ENVIRONMENTAL IMPACT ASSESSMENT OF INLAND WATERS FOR SUSTAINABLE FISHERIES MANAGEMENT AND CONSERVATION OF BIODIVERSITY

Edited by
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Environment Impact Assessment
of Inland Waters for Sustainable Fisheries
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FOREWORD

The history of human civilization is witness as how the water resource management (the harvesting, distribution, purification and conservation) has influenced the events of a society at different points of time. The legendary and traditional views of open waters like the rivers are hazards, the water flowing into sea is wasteful, the shallows are obstructive to navigation have gradually changed with the recognition of ecological and landscape values of natural inland waters. In this age of environmental transition, management of aquatic systems has surfaced as one the greatest challenges before the present generation. It is really heartening to understand that today more than two billion people have no access to clean drinking water and only 5% of the world's wastewater is treated or purified. Besides, every second person in the thickly populated third world countries suffers from water borne diseases and approximately 5 million people die every year due to the use of contaminated water, loaded with deadly parasites or poisonous chemicals. The days are not very far when all the Heads of Governments from different countries would follow suit to Mr. Sadat, former President of Egypt, who once said "anyone who plays with the waters of the Nile is declaring war on us". The greatest dilemma of the current century is how to reconcile with our immediate needs so as to promote the concept of long-term sustainability, where the environment is ecologically sound and aesthetically acceptable. The road ahead is bumpy and the goal can only be achieved through strategic planning, rational utilization of resources and better understanding of ecological variables.

It is in this backdrop that the present Summer School on *Environment Impact Assessment of Inland Waters for sustainable Fisheries Management and Conservation of Aquatic Biodiversity* is conceived. The main objective of the Summer School is to generate environmental awareness amongst the researchers, teachers, developmental officers and extension personnel through effective dialogues, discussions and exchange of views. This compendium contains the Lectures delivered by some eminent persons who are actively engaged in environmental activities. We shall feel gratified if the participants carry the message of conservation and sustainable development to their respective realms of activities.

M. Sinha
Director

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Summer School on ***Environment Impact Assessment of Inland Waters for Sustainable Fisheries Management and Conservation of Biodiversity***
CIFRI Barrackpore 25 July to 14 August 2000

INLAND AQUATIC RESOURCES OF INDIA, ISSUES AND THREATS- A FISHERIES PERSPECTIVE

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The Resource

India by virtue of its geo-geographic location is endowed with vast expanse of inland fishery resources, comprising rivers, canals, lagoons, resrvoirs, floodplain wetlands and ponds (Table 1), which is largest in the world. The enormity and diversity of these resources demand separate sector-wise approach in their development as they portray different pictures of environmental parameters and production dynamics.

Inland fish production in the country has registered a phenomenal increase in last about five decades. As against 0.24 million tons produced in 1950 – 51, the production of inland fish in the country during 1998 – 99 is estimated at 2.6 million tons. It is the second largest producer of inland fish, only next to China. But it is able to provide only

TABLE 1 : Inland fishery resources of India

Resource	Length/Area
Rivers	45,000 km
Canals/Creeks	1,26,334 km
Estuaries	27,00,000 ha
Floodplain wetlands	2,10,000 ha
Lagoons	1,90,000 ha
Reservoirs	30,20,000 ha
Ponds & Tanks	22,50,000 ha

about 8 kg per capita to the present populace (taking 55% as fish eaters) as against the nutritional requirement of 11 kg. The projected domestic requirement of the country by 2020 AD is estimated to be 12 million tons, more than $3/4^{th}$ of which has to come from inland sector. To achieve this national goal, proper development/conservation of inland waters is a must for which a scientific understanding of all types of inland fishery resources is imperative to back up their optimum exploitation. However, there exists as many opportunities to augment the yield from these resources as there are constraints which operate against them.

The status

Riverine fishery

The rivers of India are being subjected to considerable stresses and accordingly the adverse effects are being manifested in poor fish landing both in terms of quality and quantity. The prized fishery, such as Indian major carp and hilsa, of recent past have either collapsed or are at the threshold of collapse. The reasons for this state-of-art lies in the un-holistic utilization of the resource. The riverine resource has brutally been assaulted during the last few decades causing large-scale habitat loss. Recent studies conducted by CIFRI reveal that the rivers have lost their original characteristics due to rapid change in the hydrological regime and other man induced river valley modifications. The river beds are becoming shallow at a rapid pace with the ingress of excessive silt load and excessive water abstraction. These have resulted in reduction of water volume considerably leading to loss of feeding as well as breeding grounds. Sandification of river-beds is another area of serious concern, as evidenced from a study conducted by CIFRI in case of river Ganga. In such a condition due to blanketing effect assimilation and release of necessary nutrients become difficult.

Data collected by CIFRI suggest considerable decline in fish catch in the middle stretch of the river Ganga (Kanpur to Farakka). The major carp yield also followed the same trend and over these years substantial decline in its catch has been observed (from 26.62 kg/ha/yr in 1958 – 61 to 2.55 kg/ha/yr in 1989 – 95). The decline of hilsa catch, upstream of Farakka barrage, has also caught the imagination of fish lovers, specially during the post Farakka period. Currently the contribution of hilsa, in this stretch has gone down by 83 to 98% in comparison to pre – Farakka period. Similarly in the upland rivers the migration of mahaseer has been adversely affected due to construction of barrages and accordingly its fishery has gone down.

Estuarine fishery

Estuaries are amongst the most productive systems in the world. The fisheries of estuaries in India are above the subsistence level and contribute significantly to the production. The average yield is estimated to sway from 45 to 75 kg/ha. India has the distinction of having one of the finest and most productive estuarine systems in the form of Hoogly-Matlah estuarine complex in West Bengal. The greater ingress of freshwater from Farakka barrage has changed the estuarine characteristics of the system. It has been observed that the salinity regime is on a declining spree due to more ingress of freshwater from the barrage and as a result pushed the true estuarine zone downward.

The fish landing figures of the Hooghly estuary (Table 2) are quiet in contrast with riverine fish catch statistics of freshwater zone of river Ganga or any other estuary of the country. The annual avaerage prawn and fish yield from this estuary has constantly been showing an increasing trend with an increase from 9,481.5 tons of pre-Farakka barrage period (1966 – 67 to 1974 – 75) to 33,341.4 tons during post barrage period (1964 – 85 to 1994 – 95) and further to 42,703.2 tons during 1995 – 97 and 44,453.8 tons during 1997 – 98 to 1999 – 2000. With the commissioning of Farakka barrage, resulting in higher flow of freshwater in the estuary, the general habitat for hilsa in the areas downstream has improved, resulting in its increased landing. The species now spawns in the entire freshwater zone of the estuary whose area has considerably increased with increased freshwater discharge. The average catch of other neritic species has also generally improved in the marine zone of the estuary during post – barrage period. Below Farakka barrage, certain freshwater fishes and prawn species (*E. vacha, C. garua, R. rita, A. seenghala, A. aor, C. catla and L. rohita*) have also made their appearance in upper zone of the estuary. These species were not reported from Nabadwip downwards prior to 1975. The present improved ecological condition, in terms of water volume as a result of increased freshwater release from Farakka barrage is definitely more conducive for fish production. This sharp and continued rise in fishery below Farakka barrage, during the last nearly two decades supports the view that higher sedimentation and increased water abstraction, resulting in substantial reduction in water volume in the river and, thus, habitat loss is the main cause of decline in fisheries in the stretch of river above Farakka barrage.

The likely impact of taming of river Narmada on its estuarine fishery is another example of impact of river course modification. According to Narmada Water Dispute Tribunal there would be 72.71% reduction in water availability downstream at 30 years of commencement of construction. It may not effect the salinity regime but shall effect the migratory fauna. Stage attained at 45 years from commencement of construction shall be very critical when freshwater release from Sardar Sarovar shall cease. It will result in steep hike in salinity. Fishery shall drastically change. With the present height of 80.3 m attained by Sardar Sarovar dam, impact of impoundment are already discernible in the water downstream in form of increased transparency, significant increase in dissolved oxygen, decline in nutrient status and localised spurts in planktonic biomass.

Table 2 : Average contribution of dominant fishes and prawns (in t) of Hooghly estuarine system

Sl.No.		Pre-Farakka barrage period		Post-Farakka barrage period1999-2000		
		1960-61 to 1962-63	*1966-67 to 1974-75*	*1984-85 to 1994-95*	*1995-97*	*1999-2000*
1	*2*	*3*	*4*	*5*	*6*	*7*
1.	**Hilsa** *(Tenualosa ilisha)*	**743.9**	**1457.1**	**2336.6**	**5,045.8**	**7906.6**
2.	**Mullets** *(Liza parsia, L. tade)*	**39.5**	**30.8**	**18.2**	**16.5**	**22.1**
3.	**Threadfin** *(Polynemus paradiseus, Polydactylus indicus, Eleutheronema, tetradactylum)*	**74.4**	**63.9**	**296.7**	**400.6**	**492.1**
4.	**Perch** *(Lates calcarifer)*	**45.9**	**24.5**	**49.9**	**4.5**	**17.6**
5.	**Sciaenids** *(Pama pama, Otol'thoides biauritus)*	**118.9**	**203.7**	**4327.7**	**3935.7**	**2875.5**
6.	**Catfishes** *(Osteogenious militaris, Pangasius pangasius, Arius sona, A. sagar)*	**152.5**	**109.6**	**992.9**	**964.2**	**1809.1**
7.	**Other clupeids** (*Setipinna* spp., *Ilisha elongata, Chirocentrus dorab*)	**136.2**	**437.8**	**4081.6**	**5920.1**	**5894.0**
8.	**Ribbon fish** *(Trichiurus gangetica, Lepturacanthus puntului)*	**83.1**	**454.0**	**2835.5**	**6136.2**	**3778.7**
9.	**Bombay duck** *(Harpodon nehereus)*	**797.1**	**2067.9**	**5301.0**	**10576.3**	**9570.8**
10.	**Pomfret** *(Stromateus cinereus)*	**Recorded under others**	**71.6**	**866.3**	**620.0**	**665.9**
11.	Prawns	574.1	1338.3	2939.3	2858.2	1752.3
12.	Others	438.4	3222.3	9295.7	6225.1	9669.1
13.	Total	3204.0	9481.5	33341.4	42,703.2	44,453.8

Source : Sinha (1998) & Anon (1997), Annual Report, CIFRI, Barrackpore, West Bengal, India.

Floodplain Wetlands fishery

The floodplain wetlands or lakes, a continuum of river basins, were known for their high production potential and lucrative fishery till recently. However, man induced river valley modifications have adversely affected the fishery of these lakes,. Moreover, most of such lakes are facing the problem of eutrophication to the extent that if, left unmanaged, swampification is inevitable. Currently, the floodplain lakes have been subjected to so many stresses and as a result the production functions have gone array. Massive proliferation of unwanted biota has overshadowed the growth of biota necessary for human welfare. Prior to the construction of flood protection measures most of the lakes were serving as the feeding and breeding ground for riverine fish stock, the prized fishes in particular. Evidently, auto-stocking was a continuous phenomenon. During the post flood construction, however, this process of natural recruitment of riverine fish seed has become rare and as such the fishery of prized fish species has gone down. The non-ingress of river water in the lakes has also paved ways for higher colonization of macrophytes, a symptom of higher degree of eutrophication. The floodplain lakes are currently facing twin problems – a) excessive enrichment of nutrients from external sources , and b) locking of necessary nutrients in hydrophytic chain. Accordingly, the quality and quantum of grazing chain required for the healthy growth and sustenance of prized fish species such as IMC has been broken with the emergence of unwanted biota. The scenario, today, is that the lakes have massive infestation of macrophytes at the surface and column and mollusk at the lake bed. Unfortunately, however, both these dominant biotic communities are not being converted into fish flesh in absence of efficient grazers.

The production potential of these lakes have been estimated to the tune of 1000 –1500 kg/ha/yr, but the actual fish yield ranges between 160 (Bihar lakes) and 210 (West Bengal & Assam lakes). Floodplain lakes, by virtue of their production potential, constitute one of the prime open water fishery resource, capable of yielding about 0.21 million tons of fish per year even with a modest production target of 1 ton/yr. The mangement strategy for this vital sector is based on a category-wise approach. Optimum exploitation norms for lakes with riverine connections revolve around the concept of keeping the deeper central portions for open water fishery and the margin and pockets for aquaculture. Fisheries would entail monitoring of recruitment and subsequent growth of the natural populations.

In closed lakes stocking is the mainstay of management. In weed choked lakes clearance of weeds and detritivore oriented stocking schedule would enhance the yield rate considerably. These lakes also provide ideal condition for pen and cage culture operations. CIFRI has developed technologies for pen and cage culture in beels with production possibilities in pens of 4t/ha/6 months of carps, 1t/ha/6 months of prawns and of 0.25 kg/meter square of air breathing fishes in cages.

Recent research efforts in beel fisheries consist of a new approach by exploiting the activity coefficient and energy conversion within the system. Studies conducted in some beels of West Bengal have shown that energy transfer at the tertiary level can be increased from 0.226% to 0.41% by ecological manipulations.

Lagoon fishery

Chilka, Pulicat and Vembanad are the important lagoons of the country. There fishery is showing a declining trend. Recently conducted survey of Chilka lagoon in 1995 –96 by CIFRI has indicated that regulated discharge of incoming rivers, siltation and anthropogenic pressure have made marked negative impact on the lagoon ecology and its fishery. Considerable decrease in size (from 906 sq km in 1965 to 620 sq km in 1995), siltation of lagoon bed and its connecting channel with the sea, profuse weed infestation, decrease in salinity (from 7.0 – 25.5 ppt in November, 1957 to 1.41 – 2.69 ppt in November, 1995) and qualitative (28% prawn in 1965 to 14.4% prawn in 1995) as well as quantitative decline in the fishery (4237 tons in 1990 to 1672 tons in 1995) of this lagoon has been observed.

Reservoir fishery

Large number of river valley projects have been built and commissioned in our country since independence as part of developmental activities. Though created basically for irrigation or power, this resource has tremendous scope for enhancement of fish production in India. The current yield of fish from this resource, however, remains much below than the desired level. It has been estimated that the yield rate from large and medium reservoirs is as low as 14 kg/ha/yr, where as it is around 49 kg/ha/yr from the small reservoirs. The three pronged strategy, developed by CIFRI, comprising enlargement of mesh size, increase in proper fishing effort and stocking support has paid much dividends, wherever tried. In large and medium reservoirs the stocking support is for the purpose of establishing a breeding population of suitable species, whereas, in small reservoirs it is for the purpose of extensive aquaculture. Data collected by CIFRI suggest that the fish production potential of reservoirs is much higher in the range of 100 kg/ha/yr (large/medium reservoirs) to 300 kg/ha/yr (small reservoirs).

