn which needs highly proteinous diet for their growth. The prawn is fed once @ 2-5% of their body weight during evening hours depending on the availability of natural food. The supplementary feeding may be done with commercially available pelletized feed or locally made mixture of animal protein with carbohydrate and fat. Cockle flesh and fish meal are well known sources of animal protein. Feeding in trays saves loss of feed and thereby reduces the cost of production.

Precautions

Although pen culture paves the way for augmenting production and provides economic benefits, many potential social and environmental problems can crop up. Rapid growth of pen culture, impervious to environmental concerns can lead to disastrous consequences as happened in the Laguna de Bay in the Philippines. Rapid and haphazard development of fish pens converted the Laguna lake into a battery of pens reducing the open water fishing area. This also caused unemployment for traditional fishers. Supplementary feeding of the stocked fish in the pen can lead to eutrophication of the lake very fast. Unchecked proliferation of this activity in the inland water bodies of the country can lead to large scale environmental problems as witnessed in the case of brackishwater shrimp farming in India and abroad during the last decade. Therefore, pen farming, though considered as very lucrative, should be propagated by the government agencies with adequate precaution and care.

Planning criteria

Before launching any large-scale pen culture drive, it is necessary to conduct a survey of the resources with a view to selecting suitable sites after taking all environmental, social and economic aspects into consideration. It is also necessary to estimate the carrying capacity of each water body selected, so that its maximum pen area can be determined. This is essential to avoid Laguna de Bay type debacles. Moreover, the socio-economic impact of such measures needs to be determined. Conversion of open water fisheries into pen enclosures can change the normal pattern of community management with open access, adversely affecting the employment, livelihood, distribution of income and an array of other socio-economic parameters. If the present crisis in coastal aquaculture is any guide, the environmental and socio-economic impact assessment is an essential pre-requisite for adopting pen culture in large scale.

Pen culture of prawn in beels

A series of experiments conducted in beels of West Bengal, with different species composition and stoking densities, a method for monoculture of *Macrobrachium rosenbergii* has been standardized with stocking density of 40,000. The experiments are conducted in different beels viz. Akaipur, Kola (24-parganas North District) and Bhomra (Nadia District).

In Akaipur beel pen material was prepared from bamboo, which was locally available in plenty. Split bamboos were woven together with coir ropes. The split bamboo mats were erected in the beel and they were covered with fine meshed nylon clothes. The bamboo screens were further reinforced externally with galvanized iron mesh for protection against crabs. The pens (0.06 ha) were stocked with prawn juveniles of 75-80 mm size (4 g) @ 12,000 nos per hectare. The prawns, harvested after a grow out period of 89 days were found to grow up to 230 mm length and 160 g in weight, the average being 190 mm and 86 g respectively. Lime was applied in the pen enclosure as a prophylactic measure against diseases. A locally manufactured feed was given to prawns to supplement the natural feed available in the pen. The artificial feed made of prawn meal, contained 39% protein. Feeding was done during night @ 3-4% body weight. Cost return of pen culture is shown in Table 19.

Minimum of 2 crops is expected per year though 3 crops are also possible. The total annual capital cost (Rs. 3840=50) plus recurring cost (Rs. 9,550=00), for one crop is (Rs. 13,390=50). Total sale proceeds from one crop was 14,850=00. The profit for the first crop was only Rs. 1,460=00. The annual profit (2 crops) was worked out to be Rs. 6,759=50. However, subsequent crops for the next 4 years the total expenditure will be only cost of seed and feed. After the small amount for maintenance of the pen. The percentage return on investment would be very attractive.

Table 19. Cost of production in pens

		Rs.
A. Capital cost		
Bamboo and bamboo mats		4,502=50
Wire mesh		14,700=00
	Total : A	19,202=50
B. Annual capital cost		
Bamboo and bamboo mats		900=50
Wire mesh		2940=00
	Total : B	3840=50
C. Recurring cost		
Coir		200=00
Paints		700=00
Installation		450=00
Netting		1100=00
Cost of seed		5400=00
Feed		1700=00
	Total : C	9550=00
Total cost B+C (one crop)		13390=50
D. Total sale proceed (one crop)		14850=00
Profit (one crop) D-(B+C)		1460=00
Cost for two crops B +(Cx2)		22940=50
Profit for two crops (Dx2)-(B+Cx2)		6759=50
Return on investment		29.5%

Pen culture in beels - Preparation of pen material

Split bamboo screens to be used for pen erection

Pen being erected in beel