Aquaculture

The development of technologies of induced breeding and composite fish culture by CIFRI revolutionised aquaculture in the country, specially from seventies onwards. These scientific fish seed production and fish culture practices have spread throughout the country at a fast pace through a network of Fish Farmer's Development Agencies, set up by Govt. of India. Consequent to this, quality fish seed availability is no longer a problem for aquaculture and average fish production has gone up to 2200 kg/ha/yr, from a low of 600 – 800 kg/ha/yr. Aquaculture has evolved from a domestic activity to the status of a industry, specially in eastern and south east part of the country, during the last three decades. In all about 4.25 lakh ha of pond area (out of 2.25 m ha of total resource) has been brought under scientific fish culture. Presently, aquaculture contributes about 78% of the total inland fish production in the country.

Intensification of aquaculture has also brought in certain environmental problems in the recent past. Though there is ample scope of enhancement of fish production from this resource, but it need be with sufficient degree of caution. Availability of required quantity of desired inputs, to bring in the remaining areas of this resource under scientific fish culture, is a further constraint for its future development.

The threats

The aquatic ecosystems, specially the open waters, have been subjected to many threats, primarily emanating from man induced modifications at various stages of the trophic structure. The problem is more acute in developing country like India, where biomass economy has to stay with 75% people dependent on agriculture. The main threats to inland fishery resources have been identified as:

- Loss of and change in habitat owing to river valley modifications
- Encroachment
- Introduction of exotic species in open waters
- Eutrophication/ Pollution/ Poisoning
- Overfishing in open waters

The issues Management of IFR

The inland fishery resources are facing many problems due to significant increase in anthropogenic activities in and around these aquatic systems.

- *The riverine ecosystem, including the biodiversity, is reeling under acute to very acute conditions in the face of increasing man-induced interferences, as such conservation of resource, both physical and biological, should top the agenda of river management.*

- *Rationality in civil constructions is the need of the hour so as to protect the ecological integrity of aquatic resources.*

- *Catchment ecology needs greater attention to understand the threat perceptions emanating from catchment modifications.*

- *Irrational and reckless fishing activities need immediate halt so as to allow the ecosystems to build their natural fishery.*

- *Immediate development of resource as well as location specific management guidelines for better and rational utilization of resources on sustainable basis is required.*

- *Aquatic resources, specially open waters, being a common property right, conflicts amongst the various user groups need be reduced through effective coordination.*

- *Point source of pollution needs careful monitoring to maintain a minimum standard of water quality for better growth and proliferation of biotic communities including fish fauna.*

- *The extension machinery for extension of scientific technologies needs to be trained and strengthened adequately.*

- *Refinement of technologies to keep pace with demand of time is required for proper extension and development of aquaculture.*

The prospects for development

The development of inland aquatic resource for enhanced fish production in our country is a must to obtain required quantity of this important animal protein constituent in the diet of the expected populace in years to come. But it is at a critical point in its development. In case of our rivers, estuaries and floodplain wetlands, degradation and loss of habitat is increasing, day by day, and a national perspective, as well as mass awareness, is essential regarding utilisation of these common property resources. The moot point is can the fishery of rivers be improved? The environmental status of rivers are such that enhancement of fish yield appears to be a distant possibility. The multiple use nature of this resource makes implementation of ameliorative measures impractical. Evidently, conserving the fish germ plasm is more important than getting more yield, as we cannot afford the lose our biodiversity, the fish fauna in particular, in view of maintaining an ecological equilibrium.

There is immense potential to increase fish production from reservoirs simply because of vastness of this resource and its untapped potential. Moreover, this is the only aquatic resource whose hectarage is expected to increase with increase in population. Scientific technologies are available for developing its fishery. Besides adding to production basket, it has also the capability of providing vast employment to the poorest of the poor *i. e.* fishers. The fact remains as to why the yield from Indian reservoirs is so low, in spite of the fact that many reservoirs have indicated high to very high levels of primary and secondary production? Micro-level reasons may be many, but inadequate management of reservoirs, with due importance not given till recent past, may be attributed as the major constraint for such a situation. Moreover, lack of efforts to understand ecological variables, associated with reservoir productivity, may be identified as the another reason for this impasse

Aquaculture is already contributing the major share in inland fish production. But much more is possible from this resource in future. Besides proper extension machinery, research inputs in the field of genetics and nutrition is the need of the hour to achieve the required enhanced fish production from this resource.

Summer School on ***Environment Impact Assessment of Inland Waters for Sustainable Fisheries Management and Conservation of Biodiversity***
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ENVIRONMENTAL CONSIDERATIONS AND FISHERIES OF RIVER GANGA.

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Introduction

The holy river Ganga in the Indo-Gangetic delta is the fourth largest river in the world with a basin covering 8,61,404 km^2 and about one tenth of the world's population live within its river basin. The Ganga and its various tributaries constitute the largest river system in India. It is a perennial river taking its origin from two headwaters at a height of about 6,000 m in Garhwal Himalaya (30^o55` N, $79^o$ 7` E) the Gangotri and the Alakananda. It enters the plains at Haridwar. Then it flows southeast and meanders through the Indo-Gangetic plains in the states of Uttar Pradesh, Bihar and West Bengal, finally leading to Bay of Bengal. The Ganga is 2,525 km long and its basin drains about one fourth of the countries area. At present the surface water availability in the Ganga basin is 446 million acre feet (MAF). The annual flow of freshwater in the Ganga is estimated at 142.6 billion m^3 resulting from the melting of snow in Himalayas during the spring and hot months and monsoon rains during June to September. The river Ganga has an annual runoff of 493 Km^3 and carries 616 X 10^6 tonnes of suspended solids to the Hooghly estuary (Qasim *et al.*, 1988) . The Ganga, considered as the second major river of the world in terms of suspended load is the main contributor of sediments to the Bengal Fan which is the largest deep sea fan in the world (Lisitzen, 1972).

During recent years the water quality and quantity of the mighty river Ganga have gone down considerably due to increased deforestation in its catchments, rapid development of industries on the river banks, development of irrigation projects, many fold increase in the discharge of domestic, industrial, agricultural wastes into the system and river modifications along with population explosion. These have adversely affected the river biota including the fish community. With a view to assess soil and water quality, community organisation of plankton, macrozoobenthos and fish fauna, an exploratory survey was carried out by the Central Inland Capture Fisheries Research Institute during 1995 to 1996 at 43 selected centres of the river Ganga, Bhagirathi and Hooghly estuarine system from Tehri to Gangetic delta (Sunderbans). The existing knowledge on water quality and fishery of the river Ganga is very fragmentary and restricted to limited stretches of the river system (Sinha *et al* 1998). While Krishnamurti *et al*. (1991) described water quality and biological profile at 28 centres of river Ganga from near origin to Farakka only. The present work was planned to have a complete idea of present status of environment, including soil quality of the river bed and fishery of river Ganga, from near its origin to sea, following an uniform methodology.

Soil and physico-chemical characteristics

The entire river bed from Haridwar to Patna has been transformed into sandy soil with 79 to 99.7% sand and nil to 12% clay . The stretch upto Farakka is already under threat where the sand percentage is 48 to 54%. In the stretch between Sultanpur and Uluberia(upper delta region) the bed soil is more or less loamy in texture. The bed soil contains 31 to 79% sand, 12 to 60% silt and 5 to 30% clay. Lower zone of Hooghly estuary and adjacent estuaries contain high percentage of silt and clay particles forming 25 to 58% and 11 to 36% of the bed soil respectively. The study revealed that the stretch between Tehri and Patna suffers severly from textural deformity and the entire stretch is blanketted by sand drifted through a number of tributaries *viz*. Ramganga, Yamuna, Gomti, Ghagra, Sone and Gandak. The denuded catchment washings are also responsible for the deformation of the river bed. The sandy bed of the upper and middle stretches of river Ganga can naturally contribute very little to the aquatic productivity. The entire river bed soil has been found to have slightly alkaline to alkaline pH. Moderately alkaline (pH 7.9 to 8.9) between Roychowk and Hasnabad. The allochthonous materials carried by Ganga is generally deposited in this zone making it alkaline. Soil with alkaline reaction are comparatively less responsive than neutral soil, both for agriculture and aquaculture production. Organic carbon, total nitrogen and available phosphate contents in bed soil were low in the freshwater stretches of the river Ganga as compared to estuarine stretch, indicating that the estuarine region is more productive region.

The water pH observed was generally true reflection of the soil of the area. The present value of water pH of upper, middle and lower stretches of the Ganga ranged from 7.3 to 8.6; 7.0 to 8.8 and 7.3 to 8.8 respectively. These values were almost similar to observed values of pH in 1960 and 1984. This is so because the Ganga water has a high buffering capacity. Almost similar trend was observed in case of Hooghly estuary. Appreciable improvement in dissolved oxygen content of water was noticed in the middle (3.4 to 11.9 mg/l) and lower (4.8 to 9.6 mg/l) stretches of the river system as compared to 1985-90 period. Considerable increased value of dissolved oxygen (6.0 to 8.2 mg/l) was also observed in the estuarine system. As regards phosphate content., the entire upper stretch from Tehri to Kannauj had very low values (trace to 0.31 mg/l). In the middle stretch, besides Kanpur, Allahabad and Varanasi, the value of phosphate was found to trace to 0.4 mg/l during summer months. Higher values were recorded at Kanpur (2.5 mg/l), Allahabad (0.8 mg/l) and Varanasi (1.05 mg/l) in the present study as compared to values in 1960 and 1985-90 periods. In the lower stretch, phosphate value was observed between 0.045 and 0.130 mg/l. In the estuarine system the fluctuation of phosphate value was from 0.020 to 0.160 mg/l. While during 1953-55 period, the phosphate content was very low . After commissing of Farrakka barrage the phosphate content has shown some improvement. The present values of nitrate (tr. to 0.86 mg/l) in the river water as compared to earlier values indicate the improved condition of water quality as well as lower degree of pollution. Increased level of nitrate (0.05 to 0.54 mg/l) was also recorded from the estuarine stretch barring Tribeni centre in the present study as compared to very low values ranging from 0.03 to 0.12 mg recorded during 1985-90. Silicate content was moderately high (4.5 to 9.4 mg/l) in the riverine stretch between Tehri and Katwah. In the freshwater zone of Hooghly estuary, it was also moderately high (5.4 to 12.4 mg/l). However, it was poor (0.5 to 5.9 mg/l) in the marine zone of the estuary. A critical analysis of the earlier works during pre Farakka barrage period and post barrage period revealed that additional discharge of freshwater through Farakka barrage had changed the ecology of the system significantly by reducing salinity and converting the earlier gradient zone into almost freshwater one. The present study indicates that the salinity incursion of the Hooghly estuary was observed upto Diamond Harbour (near Roychowk) situated 60 km from the mouth of estuary. Physico-chemical characteristics of water of the river Ganga during past and present are depicted in Table 1(a) & (b).

Plankton

The information on the plankton community of the Ganga river system is very meagre besides a solitary investigation during 1960 (Pahwa and Mehrotra, 1966) over a stretch of 1090 km from Kanpur to Rajmahal. A few more information (Shetty *et al.* 1961; Saha *et al* 1975; Bilgrami & Dutta Munshi, 1985; Nandi *et al.* 1983; Krishnamurti *et al.*, 1991; Bilgrami, 1992; Khan, 1996 etc.) are available on the subject where the studies were restricted to a perticular stretch.

The present study on plankton indicates that the density has considerably decreased in the middle and lower freshwater stretches of the Ganga as compared to 1960 but the composition of plankton has not changed much. The dominant groups of phytoplankton was found to be Bacillariophyceae, Chlorophyceae and Cyanophyceae, while Rotifers and Copepods dominated the zooplankton population throughout the year. The maximum density of plankton was 80, 291; 45, 613; 25, 125; 7, 685; 765; 1, 444 and 2.390 units/l at Kanpur, Allahabad, Varanasi, Buxer, Patna, Bhagalpur and Rajmahal respectively, while it was decreased to 3,649; 2,400; 434; 765; 365; 675; 936 units/l in the respective centres during 1995-96. But the abundance of pollution indicator species such as *Ankistrodesmus, Coelastrum, Pediastrum, Scenadesmus, Actinastrum* (under Chlorophyceae), *Cymbella, Cyclotella, Fragilaria* (under Bacillariophyceae) and *Anabaena, Lyngbya, Merismopodia, Spirulina*(under Cyanophyceae) was less in the lotic waters of Ganga during the present study which indicates better water quality. On the contrary, there is in general an increase in plankton density in the estuarine stretch in the present study as compared to pre-Farakka barrage period. This is positive effect of increased flushing of freshwater into the estuary after commission of Farakka barrage.

Macrozoobenthos

Available information on macrozoobenthic population in the entire Ganga is also very meagre barring the account of Pahwa, 1979. Considerable decline in the macrozoobenthic density was observed in the middle and lower stretches of the river Ganga. The present study indicated that maximum density of macrozoobenthos was 1,432; 418; 2,584; 1,709; 950; 889 and 319 unit/m^2 as compared to 21, 143; 3,436; 2,214; 264; 8,415; 473 and 1,859 unit/m ^{2} at Kanpur, Allahabad, Varanasi, Ballia (Buxer), Patna, Bhagalpur and Rajmahal (Manickchak). While many fold increase in macrozoobenthic density was recorded in the Hooghly estuarine stretches. In the upper stretch between Tehri and Kannauj, the macro-zoobenthic fauna varied from 18 to 4,598 u/m^2 and the population of Tehri was minimum in all the seasons which varied between 18 and 111 u/m^2 . It was also observed that occurrence of pollution indicator groups such as Oligochaeta, members of Ephemeroptera and Trichoptera was very negligible in the improved water quality of the river system.

Fishery

In the upper reaches of the Ganga from its source to Haridwar the fisheries are dominated by snow trout (Schizothorax richardsonii), mahseers (Tor tor, T. putitora), Catfish (*Bagarius bagarius*), *Labeo* spp. and *Garra gotyla*. The stretch between Tehri and Rishikesh of the upper Ganga was practically non fishing zone as there was no regular fishing activity in the area. Commercial fisheries assume importance in the middle (Kanpur to Patna) and lower (Sultanpur to Katwah) stretches of the river from Kanpur to Katwah. The important available fish species in the middle and lower stretches of the system are Gangetic major carps (*Cirrhinus mrigala, Catla catla, Labeo rohita, L. calbasu*), catfishes (*Aorichthys seenghala, A. aor, Wallago attu, Bagarius bagarius, Rita rita, Clupisoma garua, Eutropiichys vacha, Ompak pabda, Ailia coila* etc.), clupeids (*Tanualosa ilisha, Setipinna phasa, Gudusia chapra*), feather-baacks (*Notopterus notopterus*), other carps (*Labeo bata, L. dero, Cirrhinus reba*). On an average annual fish yield has fluctuated in the middle and lower stretches between a high 205.43 t and a low of 18.00 t during 1958 to 1995. The fish in the lower stretch at Bhagalpur have shown a sharp declining trend, both qualitatively and quantitatively (Table 2). The contribution of Indian major carps, the most valuable fishes, has gone down considerably. *C. catla* catch has drastically declined in the middle ganga. Proportionately, the contribution of catfish has increased in the total fish production in both-middle and lower Ganga. The abundance of certain commercially important species such as *N. chitala, L. fimbriata, O. pabo, O. bimaculatus, Pangasius pangasius* and *Mystus vittatus* was very less in middle and lower stretches of the Ganga river as observed in the present study. Considerable reduction in spawning grounds as well as lower degree of recruitment of IMC have also been observed in the middle and lower Ganga due to changes in river morphology, hydrography in terms of flow and flow rate, water abstraction for canal projects etc. and irrational fishing. Collapse of hilsa fisheries in middle and lower stretch, after commissioning of Farakka barrage in 1975, is also one of the main reasons for depletion of over all fisheries in the area. However, hilsa fisheries have shown some improvement during the last two-three years. In pre-Farakka barrage period (1958-74), the yield of hilsa at Allahabad ranged from 7.87 to 40.16 t, at Buxar from 7.38 to 113.36 t and at Bhagalpur 1.47 to 9.79 t. While in post-Farakka period the catch has declined to 0.13 to 2.04 t, 0.07 to 2.60 t and 0.01 to 2.18 t respectively at the above centres.

On the contrary, many fold increase in fish yield has been observed in the estuarine zone during post-Farakka barrage period. The average annual prawn and fish yield from the estuary increased from 9,481.5 tons during pre-Farakka barrage period (1966-67 to 1974-75) to 33,341 tons during post barrage period (1984-85 to 1994-95) and further to 42,703.2 tons during 1995-97. With the commission of Farakka barrage and higher flow of freshwater in the estuary, the general habitat for hilsa in the estuary has improved for its migration, breeding and growth, resulting in its increased landing from 1,457.1 tons in 1975 to 5,045.8 tons in 1995-97. The species now spawns in the entire freshwater zone of the estuary. Certain freshwater fishes and prawn species *viz. Eutropiichthys vacha, Clupisoma garua, Rita rita, Wallago attu, Aorichthys seenghla, A. aor, C. catla, Labeo bata* etc. have made their appearance in the entire upper estuarine zone upto Uluberia and these species were not reported prior to pre-Farakka barrage period upto this extent. The freshwater zone of the Hooghly estuary is a potential source of hilsa and prawn (particularly *M.*

rosenbergii) seed. Like freshwater zone of the estuary, lower marine zone is also considered as very potential for brackishwater prawn and fish seed resources. The seed of giant freshwater *M. rosenbergii* was also available in certain stretches of Sunderbans and gradient zone of Hooghly estuary where salinity range varied from 5 to 12 ppt during May to July. The present study also reveals that the gradual decline in catch per unit of effort in winter bagnet fishery of lower estuary which contributes over 70% of the total estuarine catch indicated over exploitation and is thus alarming.

The present study has conclusively proved a general improvement in the water quality (specially in dissolved oxygen) of river Ganga than what it was during 1985-90. The holistic sampling done during the present investigation has not indicated any marked pollutional effect in the river water as far as fish and fish food organisms (plankton and benthos) are concerned. Contrary to the expectations, a sharp continued decline in fish production, both qualitatively and quantitatively, alongwith other biotic communities (plankton and benthos), is clearly evident in the freshwater zone of the river above Farakka barrage. The probable causes of the same are I) high sedimentation of river bed upto Patna from Haridwar due to deforestation in the catchment areas which reduces the productivity, ii) increased water abstruction for irrigation and other purposes as a result there is general reduction in total volume of water in the system. iii) loss of original breeding ground iv) irrational fishing of the brood stock and juveniles and v) river course modifications have affected the migratory species. Sharp decline in fishery of hilsa above Farakka barrage, immediately after its commissioning, is a glaring example of river course modification.

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Table 1(a) Physico-chemical characteristics of water of the river Ganga during past and present

Para-meter	Haridwar		Kanpur			Allahabad			Varanasi			Ballia-Buxar			Patna		
	1984-85(i)	1995-96	1960(ii)	1985-90 (iii)	1995-96	1960 (ii)	1985-90 (iii)	1995-96	1960 (ii)	1985-90 (ii)	1995-96	1960 (ii)	1985-90 (ii)	1995-96	1960 (ii)	1985-90 (iii)	1995-96
Water temp. (°C	11.25-19.75	12.5-26.0	16.5-30.5	Na	16.0-30.0	17.5-31.5	Na	17.0-32.0	18.5-31.5	Na	20.0-31.5	18.0-31.0	Na	19.0-33.0	18.5-31.0	Na	19.5-31.0
pH	7.6-8.0	7.9-8.3	7.7-8.3	6.10-7.90	7.1-8.3	7.95-8.25	7.48-8.40	7.0-8.4	7.6-8.4	7.13-8.5	7.4-8.3	7.8-8.3	Na	7.3-8.3	7.7-8.2	7.8-8.0	7.2-8.8
D.O. (mg/l)	7.6-12.5	8.3-9.6	5.0-10.5	3.73-8.60	5.0-9.0	6.0-10.8	7.33-8.0	5.0-11.9	5.0-8.9	2.04-9.0	4.5-10.2	5.5-10.3	Na	3.4-10.0	5.4-8.6	4.7-7.9	5.0-10.8
Free CO_2 (mg/l)	0.75-4.65	Nil-3.0	0.6-4.5	Na	Nil	1.1-3.7	Na	Nil	Nil-6.5	Na	Nil-2.0	2.9-5.0	Na	Nil	2.25-10.0	Na	Nil-1.0
Phosphate (mg/l)	Na	Tr.	.067-0.21	0.01-2.10	Tr.-2.5	.09-.20	0.11-.32	Tr-0.8	.08-.12	0.12-0.73	Tr-1.0	.05-.12	Na	Tr-0.4	.07-.11	Na	Tr-.01
Nitrate (mg/l)	Na	0.01-0.24	.09-0.19	.08-1.90	Tr-0.24	.11-.22	.10-.33	.06-.24	.08-.14	0.16-12.49	Tr-.28	.08-.18	Na	Tr-.28	.09-.18	Na	Tr-.86
Silicate (mg/l)	Na	0.01-0.24	.09-0.19	.08-1.90	Tr-0.24	.11-.22	.10.33	.06-.24	.08-.14	0.16-12.49	Tr-.28	.08-.18	Na	Tr-.28	.09-.18	Na	Tr-.86

Na= Data not available

Source: (i) Khanna (1993), (ii) Pahwa & Mehrotra (1966), (iii) Anon (1997)

Fig. 1. River Ganga showing various sampling centres

Table 1 (b). Physico-chemical characteristics of water of the river Ganga during past and present

Parameter	Bhagalpur		Rajmahal (Manichak)		Hooghly Estuary								
					Uluberia			Roychowk (Diamond Harbour)			Kakdwip		
	1960 (i)	1995-96	1960 (i)	1995-96	1953-55 (ii)	1985-90 (iii)	1995-96	1953-55 (ii)	1985-90 (iii)	1995-96	1953-55 (ii)	1985-90 (iii)	1995-96
Water temp. (°C)	18.5-31.5	18.5-31.0	18.5-31.5	21.0-30.0	20.0-33.0	Na	19.9-28.5	18.0-33.0	Na	20.5-30.0	20.0-32.0	Na	22.0-30.4
pH	7.5-8.2	7.5-8.8	7.6-8.1	7.3-7.6	8.0	8.10-8.25	7.4-7.9	8.2	7.9-8.3	7.6-8.0	7.9	8.0-8.3	7.7-8.3
D.O. (mg/l)	5.2-9.1	6.2-8.2	5.0-8.9	5.9-8.8	2.3-4.6	4.8-7.3	5.8-7.2	2.1-6.8	6.9-7.6	6.4-7.9	3.4-5.1	6.1-7.8	5.9-8.2
FreeCO_2 (mg/l)	1.4-10.0	Nil-2.0	Nil-6.5	Nil-5.0	Na	Na	4.0-12.0	Na	Na	3.5-8.0	Na	Na	2.5-4.0
Phosphate (mg/l)	.06-12	.06-09	.07-12	.06-11	Tr	0.12-28	.05-0.10	Tr	08-16	06-0.08	Tr	.04-29	.07-.08
Nitrate (mg/l)	.09-15	.05-.09	.08-14	.05-12	Na	.03-12	.08-54	Na	.03-.06	.05-37	Na	.01-.04	.08-.24
Silicate (mg/l)	3.5-12.3	7.8-8.6	4.0-12.6	7.6-8.3	.09-.36	Na	6.4-7.2	.05-.20	Na	5.4-8.2	.04-.18	Na	4.8-5.9
Salinity (g/l)	-	-	-	-	0.5-14.0	Na	.04-.06	1.0-23.0	Na	.07-.39	2.0-31.0	Na	1.58-19.10

Na= Data not available; Source: (I) Pahwa & Mehrotra (1966); (ii) Bose (1956); (iii) Anon. 1977. A cost benefit analysis of the Ganga Action Plan- a draftreport

Table 2.Estimated averageannual landings (in t) of major groups of fishes at Allahabad, Patna, and Bhagalpur of the Ganga river system

ALLAHABAD								
Fish	**1958-59to 1965-66**	**(%)**	**1973-74 to 1985-86**	**(%)**	**1989-90 to 1994-95**	**(%)**	**1996-97**	**(%)**
M. Carps	91.33	44.5	40.44	28.7	11.04	11.5	4.94	8.3
Catfish	46.66	22.7	30.82	21.9	21.50	22.5	14.28	24.1
Hilsa	19.94	9.7	0.87	0.6	0.92	1.0	2.47	4.2
Misc.	47.48	23.1	68.79	48.8	62.10	65.0	37.61	63.4
Total	**205.43**	-	**140.92**	-	**95.56**	-	**59.3**	-

PATNA			
	1986-89	1990-93	1996-97
Total	**57.73**	**37.70**	**18.0**

BHAGALPUR						
Fish	**1958-59 to1965-66**	**(%)**	**1973-74 to 1983-84**	**(%)**	**1996-97**	**(%)**
M. Carps	16.60	18.2	10.06	10.8	7.31	20.4
Catfish	19.43	21.4	25.21	27.1	14.91	41.7
Hilsa	4.08	4.5	0.87	0.9	0.38	1.1
Misc.	50.82	55.9	56.96	61.2	13.20	36.8
Total	**90.95**	-	**93.90**	-	**35.70**	-

Source: Annual Reports, CIFRI,Barrackpore, West Bengal

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RIVERS COURSE MODIFICATION AND FISH PRODUCTION

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Introduction

Perhaps no aquatic system has been as significantly modified by human activity as have rivers and streams. Attempts to control the flow of rivers date back in time, and over human history and there has been a continuous increase in the variety of ways and intensity with which human kind has modified the physical, chemical and biological nature of running waters.

At present no large river of the world has been left unregulated. The year 1900-1980 saw the maximum building of dams all over the world. In 1970s the dams over 15 m in height were being completed world wide at over 700/year. It is estimated that, by the year 2000, over 60% of the total stream flow in the world will be regulated and historic connection between river and their flood plains would have been altered in many rivers of large and moderate size.

Physical effects of river modification

The effects of impoundment include a series of changes in the physical conditions downstream of the dam, especially modification of the flow and temperature regimes, and usually greater water clarity. The modified physical and chemical conditions result in changes in the plant and animal life of the river. In addition, reservoirs impede the downstream migration of young fishes, where dams are a barrier to upstream migrations. More indirectly, dams, and especially a series of dams breaks the upstream downstream connectivity that is natural features of rivers. Transport of suspended particles and the amount of fine sediments on the stream are affected by the reservoir and the rivers altered flow regime. Inflowing sediments settle out of suspension under reduced current velocities within the reservoir, sometimes leading to dramatic loss of water storage capacity.

River diversion projects have exerted a very bad impact on rivers channel. The glaring example of river diversion for irrigation is that of Aral sea (Central Asia). Since, 1960, the lake level has dropped 15 m, its surface area has shrunk by 40%, its volume by 60% and the salinity level has trippled. The system yield was 44000 metric tonnes in the 1950s but its fishery has since collapsed and all 24 natural species of fish have disappeared. The former Soviet Union had planed to reverse the flow of three north flowing rivers (Ob, Irtysh and Yenisei) for diverting 120 Km^3 of water annually some 2200 km to central Asia, partly to off set changes to the Aral sea.

Another example of diversion of river is that of taming of Colarado river (America), about nine storage reservoirs built in its basin have a collective storage capacity of roughly four times on long-term average virgin flow of $18.5 \times 10^a m^3$ (15 ma f and practically, no flow has entered the Gulf of California since1961. Today, the mighty colarado ends in a pipe in Tiajuana, 225 Km north of its natural terminus.

The biological effects of water diversion are not as well documented as those of dams. However, canal systems facilitate invasion by non native species, surely are of their most serious consequence.

Fish culture in reservoir

The resource

However, some good effect of river damming is the resultant "artificial lake" commonly known reservoir. These resources can be profitably used for fish culture if scientifically managed. The fish culture prospect in the reservoirs in the Indian scenario is described in the discussion that followed.

A large number of multipurpose reservoirs on natural streams have come up in India at a galloping pace particularly after independence. The reservoirs arbitrarily can be classified as small (<500 ha) medium (1000 to 5000 ha) and large (<5000 ha). The area of the reservoirs due to increased developmental activities is increasing year after year. At present, the area under reservoirs is more than 31lakh ha. There, are 1900 small (1,485557 ha), 180 medium (527541 ha) and 56 large reservoirs (1,140268 ha). The reservoirs may be shallow or deep. The production from large reservoirs is very low (20 kg/ha/yr) while from small reservoirs is comparatively higher (50kg/ha/yr).The reason for this frustatingly low production is unscientific management. The productivity of reservoir is governed by a host of factors: such as climatic, edaphic and morphometric. The geographic location affects the metabolism of a reservoir through nutrition supply, shape of the basin and the efficiency with which the climatic factors are able to act in the dynamic exchange. The small reservoirs being small and shallow are biologically more productive per unit area while reverse is true for the large reservoirs. The main differences between small and large reservoirs are summarised in Table 1.

Table 1. The differences between a small and large reservoirs

(After Jhingran 1965)

Small reservoirs	Large reservoirs
Single-purpose reservoirs mostly for minor irrigation	Multipurpose reservoirs for flood-control hydroelectric generation, large-scale irrigation etc.
Dams neither elaborate nor very expensive. Built of earth, stone, masonary work on small seasonal streams.	Dams elaborate, built with precise engineerings kill on perennial or on seasonal rivers. Built of cement, concrete or stone.
Shallower, biologically more productive per unit area. Water-weeds commonly observed in perennial reservoirs but absent or scanty in seasonal ones.	Deep, biologically less productive per unit area. Usually free of aquatic weeds. Subjected to heavy draw downs.
May dry up completely in summer. Notable changes in the water regimes.	Donot dry up completely, changes in water regimen not so pronounced. Maintaining a conservation-pool level.
Sheltered areas absent.	Sheltered areas by way of embayments. coves, etc. present.
Shore line not very irregular. Littoral areas mostly gradually sloping.	Shore line more irregular. Littoral areas mostly steep.
Oxygen mostly derived from photosynthesis in these shallow, non-stratified reservoirs lacking significant wave action	Although photosynthesis is a source of D. O. the process is confined to a certain region delimited by vertical range of transmission of light (euphotic zone). O_2 also derived from significant wave action.
Provided with concrete or stone spillway, the type and size of its structure depending on the run off water handled.	Provided with much more complex engineering devices.
Breeding of major crops in variably observed in the reservoir above the spill way.	Beeding mostly observed in the head waters or in other suitable areas of the reservoir.
Can be subjected to experimental manipulations for testing various ecosystem responses to environmental modifications.	Cannot be subjected to experimental manipulations.
Trophic depression phase can be avoided through chemical treatment and draining and cycle of fish production can be repeated as often as the reservoir is drained.	Trophic depression phase sets in.
The annual flooding of such reservoirs during rainy season may be compared to over flowing flood-plains. Inundation of dry land results in a release of more	Loss of nutrients occurs which get locked up in bottom sediment. Reduction in benthos also occurs due to rapid sedimentation.

nutrients into the reservoir when it fills up, resulting in high production of fish food through decomposition of organic matter, predominantly of plant origin leading to higher growth and survival.	
Through complete fishing or over fishing in such seasonal reservoirs, no brood stock is left over to contribute to succeeding year's fishery through natural recruitment. The fish population has to be built up solely through regular stocking. there is thus established a direct relationship between stocking rate and catch per unit of effort.	In contrast, prominent annual fluctuations in recruitment occur and balancing of stock number against natural mortality requires excessive number of fingerlings in such large reservoirs. Their capture requires effective exploitation techniques.

Characteristics of the lacustrine ecosystem

Construction of dams dramatically change riverine habitat both upstream and downstream of the river farming new artificial aquatic environment. The quality of impounded water varies from watershed to watershed and within the water shed, depending on soil, climatic conditions and human activities. It also varies with shape of the reservoir basin, exposure to light and wind action and the amount of water change. Owing to these variables although generalisation about the productivity of reservoirs can be made evaluation of specifics of water quality have to be made separately for different set of families of reservoirs sharing the similar eco-climatic conditions.

For successful fish farming in man-made lakes, it is a must to know proper understanding of the alterations the impoundments has caused in the environment and organisms. The fish food organisms characteristics of riverine system are replaced by lacustrine forms. Soon after impoundment, there occurs a phase of high fertility caused by a nutrients leaching from the submerged vegetation and other organic matters. This accelerate the growth of the bacteria, phytoplankton, zooplankton and benthos. The maximum productivity in newly filled reservoirs is attained within the first few years of their existence. However, this production is not sustained for long and within a period of few years (1-7), it declines to much lower level, partly due to diminution of bottom leaching as volume of impounded water increases and partly as nutrients are used up by aquatic vegetation when it becomes established in greater quantity. The productivity ultimately gets stabilised near half the magnitude of initial phase.

Determinants of biological productivity

Biological productivity of a impoundment is influenced by a host of factors such as climatic, edaphic and morphometric. The geographic location affects the metabolism of reservoir through nutrition supply, shape of the basin and the efficiency with which the climatic factors are able to act in the dynamic exchange. They will have varying effect on final productivity. The climatic factor has a profound effect on the utilization of nutrients in the particular lake basin, the lower temperature retard the fish growth while the high accelerate. The edaphic factors affects the supply of dissolved nutrients in the reservoir water. Soil basin quality influences the reservoir productivity to a great extent. Area, mean depth and regularity of shore line are the most important morphometric measurements having a significant bearing on the proudctivity of impoundment. The important abiotic factors that may influence the productivity of various trophic levels are listed in Table 2.

Table 2. Range of physicochemical features in reservoir ecosystems

Parameters	**Range of values**		
	Low productive reservoir	**Medium productive reservoirs**	**Highly productive reservoir**
A. Water			
pH	< 6.0	6.0-8.5	> 8.5
Carbonates (ppm)	<35.0	35-80	>80.0
Alkalinity (ppm)	<40.0	40-90	>90.0
Nitrate available (ppm)	Negligible	Upto 0.2	0.2-0.5
Phosphates (ppm)	Negligible	Upto 0.1	0.1-0.2
Total dissolved solids (Sp. Cond. micromhos cm^{-1})		Upto 200	>200
Temperature (^0C) (With minimal stratification: i.e.,>5.0)	18	18-22	22
B. Soil			
pH	<6.5	6.5-7.5	>7.5
Available P (mg 100 g^{-1})	<3.0	3.0-6.0	>6.0
Available N (mg 100 g^{-1})	<25.0	25-60	>60.0
Organic carbon	0.5	0.5-1.5	1.5-2.5

(after Jhingran, 1991)

Options for management policies in large and medium reservoir

A thorough understanding of ecological conditions alongwith existing fish population in the reservoirs located in different agroclimatic region of the counry is a must for their scientific management. The management policies for stabilizing fish populations and increasing yield are generally grouped under 3 categories (I) the manipulation of habitats (ii) the regulation of fish population, and their food supply, and (iii) the regulation and control of fisheries (Bhukaswan, 1980). To achieve the above objectives, it is desirable to know changed pattern of fish populations in reservoirs such as the formation of fish population, fish population dynamics, the abundance of fish in the stocks and their biomass, and maximum yield which the reservoir could maintain.

The reservoir fisheries is basically extractive in nature and policy for its development is mainly based on capture lines *i.e.* stock monitoring vis-a-vis fishing effort. Sometimes stocking become essential to widen species spectrum and to correct the imbalance in utilization of different ecological niches by the commercial species. During first 2-3 years of impoundment, reservoir pass through a 'trophic burst' characterised by abundant supply of fish food organisms. This is the best time for stock manipulation by introducing desirable species with special emphasis on fishes with shorter food chain (Indian major carp). Any lapse in this important management policy may likely result in proliferation of weeds fishes on account of trophic burst and these fishes in turn may provide the forage base for catfishes. Moreover, trash fishes like *Ambassis nama, A. ranga, Osteobrama cotio* and *Gadusia chapra* compete with *Catla catla* for food and reduce latter's productivity. Similarly, some carps minnows compete for food with *Cirrhinus mrigala, Labeo rohita* and *L. Calbasu* (Natarajan et al., 1976).

The whole situation becomes undesirable because of considerable energy dissipation at all levels from primary resource to catfishes, stocking also become necessary to correct situations coming out of erratic breeding of desirable fishes. Sometimes, even after successful breeding the offsprings fail to survive due to certain unfavourable features of reservoir morphometry (Govind & Khan, 1969). Thus an imperfect understanding of the ecology of the reservoirs has set in train a new set of unfavourable biological equilibrium in which weed fishes and catfishes dominate.

Selection of suitable species for stocking

Fish farming in artificial lakes largely consists of selection of suitable species for stocking at the initial stage and at a latter stage reservoirs could be developed into capture fisheries. Therefore, it is imperative that the stocked fishes breed, resulting in autostocking. Management involving persistant stocking escalate the input costs.

Primarily selection of fishes for stocking is based on the assessment of existing biotic communities and their efficiency in covering primary trophic resources to harvestable products.

Reservoir management in India largely emphasizes on the development of carp fishery, especially the Indian major carps. These fishes by virtue of their feeding habits close to primary producers and their fast growth rate are indispensible in reservoir management. But at the same time Indian major carps are ill equipped to utilize the phytoplankton, the most dominant component of plankton in reservoirs. Hence, a suitable indegenous fish like Sandhkol carp (*Thynnichthys sandhkhol),* a native of Godavari basin which subsists on algae may be given a trial in north Indian reservoirs Though the exotic silver carp is an excellent phytoplankton feeder but their introduction in Indian water is still a subject of controversy due to the possible adverse effects on the indigenuous fauna. *Pangasius pangasius* is suitable for the reservoir rich in molluscan fauna. Similarly, *Puntius* group are known to consume insect larvae, macrovegetation and molluscs. *Mystus cavasius* and *Ompok bimaculatus* which subsist on insects and molluscs are also desirable additions. For reservoir situated at higher altitude and with cold water regime, the fishes like *L. dero, Tor* spp. *Schizothorax* spp and *Orienus* spp are suitable. Trout has been stocked in some of the impoundments in Nilgris. *Tilapia mossambica* has shown great promise in a few reservoirs in Tamil Nadue but they proved harmful to carp fishery. Great caution is to be observed before this fish is considered for stocking in the reservoir in India.

A rate of 250 fingerlings per has been recommended for reservoirs without catfishes and 600 fingerlings (6" in length) with rich catfish population. But for new reservoirs, the stocking rate should be at higher level (1,000 kg/ha). Irrational stocking of fingerlings had a deleterious effect on reservoir fisheries. However, a rational approach for formulating stocking policy is through estimation of potential fish yield of the reservoir and adjustment of stocking rate in such a manner as to obtain the yield close to the potential productivity.

Fishing and mesh regulation

Reservoirs that have converted into autostocking reservoirs offer lasser problem in their management. In such cases the management measures involve deployment of optimum fishing effort and selecting right type of gear. Raising the fishing effort to the optimum, coupled with monitoring of stock abundance by catch per unit of effort, is a recognized tool for improving stock productivity. Such type of management has paid rich dividens in Bhawani Sagar and Govind Sagar reservoirs.

Finally, it may be concluded that for integrated development of reservoirs continuous supply of stocking material is a must for which construction of fish farm attached to reservoir should get a priority and their functional operation should be under supervision of dedicated workers, otherwise, it would become defunct as the case is at present with most of the reservoir attachad with fish farms.

Extensive aquaculture in small reservoir

The aquaculture, practiced in these impoundments, may be described as *'extensive'*, where cultured fingerlings are raised in water bodies with few or no modification of the habitat. This is in contrast to the intensive culture practised in ponds raceways etc. where abiotic and biotic components are under control. The capture and culture fishery principles grade into each other in small reservoirs where the fishery depends on stocked fingerlings.

Stocking policy

Stocking of fish in small reservoirs has proved to be a useful tool for developing their fisheries potential. Stocking of economically important, fast growing fishes from outside is aimed at colonizing all the diverse niches of the biotope for harvesting maximum sustainable crop from them. This widespread management practise has been proved to be highly remunerative in such small water bodies where almost complete annual harvesting is possible. This has amply been demonstrated in Gularya, Bachhra and Baghla reservoirs (U.P.) and Aliyar reservoir in Tamil Nadu (Table 3). Stocking is not merely a simple matter of releasing of appropriate species into an ecosystem but needs evaluation of an array of factions *viz.,* biogenic capacity of the environment, the growth rate of the desired species and the population density as regulated by predatory and competitive pressure.

During summer months, small reservoirs either dry up completely or else the water level in them gets so drastically reduced that through over fishing no brood stock is left over to contribute to the succeeding years fishery through natural recruitment. Consequently, the entire catch from these water bodies depend on the fishes stocked from outside to offset this loss. There is thus established a direct correlation between the stocking rate and catch per unit effort in such heavily fished waters (Jhingran *et al.*, 1981, Khan *et al.,* 1990). Stocking is therfore a useful tool for the management of small reservoirs where stocks can be maintained at levels higher than the natural carrying capacity of the environment through supplemental fertilization. The number of fish to be stocked per unit area was to be based on the natural productivity of the system, growth rate of fishes, natural mortality rate and escapement through the irrigation canal and spill-way.

Table 3. High yields obtained in small reservoirs due to management based on stocking from (*modified after Sugunan, 1995*)

Reservoirs	State	Area ha.	Stocking rate mo ha^{-1}	Yield Kg ha^{-1}
Aliyar	Tamil Nadu	650	353	194
Meenkara	Kerala	259	1226	107
Chulliyar	Kerala	159	937	316
Gularya	Uttar Pradesh	300	517	150
Bachhra	Uttar Pradesh	140	763	140
Baghla	Uttar Pradesh	250	-	102
Bundhk Beratha	Rajasthan	-	164	94
Chapparwara	Rajasthan	200	300	79

Determination of stocking rate

Stocking in small reservoir is mainstay of fisheries management in these water bodies and is therefore of utmost importance. The stocking rate can be calculated based on the average growth rate of the individual fish and the expected production and using the formula (Huet, 1960).

$$\text{stocking rate} = (\text{no. of fingerlings ha}^{-1}) = \frac{\text{Expected production (kg)}}{\text{Av. Individual growth rate (kg)}} + \text{loss due to mortality and escapement (\%)}$$

Planning criteria

A systematic and integrated approach towards scientific studies and planning criteria for undertaking fish culture in small reservoirs should have an understanding of the following factors.

1. The reservoir morphometry and water resident time
2. The physico-chemical characteristics of water and soil
3. The animal and plant inhabitants
4. The relation between the inhabitants and the physico-chemical aspects of the environment in terms of population and community dynamics.

General consideration

1. Since the breeding of the major carps has been repeatedly observed to take place above the spill way, resulting in heavy escapement of the brood, this poses a serious problem for building up stocks of desirable fishers in such reservoirs. The situation is further worsened by heavy escapement of fingerlings and adults through irrigation canals. Development of fisheries in such water bodies, therefore requires suitable screening of the spillway and the canal mouth. Such protective measures have already been installed in Loni, Bachhra, Baghla and Gulariya reservoirs and have paid rich dividends in enhancing the fish yield from these reservoirs (Table 3).

2. In some of the reservoirs fishes have also been observed to move up the spillways into the reservoir whereas in others the spillways provide an insurmountable barrier to fish moving up the dam. To minimize losses by way of escapement of fish through spillway and canal, it would be an economic proposition to have an annual cropping policy so that the reservoir is stocked in August-September and harvested by June end next year.

3. Vegetation should not be planted in the reservoir, since the wrong kinds can chocke up the reservoir and the canal.

4. Methods for predator control and check of weed fishes are already available in literature.

5. Extensive aquaculture in small reservoirs can also play an important role in integrated rural development since it can be profitably combined with duckery and piggery.

Summing up, it may be stated that small reservoirs occupy a unique position in limnology analogous to field plots used in agriculture science *ie.* a means of assessing effects of environmental modifications on the ecosystem on a reduced scale.

Socio-economic consideration

It has become necessary to impart certain measures of stability to fish production in reservoirs since wide fluctuations in yield rates result in consequent rise or fall in income of those who toil on water. The fishery potential of the reservoir is largely under utilized and it is well witness by prevailance of low productivity, low income low saving and almost complete absence of inventory building process. The exploitation policy ought to have twin objectives of development and conservation. Even, a cursory look of the existing leasing systems indicate lack of development bias further, imperfections of marketing system have also contributed to shrinkage in fishermen's returns. Presently earning of fisher folk is lower than those unskilled form workers though risks and uncertainties in catch and incomes are much more in their case. Therefore, there is an urgent need to evolve a package approach comprising stocking monitoring programme equitable and just royalty arrangements, marketing intervention by cooperatives and corporations and quick distribution channels.

Conclusion

It is evident from above that presently obtained production from reservoirs in the country a major existing resource simply because of its magnitude, is much below its potential Sugunan (1995) has compiled the present level of fish production and potential of different categories of reservoir in the country. It is evident there from that presently existing reservoirs fishery resource in the country has the potential to yield 2.4 lakh tons of fish, with modest targets of average production, if managed on scientific lines. Moreover, it holds maximum promise in view of the fact that this is the least tapped resource at present and that this is the only fishery resource whose hectarage is bound to go up with the increase in population and resultant development activities.

Due emphasis on reservoir fisheries development, following scientific management techniques evolved and providing necessary infrastructure support, is a must both for quantum jump in inland fish production and economic well being of fishers involved.

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ENVIRONMENTAL ISSUES IN RELATION TO RIVER BRAHMAPUTRA - A FISHERIES PERSPECTIVE

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Introduction

River Brahmaputra, originating from the snout of Chemayungdung mountains about 100 km South East of Lake Mansarovar at an altitude of 5150m, runs for about 1250 km in a shallow valley through Tibet before entering India near Tuting, in Arunachal Pradesh. The river travels a distance of nearly 160 km in Arunachal as river Siang or Dihang and then enters Assam at Saidiya where it joins two equally important trans-Himalayan tributaries Dibang and Lohit. After meeting with these tributaries the river assumes the name Brahmaputra. All along its 720 km stretch in Assam the river is joined by a number of tributaries on both the banks, each one of them having their own ecological setup. The combined length of the river together with 47 important tributaries is about 4,000 km with a catchment area of 5,80,000 km^2 and annual average water discharge of 5,10,450 Mm^3.

Man made environmental modifications and dumping of huge quantity of industrial and sewage effluents have not only damaged the ecological set up but also reduced the fisheries potential of many of the Indian rivers. The situation is so alarming that it has become common concern of the environmentalist all over the world. It is in this back ground an attempt has been made in the present comunication to examine the magnitude of the impact of environmental degradations on the fisheries of "moving ocean of North East".

Water quality (Changes over the years)

The most significant variation among physical factors is the clarity of water which has shown considerable decline year after year. The water transparency, which was 150 cm during 1974-77, has been reduced to 30 to 40 cm during 1997-98. The reduction in transparency is a clear example of increasing silt load in the system. Other water quality parameters like pH, dissolved oxygen, total alkalinity, specific conductance, dissolved solids, calcium, hardness and nutrients have not shown any significant variatioin over the years. The quantum of discharge of industrial and sewage effluents at various points is negligible in comparison to the vast sheet of water and fast current of the river, and, it has practically no impact on the water quality. Even, the industrial effluents from oil refineries at Guwahati or the city sewage brought and discharged into the river through Bharalu get diluted at the confluence point itself and the water quality below the discharge point did not show any significant change. It needs to be mentioned that tributaries play key role in maintaining the annual water quality cycle of the main river and increase in turbidity over the years is due to the discharge of huge quantity of silt into Brahmaputra by these tributaries year after year. No significant change in other water quality parameters over the years clearly indicate that there has been practically no qualitative degradation in the tributaries or the main river so far as water quality is concerned.

Anthropogenic impact on environment and fisheries

(i) Deforestation and soil erosion in the catchment area

Large scale deforestation in the region has possed sever threat to the environment. Except Arunachal Pradesh where at least 61% of the geographical area is still under forest cover, the existing coverage in Nagaland (17.34%), Meghalaya (37.0%) and Assam (25.4%) portray a disimal picture. Mass destruction of forest cover for timber and fire coupled with shifting and jhoom cultivation not only disturb the delicate balance of forest ecosystem but also lead to erosion of the top soil bringing high silt load in the river basin. Observations in Assam hills indicate that atleast 10 cm of the soil is washed away even from moderate slope in each jhoom cycle. The problem of soil erosion is more acute in the North bank due to heavy deforestation in Arunachal Pradesh and Bhootan foot hils and general topography of the land being 3 to 5% slope towards Brahmaputra valley. As a result of man made degradations in the environment these tributaries carry and discharge huge quantity of silt in the main river. Observatioins have shown that the annual average silt discharge by North bank tributaries into Brahmaputra is of the order of 666.7 m^3 km^{-2}. Due to accumulation of huge amount of silt, the Brahmaputra bed is rising alarmingly. Siltation in tributaries and the main river has become such a serious problem that many of the tributaries often change their path. Jiabharali and Morabharali, Noadihing and Burhidihing are clear examples of this phenomenon. Due to this the natural breeding grounds of fishes are lost.

Heavy siltation, drastic reduction in water volume and loss of breeding grounds are some of the major factors responsible for decline in fisheries of Brahmaputra including its tributaries.

(ii) *Habitat destruction in flood plain lakes*

The problems of potentialities of river Brahmaputra can be viewed in totality only with the inclusion of flood plain lakes, locally known as beels. Almost 70 to 80% of the total lentic waters of Assam State is represented by beels. Being an integral part of the river ecosystem these beels serve a vital spawning ground for major carps as their easily accessible shallow areas provide optimum breeding conditions. There are about 1392 beels in the State covering an area of 0.1 million hactares and fish harvest from these beels have been considered as a renewable natural resource available for fish exploitatioin. Of late the developmental activities in the river basin specially in relation to irrigation and flood control, indiscriminate and unscientific construction of sluice gates as well as excessive siltation of connecting channels or lake mouth have led to severing of links with the main stream. As a result of these activities the natural breeding ground is lost. The loss of connection of beels, with the main river or with tributaries not only prevents the wetlands from autostocking but also leads to failure of recruitment in the river itself. As a result of which there is severe decline of fishery in the beels as well as main river. Studies in the beels of Dhemagi and North Lakhimpur districts have shown that these beels get connected with the river Subansiri during flood season and are autostocked by the river year after year. As a result of this autostocking these beels have shown very high productions and the fishery structure of beels and Subansiri river is almost same.

(iii) *Mass destruction of juveniles*

Heavy exploitation of spawners (Ujaimare fishing) during breeding season and subsequent fishing of juveniles does the maximum damage to the natural recruitment process. The landings pattern from Brahmaputra have shown maximum fish catch during September and October (almost 60% of the annual landing). Bulk of the catch recorded during these months is due to large scale fishing of carp juveniles (70 to 80%). Mass destruction of juveniles results in failure of natural recruitment of the quality fishes which ultimately leads to decline in the overall fishery of the river.

(iv) Application of explosive materials for fishing

Many tributaries of river Brahmaputra used to harbour good quantity of prized fishes like Mahseer, trout and many cold water species. The tributaries Jiabharali, Manas Subansiri were good attraction for tourists and were famous for Mahseer angling. But use of explosive materials for killing these fishes in the upper reaches and indiscriminate fishing have completely damaged the fishery of these rivers. The situatioin has become very critical and the stock of these prized fishes in many of these tributaries have severely declined.

Qualitative shift in the fishery structure of river Brahmaputra

The qualitative variations in the fisheries of river Brahmaputra over the years in the stretches between Tezpur and Dhubri have been presented in Table-1. At Tezpur during 1974-77, the fishery was mainly represented by major carps (21.03%), Minor carps (15.65%) and catfishes (26.08%), the three together contributing almost 62.7% of the total catch. The contribution of miscellaneous and trace fishes was only 24.87%. But with the passage of time the complexion has changed and during 1996-98, the major carps have declined to 11.5%, minor carps to 3% and trace fishes have gone upto 52.4%. Hilsa which formed 4.42% of the total catch, has reduced to almost zero.There has been considerable decline in the total catch from 137.45 $kgday^{-1}$ to 93.2 $kgday^{-1}$. At Guwahati during 1973-79 major carps contributed 18.66%, minor carps 14.56% and catfishes 21.09%, the three together contributing almost 54.3% of the total catch. The contribution of Hilsa and miscellaneous species being 13.74% and 24.01% respectively. Observations in 1996-98 have shown considerable change in the catch structure with major carps declining to 15.2%, catfishes 8.7%, Hilsa 3.01% while miscellaneous and trace fishes have increased to 52.0%. At Dhubri observations during two and half decades have shown decline in major carps from 18.41 to 14.2%, Minor carps from 12.23 to 1.5%, catfishes 24.11 to 15.8%, Hilsa from 15.5 to 3.4%, while miscellaneous species have increased from 20.02 to 59.5%. The fish yield has declined from 302.85 $kgday^{-1}$ during 1973-79 to 198.7 $kgday^{-1}$ during 1996-98 at Guwahati and from 150.48 to 120.2 $kgday^{-1}$ at Dhubri. These observations have clearly indicated that there has been considerable variations both in the quality and quantity of fishery with passage of time.

Conclusion

Studies in the entire Brahmaputra system have shown that there is no threat on the ecological status and fishery from industrial and sewage effluents as observed in case of many Indian rivers but other man induced environmental modificatioin have great bearing on the fishery of the river, which has shown severe decline with passage of time.

Qualitative shift in the fishery structure of river Brahmaputra over the year

Percentage composition of Major groups of fishes	Tezpur 1974-77	Tezpur 1996-98	Guwahati 1973-79	Guwahati 1996-98	Dhubri 1973-79	Dhubri 1996-98
Major groups of fishes						
Major carps	21.03	11.5	18.66	15.2	18.41	14.2
Minor carps	15.65	3.0	14.65	16.4	12.23	1.5
Catfishes	26.08	18.2	21.09	8.7	24.11	15.8
Feather backs	4.18	10.1	4.2	4.0	2.32	3.4
Hilsa	4.42	0.0	13.74	3.0	15.51	3.4
Prawn	3.86	3.2	3.74	0.7	7.4	2.3
Miscellaneous & trace Fishes	24.87	52.4	24.01	52.0	20.02	59.5
Average catch ($kgday^{-1}$)	137.45	93.2	302.85	198.7	150.48	120.2

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the catchment area of our national riverine assets. Deforestation can be considered as the eminent culprit , leading to enhanced siltation and flash floods which invades the ecological cycle by impacting the benthic function.

The " River Continuum Concept" encompasses the role of its different components being the landscapes, tributaries , distributaries etc. as river continuum and has gained reputation with regard to management of the river basin as a single entity . This has assumed greater relevance at present due to conflicting uses at different levels of continuum components. As such, the scientific management of river mainstream alongwith its continuum components is *sine qua non* for a meaningful endeavour towards sustainable development.

Owing to great potential of the Narmada River Basin for developing multi-purpose resources ,the three riparian States namely Madhya Pradesh , Maharashtra and Gujarat have embarked upon a comprehensive resource development plan involving commissioning of 30 major dams on the main course and 2825 medium and minor impoundments on tributaries etc.The turpitude of such enormous impoundment plan has triggered an animated debate and certain apprehensions regarding the sustainable development have been expressed at different levels.

Sardar Sarovar Project (SSP) entailing construction of a high dam (FRL 138.68 m), a large network of canal system and provision of sophisticated reversible turbine system is being commissioned at a distance of 161 km from the estuarine mouth. Commensurating with the pace of development of SSP and other upstrem projects , the downstrem of SSP will experience freshwater crunch. The freshwater availability at the downstream has been precisely documented in the Narmada Water Dispute Tribunal (NWDT) award. The lower estuarine extent is surrounded by a score of townships and large industrial complexes on both the banks and this will further compound the whole scenario involving environmental degradation, bio-diversity shift and decline in biological production functions. Keeping in mind the above consequences , let us conceptualise and scan the impact of anthropogenic invasions in the form of catchment and river course modifications on the fishery spectrum of riverine ecosystems from global perspective.

2.0 Impact of catchment and river course modifications associated with the variations in land use patterns, on the fishery and its conservation

The anthropogenic invasions lead to a host of impacts owing to changes in land use patterns as well as habitat modifications .We go for an exercise of inventory preparation of such constraints leading to environmental degradation of our river systems by and large and these are :

2.1 Deforestation

Denudation of forests for agricultural practices and fuel in the catchment area lead to soil erosion and accelerated rate of siltation of river basins. “Zoom” or shifting cultivation practice involving clearing of forests of hills by the tribal inhabitants in Narmada basin has accelerated the pace of deforestation. Walker(1983) has categorically identified flow regulation , siltation and clearing of river banks and associated agricultural practices as the major constraint affecting the fisheries of the river basins. Senanayak and Moyle(1982) have attributed loss of endemic fauna to the extensive conversion of forests for tea and rubber plantation in Sri Lanka. Petr (1983), while documenting tropical forest loss to the tune of 1 million ha yr-1 has specified this as the major impact exerting event leading to environmental degradation.Based on the satellite imagery, our country is losing tree cover at a rate of 1.3 m. ha yr-1 and this has affected the annual siltation rate of a number of reservoirs. The report prepared by Irrigation Commission has projected the observed annual siltation rate of 41.27 mcm against the assumed rate of 28.36 mcm in Bhakra dam. Similarly, the observed annual siltation rate for Ukai reservoir was seven times more than the assumed rate.

The manifestation of high silt load exerting negative pressure on the freshwater ecosystem is summarised as follows :

- cause high turbidity and affects primary production, leading to decline in fish production
- smothers/destroys spawning grounds, exerts deleterious impact on benthic organisms, cause gill chocking and limits the ability to locate food, and confines the fish fauna.

2.2. Agricultural inputs

Excessive and irrational use of fertilizers, pesticides and weedicides as agricultural inputs affect the fisheries. The washings from such agricultural fields using high doses of fertilizer lead to eutrophication, followed by negative seral changes. The weedicides and pesticides may prove toxic to fish and their accumulation (biomagnification) in tissues of fish adversely affects the health of such fish consumer. This non-point source of pollution has quite adverse ramifications.

2.3. Mining

The mining operations starting with excavation of ores followed by processing exert negative impact on the habitat, as follows : discharge toxic substances and contaminated wastes(tailing, slime-charged water and leacheates), water abstraction, mine wastes exert mechanical impact, and biomagnification of heavy metals in fish tissue:

2.4. Township development

With the development of civics amenities and other facilities , population settlements take place and leads to release of domestic sewage which causes organic enrichment at the receiving site.The receipt of such organic rich effluents at accelerated pace, initially causes eutrophication followed by piling of organic load leading to negative successional stages.The population explosion has led to manifold magnification of hazards due to generation of enormous quantity of domestic refeuse.

2.5. Industrialization

This generates considerable quantity of industrial effluents depending upon the type of industry. The toxic nature of such effluents causes heavy mortality of young as well as adult fishes. The pollutional load in the form of composite effluents confines the biota and as such adversely affects the ecosystem function. The industries discharging effluents containing heavy metals are more injurious since these are biomagnified in the fish tissue.

2.6. Damming

The ecological transformations following the impoundment of any river may be indifferent, harmful or beneficial. The dams and other such structures may cause obstructional or ecological effect. The dams acting as physical barrier, are detrimental to the migration of fishes by constraining their accessibility to breeding and nursery grounds. The damming also brings in comprehensive morpho-ecological changes both above and below the dam site and these changes are :

(a) Fluviatile biocoenoses are succeeded by lentic ones and the hydrography undergoes a shift by ways of : Fluctuation in water level, Aberrations in hydro-biological regime, and Inundation of spawning and feeding grounds.

(b) Tail-end dams constructed over estuaries or near to it, exert negative pressure on the estuarine ecology due to restricted freshwater discharge, resulting in further tidal ingress and increase in salinity regime. The creation of multi-purpose resource bring in changes in prevailing land use patterns.

The Narmada River System has also experienced most of the above referred constraints and as such , these have led to modifications in its catchment and mainstream.

3.0. The global fishery scenario vis-a-vis the catchment and river course modifications.

A host of large river basins in the world have undergone ecological aberrations due to change in land use patterns associated with the water resource development exercise.

In river, Thames, habitat modification due to water abstraction, sewage and industrial pollution has affected the fish diversity reducing the fish community to 16 species with the dominance of cyprinids, *Alburnus alburnus* and *Rutilus rutilus* and there has been decline in *Salmo salar* and *Osmerus eperlanus.*

There has been recorded almost complete extermination of *Acipenser sturio* in river Vistula as a result of combined impact of dam, channelisation and overfishing.

The fishery of anadromus cyprinid, *Vimba vimba* also suffered due to obstruction caused by the dam. In river Volga which experienced a cascade of dams, the fishery constituted *by O.eperlanus* and *Clupeonella delicatula* became the most conspicuous fraction.

Pollution, channelisation followed by impoundment have resulted into disappearance of 22 fish taxa in river Rhine while 77 fish species were pushed under rare category . *S. salar, Alosa alosa* and *Platichthys flesus* are now not encountered.

The fish taxa, *S. gilae* and *Lepidomeda albivallis* have become extinct from Colorado river as a result of damming, water abstraction and sub-basin water transfer. Other species viz. *S. apache*, *Gila cypa, G. elegans, G.robusta, Moapa coriacea and Plagopterus argentissimus* are endangered.

A chain of dams on Missouri river like the proposed on river Narmada, has affected the fish fuana. *A. fulvescens, Scaphirhyncus albus and Hybopsis meeki* and *H. gelid* are endangered while *Polyodon spathula, S. platorhynchus, Cycleptus elongatus* and *Maxostoma macrolepidotum* are scarce.

Impounding of Tenessee river and its tributaries has changed the fish faunal assemblage. *P. spathula* has been adversely affected. But the changed environment has benefitted *Lepomis sp. , Microptorus sp.*(game fish). *Cyprinus carpio, Ictiobus sp., Minytrema spp., Ictalurus spp. Aplodinatus sp., Dorosoma sp.,Morone chrysaps, Stizostedion sp.,and Promoxis* sp. and these have attained dominant status in storage reservoirs of the tributaries.

In Stanley reservoir, the predominant fish, *Puntius dubius*, a gravel spawning species has completely disappeared due to smothering of breeding grounds by fine silt. This is available only in the upper limits of the Bhavanisagar reservoir , which may be attributed to the partial destruction of gravel spawning beds. Anicuts in Cauveri and Godavari river systems have adversely affected the anadromous migration of *Tenualosa ilisha* (Sundar Raj,1942 , Sreenivasan, 1976 and 1977). After the commissioning of Farakka barrarge,*T.ilisha* fishery of Ganga (Biligrami and Dutta Munshi, 1979)has experienced set back.Mahseer represented by *Tor khudree* and *Acrossocheilus hexagonolepis* have disappeared from the Cauveri system due to habitat modifications consequent to construction of Stanley and Bhavanisagar reservoirs. *Cirrhinus cirrhosa* fishery has also declined. Catfishes *like Pangasius pangasius* and

Silondia silondia have declined significantly while the contribution of cat fishes *Mystus aor* and *Wallago attu* has increased. *Labeo kontius* and *L. fimbriatus* have become rare, but the damming has not affected the fishery contributed by *Anguilla sp* and *Mastacembelus armutus*. The fish *Puntius carnaticus* has disappeared (Sreenivasan,1976) from Tirumoorthy and Amaravathy reservoirs

Ansari (1977) has reported the decline of mahseer fishery due to smothering of spawning grounds and obstruction created after the commissioning of Tarbela reservoir on Indus river in Pakistan even after well functioning fish ladder in Chasha barrage. Modifications in fish fauna are also documented from Murray Darling basin in Australia (Walker,1983).

Following major considerations emerge after exploring and assessing the resultant fishery consequent to catchment and river course modifications.

(a) *Fish faunal assemblages do undergo transformation following impoundment, which can not be generalised since each system has its own specific characteristics,*

(b) *Over-exploitation followed by damming has led to decline in fish stock , and*

(c) *Habitat modification initially due to varied land use patterns followed by sealing of river are detrimental. Denudation of forests and other anthropogenic pressure in the form of agricultural, municipal and industrial wastes play catastrophic role.*

3.0 Impact of catchment and river course modifications on the fisheries of river Narmada

For having an insight into the impact of catchment and river course modifications on the fisheries of river Narmada, we will have to firstly look into the envisaged "Master Plan" conceived by three riparian States, besides taking into consideration other anthropogenic invasions associated with the change in land use patterns.

3.1. The envisaged Narmada River Basin Development Plan .

Harnessing of the potential of river basins to create multi-purpose reservoirs has been the integral component of country's Five Yearly Plans. These resources offer promising abodes for development of fisheries which is non-consumptive user of water and is also the most eco-friendly component.

Owing to ideal altitudinal gradient, the Narmada river basin provide high prospects with regard to resource development. The entire Narmada basin shall be tapped under a comprehensive programme leading to multi-purpose resource development (Fig.1). This plan encompasses commissioning of 30 major projects , 188 medium irrigation and about 2637 minor schemes. The major projects entail 21 irrigational, 5 hydel and 4 multi-purpose projects .Ten of the major projects are sited on the main river course while the rest have been proposed on the tributaries. The comprehensive details of the proposed projects are portrayed in Table1. The relative position of important projects have been offered in Fig.2.

The conceived "Master Plan" incises whole of the Narmada river basin area, as follows :

1. Upper zone, 2. Middle zone, and 3. Lower zone

Zone wise break-up for the envisaged project is offered in Table 2 and this reflected that the highest submergence will be in the lower zone followed by middle and upper but numerically, the middle zone shall have the maximum concentration of dams. The completion of the proposed water resource development plan will bring the Madhya Pradesh State in the forefronts so far as the reservoir fishery resources (2, 67,421 ha. based on FTL+MDDL / 2) are concerned.

4.0 The Emerging Narmada Basin Scenario

A number of projects are in different stages of completion which vary in water spread from 505 to 91,340 ha. and presently, four reservoirs namely Tawa and Sukta on the left bank tributaries, Barna on the right bank tributary and Bargi on the main-stream have already been completed. Sardar Sarovar Project(SSP) is the ultimate dam on the mainstream in Gujarat. and this has attained the dam height of 85.3 m under above mentioned Master Plan. The envisaged " Master Plan" for developing multifaceted resources involve *Compound Impounding* with a cascade of dams on the main stream and a lateral chain of dams on the tributaries etc. The accomplishment of such a comprehensive resource development plan will transform whole of the Narmada river basin into big , medium and small spreads of water associated with profound ecological consequences.

The Government of Gujarat has recently coined another ambitious project namely " Khambhat Gulf Development Project" (Kalpsar Project) and propose to erect a 34.0 km. long dam connecting the east and west banks of the Gulf of Cambay. This dam will be located between Ghogha on the Saurastra bank and Luhara , south of Dahej on the eastern bank and will be extended upto Aliabet island by crossing the Narmada estuary near Hansot. As such, the proposed developmenatal process will practically seal the mouth of Narmada estuary. The ecological repercussions of such exercise will be enormous.

5.0 The Fishery of River Narmada in space and time

Hora and Nair (1941) were the pioneer to provide the informations on the ichthyofaunal assemblage of river Narmada and recorded 40 species from the hill streams joining the Narmada river in Satpura range under Hoshangabad District. Karamchandani et al.(1967) have recorded 77 species inclusive of 11 recorded by Hora and Nair (op. cit.) by confining their survey to Hoshangabad area during the pre- and post -monsoon period of 1959-64. The Department of Fisheries, M.P. executed an extensive survey of River Narmada at Hoshangabad, Jabalpur, Maheshwar, Khalghat and Omkareshwar during the pariod 1967 to 1971 and 46 fish taxa were recorded. Rao et al.(1991) have undertaken pre-impoundment survey at Punasa , Omkareswar , Mandleswar, Maheswar and Barwani pertaining to the western zone of the river and have enlisted 84 fish species.

With the view to trace the changes in the fishery spectrum of river Narmada in space and time, a comparison of available fish catch statistics from 1959 to 1990 has been considered. A comparative statement relevant to fish catch statistics of above referred periods is portrayed in Table 3.

A perusal of data pertaining to the periods 1959-64 , 1971 and 1990 did not reflect any significant change in the catch composition and the carp fishery varied from 58.20 to 65.46% , while the contribution of cat fishes fluctuated from 21.8 to 35.92%.

The carp fishery was invariably dominated by *Tor tor* (25.30 to 30.10%) and was followed by *Labeo fimbriatus* (18.54 to 24.40%). The latest data base on the fish catch statistics has been generated as a result of execution of " Exploratory Survey of river Narmada" from its origin to its culmination in Gulf of Cambay by CIFRI,Barrackpore. Based on this survey, the carp fishery(23.40 to 62.23%), was by and large the most conspicuous component and was closely followed by cat fishes (18.34 to 43.30%).The secondary informations regarding the state of fish production as compared to yesteryears were collected and this inferred that there has been significant decline in fish production over the years.. The mahseer fishery earlier represented by three species , is now mostly contributed by *T . tor only ;* and *T. khudree* and *T. putitora* have become quite rare. There has been recorded decline in mahseer fishery(5.15 to 15.6%) as compared to the periods,1971 to 1990 (25.30 to 30.10%). The estimated inland fish production offered by the Commissionerate of Fisheries, Gujarat also indicated that the mahseer fishery have declined from 330 t in 1992-93 to meager 53 t in 1996-97 (Table.4). A perusal of the data pertaining to the collection of fry and fingerlings undertaken during the period 1987-88 to 1995-96 by the Department of Fisheries, M.P. concluded a drastic decline(77.60%) in the mahseer fry availability which possibily has been caused by the disruption of breeding and nursery grounds of mahseers, as evident from the fact that Tawa, a major tributary of river Narmada which used to offer congenial breeding and nursery grounds is now dammed resulting into negative habitat modification .

The expolratory survey of river Narmada has also identified a score of "Hot Spots" bringing in domestic and industrial effluents. The river is also used for religious ferver and the devotees in large numbers use river for bathing and release enormous amount of offerings This sort of loading is bound to degrade the riverine environment.M/s Shaw Wallace Gelatin Factory and Security Paper Mill effluents confluencing the river at Bhedaghat, Distrist Jabalpur (M.P) and Dongarwada,District Hoshangabad (M.P) respectively have made the river environment , susceptible to environmental degradation although at this juncture, the impact is confined to outfall site . This survey has also revealed that fishing by resorting to small meshed monofilament gill nets locally called " Disco net" and by using the dynamite and agricultural poisons like Demicron, Thiodiaton and Rogor are extremely injurious and such practices have degraded the riverine ecosystem leading to further jolt to Narmada fishery including mahseers. Habitat modification and over-exploitation including indiscriminate fishing of juveniles and breeders have led to this state-of-the-affair. It is high time to plan judiciously a management package for reviving the most prized mahseer fishery before it is too late. It is heartening to note that mahseer fishery is already established in a number of lacustrine environments (Sampna ,Harsi, Tigra and Sukta reservoirs in Narmada basin , Walwhan and Shivajisagar on Koyana river) although with varied abundance. This may open new vistas in the annals of mahseers conservation by resorting to artificial propagation of mahseers under a well conceived scientific management programme .

6.0 Impact of impoundment on the fishery of Narmada estuary

The natural flow of the river is moderated by commissioning of a dam and regulation of flow due to varied uses of water results in the containment of freshwater availabilty at the downstream environment including the estuary.This leads to negative impact on the estuarine environment.

Narmada estuarine system contributes 14250 ha (67.12%) out of the total estuarine extent of Gujarat State being 21230 ha. As such , this is the greatest fishery resource in the State of Gujarat and enjoys promising fishery potential. The estimated average annual fish yield of this important fishery resource varied from 11,148 to 13,954 t. ***Tenualosa ilisha*** and ***Macrobrachium rosenbergii*** constitute the prime fishery of this resource.

The impact of impoundment may be categorised as follows :

6.1 Sedimentation

Studies on sedimentation rate (Anon, 1983) based on 20 years data led to the conclusion that SSP dam will retain 96% of the sediment and will allow only 4% of the sediment transported through the outflowing water. The role of dams as check dams is well recognised and this will be manifested by reduction in allochthonous addition of nutrients at the downstream .With the completion of upstream projects, the downstream including the estuarine expanse will experience further reduction in nutrients availability leading to considerable decline in biological productivity at the downstream of the SSP dam including Narmada estuary.

6.2 Freshwater crunch

The fresh water availability at the downstream of the SSP dam has been precisely documented in the Narmada Water Dipute Tribunal (NWDT) award which prescribes the freshwater availability to the tune of 15.90 MAF at 10th year, 4.34 MAF at 30th year while at 45th year from the commencement of construction the fresh water release from SSP dam will cease. As such, the downstream will experience chronological increasing stress conditions in consonance with the freshwater availability.

The prevailing average total annual flow based on 10 years data(1981-1990) is 23.68 MAF. The average flow during the 4 months of monsoon is computed to 21.25 MAF whereas the same for the rest of 8 non-monsoon months is 2.43 MAF. In other terms . monthly average for the monsoon months is 5.31 MAF while the same for the non-monsoon months is 0.30 MAF.

Keeping in view the three scenario defined by NWDT award, the stage to be attained at 10th year from the commencement of construction , when total annual flow will be to the tune of 15.90 MAF, is safe and no major impact is apprehended. Of course, the efficiency of silt-deficient water in containing the tidal ingress will get subdued. Stage to be attained at 30 years from the commencement of construction will experience drastic reduction(72.71%) in fresh water availability at the downstream.This will involve non-attainment of annual event of dilution during the monsoon months when 89.74% of total annual flow is received. This monsoon event is associated with the anadromous migration of *Tenualosa ilisha* , as such, the *Tenualosa* fishery shall experience severe impact leading to significant decline in estuarine total fish catch.Farakka barrage over river Ganga has adversely affected the migratory hilsa fishery and this decline has been estimated to the tune of 95.16% at Allahabad and 80% at Bhagalpur during pre and post 1972 period (Jhingran,1989). Such instances of constrained hilsa migration has also been reported by Ganapati(1973) from Godavari and Cauveri rivers. The commissioning of Ukai dam on river Tapti has also affected the hilsa fishery . The reduction of flow from the river Nile as a result of construction of **Aswan High Dam** was reflected in the drastic depletion of the Sardine fishery(Baxter,1977). With the enhancement in salinity regime, the prestigious fishery contributed by *M. rosenbergii* will also get impacted. Stage to be attained at 45th year from the commencement of the construction will be very critical as this shall be associated with steep hike in salinity regime with further tidal ingrees towards inland side. The fishery not tuned to such enhanced salinity will succumb to such pressure.The major fishery contributed by *T.ilisha* and *M. rosenbergii* will have repercussions. There will be total collapse of prevailing floodplains providing congenial breeding and nursery grounds to the fishes. Mangroves will also be affected and the rich fishery supported by them will undergo drastic change. This will also have an impact on the marine fish production since many marine fishes use them as nursery grounds .

6.3 Pollution

The studies undertaken by Vadodara Centre of CIFRI have identified two "Hot Spots" at the lower estuarine expanse. The combined GIDCs at Ankaleswar and Zagadia release their composite effluents at Sakkarpura point, District Bharuch ; and at Baijalpur site, domestic sewage and industrial effluents are discharged from Bharuch City. . The impact of such un-treated effluents is visualised on the Narmada estuary With the curtailment in freshwater availabilty coinciding with the second and third stage, the diluting , flushing and transporting of waste function in the Narmada estuary will get imperilled. This will have comprehensive impact on the estuarine environment leading to stressed conditions resulting into sub-dued biological production function. Mathematical modelling has been initiated to evaluate the tidal ingress and residency time of effluents in the estuary and this approach will enable an answer to the above malady.

7.0 The Message

The resource development exercise envisaged for the Narmada River basin is likely to exert immense pressure on the environmental status of this valley.The proposed compound impounding of the basin will ruin its' fluviatile nature and this will be characterised by water spreads of different shapes and dimensions.The newly conceived project " Khambhat Gulf Development Project(Kalpsar) will exert profound negative impact on the inland as well as marine fishery. From fisheries perspective, there are certain bright areas in the form of increased hectarage under reservoir fisheries development but there are gloomy areas as well , as detailed in the foregoing account. This state-of-the-affair can well be attributed to the lack of interaction among the different developmental agencies with isolated management approach . A holistic and integerated approach is the key to the sustainable development.

There is a need to identify and define the impact of a score of factors arising out of variations in the land use patterns consequent to execution of resource development exercise.Moreover, with the view to assess the magnitude of impact in consonance to changes in land use pattern, chronological evidences need to be gathered so as to identify the negative processes and for this , scientific monitoring in time and space is essentially required. This will also help in scanning the biodiversity shift in response to the operating anthropogenic interferences and may be used as an effective alarm system to switch over to restorational practices by conceiving a relevant " River Health Restorational Programme". This programme need to be conceived on "River Continuum Concept" so that impact on any river continuum component is addressed well in time so as to prevent from possible future maladies.

Pertaining to the socio-economic impact, it is seen that the degraded aquatic environment snatch away the breads of its dependents and exert negative impact on the society by inflicting various erratic ramifications. These "Eco-refugees" as a result of environmental degradation migrate to the urban area and exert pressure in the form of slums, un-hygeinic condition etc. , leading to a score of vagaries of life including social disturbances .There is urgent need to change the mindset of the people to make them environmentally conscious so that they utilise the precious aquatic resources judiciously and participate effectively in ensuring the environmental protection of our natural wealth. We invite you all from this forum to make this earth worth sustaining . This is not an impossible task but definitely requires a will to perform accordingly.

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Table 1. Proposed Major Reservoirs in Narmada River Basin

Name of Project	Loocation of dam (Km)	River bed level at dam site (m)	Proposed: Max.Reservoir level (m)	Proposed: Full Reservoir level (m)	Proposed: Dead Storage level (m)	Capacity of Reservoir: Gross (M m3)	Capacity of Reservoir: Live (M m3)	Submergence (ha)
On Main River								
Upper Zone								
Upper Narmada	77	701.00	732.13	731.52	720.85	0.249	0.203	3043.23
Raghavpur (H)	135	597.41	649.04	648.04	631.35	0.319	0.252	2370.00
Rosra(H)	206	499.87	552.69	551.08	529.74	0.559	0.497	3200.00
Basania(H)	252	435.56	482.41	481.80	460.25	1.911	1.799	14201.00
Middle Zone								
Bargi (M)	378	366.98	424.13	422.76	403.55	3.921	3.181	27296.00
Chinki(H)	489	316.99	348.84	348.08	342.59	1.012	0.475	11107.00
Lower Zone								
Narmada Sagar(M)	845	176.78	263.35	262.13	243.23	12.220	9.750	91348.00
Omkareshwar(M)	899	159.83	198.12	196.60	193.54	1.141	0.299	9393.00
Maheshwar(H)	947	138.99	171.25	162.76	162.20	0.483	0.028	4856.00
Sardar Sarovar	1163	22.86	140.21	138.68	110.64	9.462	5.823	37030.00

Table 2. Zone-wise break-up of the proposed major reservoirs

Zones	Proposed reservoirs on main river		Proposed reservoirs on tributaries		Total	
	Nos.	Area at FRL (ha)	Nos.	Area at FRL (ha)	Nos.	Area at FRL (ha)
Upper Zone	4	22814.23	3	10024.74	7	32838.97
Middle Zone	2	38303.00	13	49275.97	15	87578.97
Lower Zone	4	142627.00	4	4376.37	8	147003.37
Total	10	203744.23	20	63677.08	30	267421.31

Table 3. Comparative percentage composition of fish landings in river Narmada

Fish species	Karamchandani et al. (1967)	Anon (1971)			Rao et al. (1991)
	Central Zone	Eastern Zone	Central Zone	Central Zone	
Carps					
1. *Tor tor*	28.00	25.30	30.10	28.10	25.87
2. *Labeo fimbriatus*	19.70	21.50	24.40	22.10	18.54
3. *L. gonius*	0.30	1.10	-	-	0.48
4. *L. calbasu*	4.10	3.50	-	5.00	5.42
5. *L. rohita*	-	-	-		0.36
6. *L. dyocheilus*	1.60	-	-	1.20	1.31
7. *L. bata*	1.70	1.40	2.90	1.30	1.40
8. *Cirrhinus mrigala*	2.50	1.20	1.80	2.70	2.71
9. *C. reba*	0.50	-	-	-	0.48
10. *Catla catla*	0.60	0.60	-	0.40	0.81
11. *Puntius spp.*	-	-	-	-	2.15
12. *P. sarana*	1.40	3.60	3.50	4.60	-
Total	**60.40**	**58.20**	**62.70**	**65.40**	**59.53**
Cat fishes					
13. *Rita spp.*	-	-	-	-	12.60
R. pavimentat	10.20	6.40	3.00	4.70	8.18
14. *Mystus seenghala*	9.00	8.20	10.30	5.60	4.84

Table 3. Continued .....

Fish species	Karamchandani et al. (1967)	Anon (1971)			Rao et al. (1991)
	Central Zone	Eastern Zone	Central Zone	Central Zone	
15. *M. aor*	4.70	6.50	9.10	6.80	7.70
16. *M. cavasius*	0.30	-	-	-	0.68
17. *M. tengra*	-	-	-	-	0.36
18. *Wallago attu*	7.70	10.50	4.40	3.90	-
19. *Clupisoma garua*	1.80	-	0.80	-	-
20. *Ompok bimaculatus*	0.40	-	-	0.80	1.56
Total	**34.10**	**31.60**	**27.60**	**21.80**	**35.92**
Miscellaneous					
21. *Channa spp.*	3.70	4.20	2.00	2.60	1.88
22. *Mastacembelus spp.*	1.30	1.90	-	3.10	1.64
23. *Notopterus notopterus*	0.50	-	-	-	0.70
24. Other small fishes	-	4.10	7.70	7.10	0.33
Total	**5.50**	**10.20**	**9.70**	**12.80**	**4.55**
Grand Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Table 4 . Species-wise estimated inland fish production (in tonnes)

Sl. No. Name of fish	Y 1992-93	E 1993-94	A 1994-95	R 1995-96	S 1996-97
1. Catla	3686	4888	8132	6753	7653
2. Rohu	4304	6580	8462	7870	9351
3. Mrigal	2868	3919	5102	5094	5883
4. Calbasu	72	52	763	91	133
5. Minor Carps	118	186	65	116	147
6. Wallago attu	1460	968	1040	1657	2167
7. Scorpion	77	65	77	194	165
8. Murrels	826	952	813	1383	1646
9. Cat fishes	4722	5743	2807	3590	5162
10.Bombay Duck	466	475	1380	480	582
11. Hilsa/ Clupids	11086	15319	5995	9346	8849
12. Mullets	2605	1715	1685	2260	2626
13. Eels	126	255	55	850	445
14. Prawn (Shrimp)	4971	6196	12152	6984	6373
15. Prawn (Medium)	6102	8425	11960	1143	2391
16. Prawn(Jumbo)	0	0	0	600	475
17. Crab	48	31	33	26	32
18. Mahseer	**330**	**152**	**103**	**133**	**53**
19. Bokti	618	237	316	333	203
20. Levta	356	213	212	649	603
21. Misc.	6313	8648	8948	10606	10339

Courtesy - Commissionerate of Fisheries, Gandhinagar , Gujarat

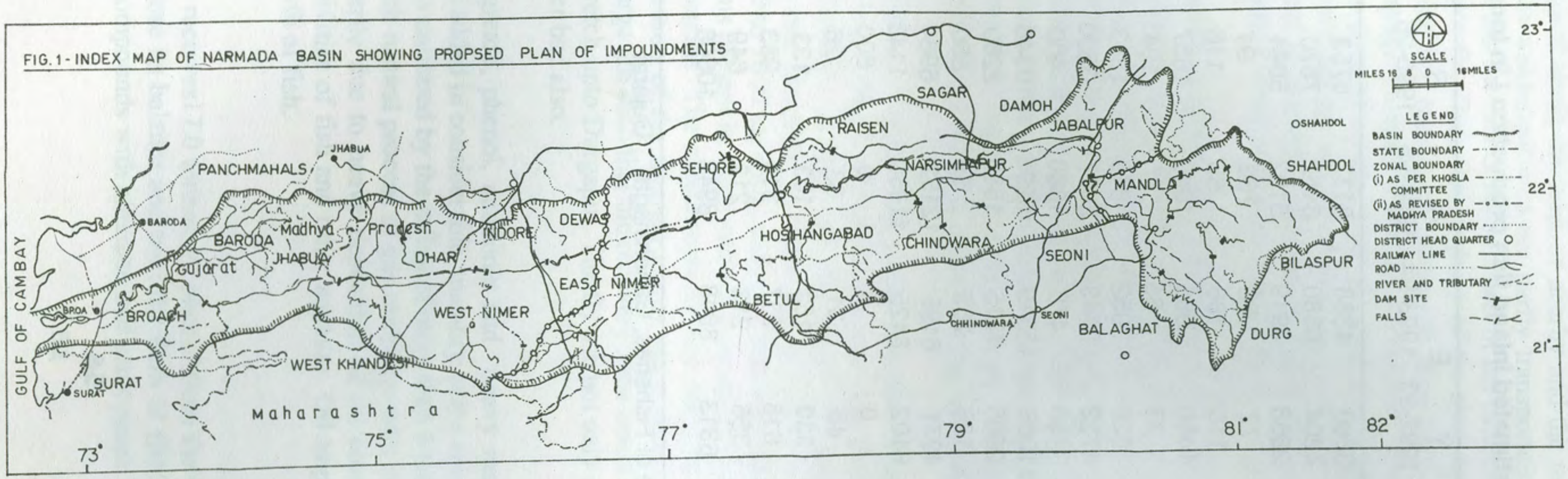

FIG. 1 - INDEX MAP OF NARMADA BASIN SHOWING PROPSED PLAN OF IMPOUNDMENTS

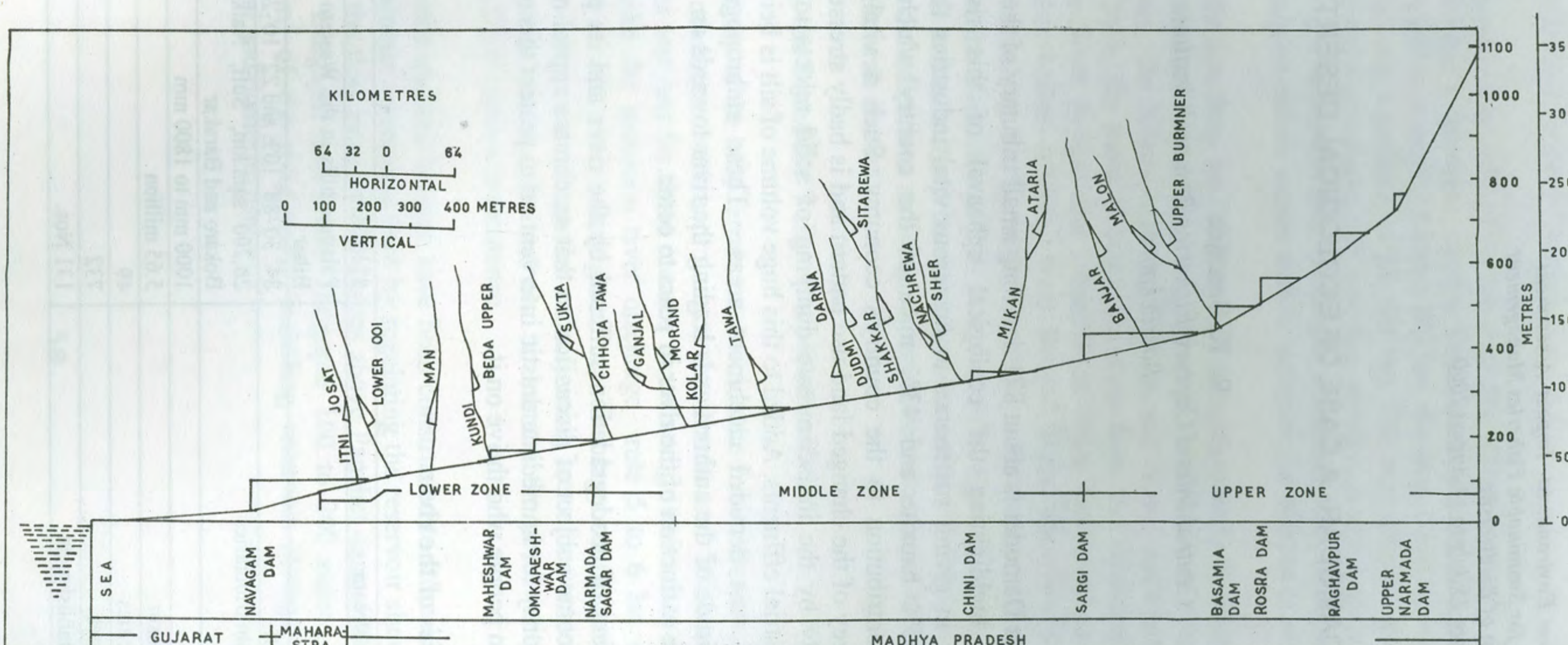

Fig. 2 Longitudinal section of Narmada River showing major proposed projects.

*Summer School on **Environment Impact Assessment of Inland Waters for Sustainable Fisheries Management and Conservation of Biodiversity***
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RIVER DAMODAR- A CASE OF ECOLOGICAL DESERTIFICATION

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The river Damodar is about 871 km long small tributary of the river Ganga. The relevencey of highlighting the ecological upheaval of this rivulet lies in its indispensibility in giving sustenance to numerous vital industries that produce about 37.2% coal, 35% bauxite and 43% mica of the country which obviously have considerable contribution to the country's economy. Such a vital watercourse has become easy prey of the changed land use pattern and is badly stressed both physically and ecologically by the indiscriminate dumping of solid rejects together with huge volume of industrial effluents. Added to this huge volume of silt is being drifted into the river from the vast denuded catchment areas. These anthropogenic activity and indifference attitude of the authorities is leading the river towards an ecological desert and might invite extinction of the river in years to come.

The extent of ecodegradation suffered by the river and its possible causative factors have become subject of discussion so that an enmass appeal might reach to the competent authority for immediate drastic intervention to protect this natural wealth and save few million people who thrive on it.

Physical features of the river

Length of the main stream	871.0 Km
Origin	Palamau hills in the Western region of the State of Bihar
Geographic location	84° 30'-88° 10'E and 22° 10'-24° 50' N
Catchment area main tributaries	26,200 sqm.km, Sufi, Nalkari, Bhairavi, Konar, Bokaro and Barakar
Rainfall	1000 mm to 1800 mm
Population of the basin	5.65 million
No. of towns and cities	49
No. of live coal mines	732
Major industrial establishment	131 Nos.

Topographical features of the river course

Damodar flows nearly 72% of its run over the valley where the surface soil is physically sandy having a thickness varying from half meter to one meter over the rocky base. From origin to a length of about 280 km, the river flows between elevations 700 and 190 meters with a gradient of 2m per km. The next stretch upto Raniganj, a length of about 105 km lies between 190 and90 m elevations with a gradient 0.6 m per km that reduces to 0.4 m per km near Burdwan. From Burdwan town downwards the river becomes a sluggish deltaic stream with a bed level 1in 5000 m or less.

The Damodar runs from the Palamau hills in south easterly direction forming the boundary between the Ranchi and Hazaribagh districts. In Bokaro, the river receives the fork twin tributaries, the Konar and the Bokaro and flows eastward through the Dhanbad district. Here, for some distance the river form the boundary between the districts Purulia in West Bengal and Dhanbad in Bihar and receives the principal tributary the Barakar before entering West Bengal. Here, the river flows in south easterly direction enmarking the border of the districts Bankura and Burdwan. This is the widest stretch of the river (about 2500 m wide). After a run of about another 80 km through Burdwan it makes a sharp bend southwards and divides into many channels. The main channel dwindles into an insignificant stream and joins the Hooghly river near Shyampur in Howrah district.

The Damodar and the Damodar Valley Corporation (DVC)

The topography of the hilly terrain over which the river flows is characterised by the denuded vast catchment with a prolonged dry season and followed by turbulent monsoon spell, that last just for three months contributing more than 90% of annual rainfall together hike the monsoon river discharge rate 5 to 6 lac cusecs from a minimum flow rate of 200 cusecs during summer. This huge on rush of water used to inundate the lower valley of the Damodar and adjoining areas for centuries. In order to minimise this perennial catastrophe and also to harness the potentiality of this huge influx of water the DVC came into existence.

Five reservoirs and one barrage have been constructed to store 1270 million m^3 of water and to maintain a perennial flow by regulating the reservoir sluices. Efforts are made to maintain the flow rates of 570 cusecs above Panchet dam, 430 cusecs for the next stretch upto Durgapur and below Durgapur 100 to 200 cusecs. A volume of 2870.92 million m^3 of the river water including reservoir storage is utilised for irrigation, industrial and domestic use.

Barrier format and water utilisation

Major reservoir	5
Barrage	2
Check dams	200
Canal	2495 Km
Reservoir storage capacity	439.42 million m^3
For irrigation	1455.59 million m^3
For industrial use	419.00 million m^3
For domestic use	502.00 million m^3
Total	**2870.92 million m^3**

The taming of the river has resulted in marked development of the entire valley in industrial and agricultural aspects that ultimately leads to the national economic gain. The judicious distribution of the river water by the DVC has made it possible to irrigate 0.4 million hectares of land. However, any human intervention over any natural ecotope has always proved to be detrimental and the river Damodar is no exception to that.

The functioning of the DVC has drastically changed the land use pattern and the nature of the catchment area of the entire valley. The population along the river course has increased many fold with rapid urbanisation. While the blocking of the natural river course by dams, barrage, check dams canals etc. has disturbed the riverine ecology by sudden reduction of normal flow, which upsets the natural physiology of the aquatic communities.

The major detrimental effect of the intermittent water abstraction is the increased rate of silt deposition on the entire water course. Poor land management denuded catchment areas with favourable contour and high intensity of down pour together have augmented the rate of silt deposition at an alarming scale. The rate of sedimentation being far in excess of the rate worked out at the time of reservoir construction, the calculated life span of the reservoirs has markedly reduced. The river bed upto the upper deltaic zone(Burdwan town) is already covered with thick layer of sand with the formation of frequent sand dunes, resulting in fast reduction of the carrying capacity of the river. This continuous process of silt deposition is endangering all the normal aquatic life. The river bed is becoming devoid of nutrients as well as microflora and fauna the food for the higher aquatics. The gorges and pools, so called sanctuaries for the bigger fishes are getting silting up. Thus, the heavy rate of sedimentation is destroying the breeding and spawning grounds of various fish communities with the result of marked reduction in fish population and diversity.

Industrialisation

Along with with DVC other existing industries are flourished and many new industries have crop up. At present the Damodar hosts, 742 live coal mines, 15 coal washery, 5 steel plant, 9 thermal and 3 hydel power stations in addition to the numerous factories in Asansol and Durgapur Industrial complexes. It is to say that Damodar host maximum number of industries per unit length compared to any other river in India(Map-1). In fact Damodar gives vitality to the industries that produce 310 million tones of coal, 80 million tonnes of steel and 2000 MW of thermal and hydel power. Unfortunately, the resiprocation is reverse. The industries are mainly responsible for the river's rapid languidness, as they discharge indiscriminately their solid rejects and toxic effluents.

The stretch between the confluence of Nalkari river and Damodar upto Durgapur receives 1,11, 700 MLD of industrial effluent loaded with TSS 3403; TDS 938; COD 203; Phenol 18.2; ammonia 17.9; oil & grease 6.76; and heavy metals (mainly Fe, Cu, Zn, Pb, Cr & Cd) 1.79 tonnes per day.

The Asansol industrial complex drains only through Nunia Khal 7000 KLD of effluent into the river that bear TSS 1.08; Phenol 0.2; ammonia 1.8; COD 2.16 and oil & grease 0.5 tonnes perday.

While Tumla Nallah the main out let of the Durgapur industrial complex drain 122.13 million litres of effluent into the Damodar per day that carries 49.1 t COD; 49.3 t TDS; 18.2 t TSS; 2.34 t ammonia;1.61 t phonol, 7.6 t nitrate and 1.27 oil & grease.

The human settlements that have come up on the eastern bank of the river from Bermo to Burdwan town discharge 273.134 MLDF of municipal effluent with 174.43 tonnes BOD load per day. A details break up of the effluent loading is depicted in Table 1.

Urbanization

The Industrialisation and mining operations have intensified the human settlements mostly on the eastern bank of the river. Population in Bihar is 3.05million and in West Bengal 2.6 million. On account of this population load, the municipal discharges amounting to 273.154 MLD of effluent with 174.43 tonnes of BOD load directly or indirectly degrades the river water every day.

Impact of the eco-toxicant on the river course

Enormously huge quantum of non degradable solid waste is getting continually dumped over the major stretch of the river bed from the Nalkari confluence point to Durgapur. The open cast mines contribute 7,000 million tonnes and the coal washeries 3.7 million tonnes solid waste per year, while the thermal power plants add 12,108 tonnes of fly ash per day. Apart from these the huge volume of industrial effluents, expelled in to the river, deposit 4420 tonnes of suspended solids on the river bed. The solid rejects dumped along the bank or nearby and the thick layer of fly ash that get deposited over the catchment area are partly transported into the river course by the monsoon runover but the rest cover vast part of the catchment areas making it sterile for any vegetative growth. Thus, the virginity of the river bed already covered with sand and silt is lost. The bed remain no longer the store house of nutrients and fail to take part in the exchange proesses with the supernatant water. The denuded catchment becomes the easy prey of erosion both by wind action and by monsoon precipitation and the eroded particles get deposited over the river bed. The ultimate impact of this enmass deposition is marked reduction of the river's water holding capacity with continuous tampering of the ecological equilibrium.

The Damodar stretch between Rajrappa and Panchet reservoir is under serious threat due to ingress of coal washery effluent. It imparts brownish black colour to the river water, the high concentration of coal dust (av. TSS 400o- mg/l) in the effluxion reduces the water transparancy lower than 10 mm, the euphotic layer of the river water is reduced to a minimum and the bed being blanketted with few mm thick coating of coal particles becomes unproductive. When the banks get exposed with the lowering of the river flow rate, they are found to be covered with thick matting of coal particles making them unsuitable as breeding and spawning grounds for fish and other aquatics.

Incessent flow of enormously huge volume of fly ash into the river both as slurry and as air borne dust is of serious concern. The dust before being wet enfilm the surface of the fluviatile system and disconnect the gases equilibrium between the atmospheric and that dissolved in water *viz,* O_2, CO_2, N, etc. The ash particle has a surface area 7000 to 9000 sq, cm/g, and, thus had high adsorbing capacity. Thus the fly ash adsorb the ions present in water and settle on the river bed making them unavailable to the aquatic biomass. The suspensoids chokes the gills of fishes and destroy of the benthos. The location of the thermal plants, their outfall points and as well as their volume of discharge are such that the recovery zone could hardly be identified over the entire riverine stretch upto Durgapur. The fly ash not only endanger the aquatic biomass but raises the river bed also.

Oil and grease, phenol, ammonia and heavy metals are the major chemical toxicants that are added in considerable quantity in the ecosystem through the effluents. The eco-system is enfilmed by the influx of more than 6 tonnes oil and grease every day that interferes with natural process of gas exchange with the atmosphere. The river bed tending to be sterile due to heavy deposition of oil coated fly ash. Oil disturbs the physiological activities of fish and other aquatics. Oil imparts negative effect on eggs, embryo and growth of fish.

The river receives17.0 tonnes of phenol from the industrial discharges. Phenol causes a fish to lose its balance and taint the flesh of fish. The undissociated molecule of phenol form compounds with albumen and protoplasm. Analysis of variance reveals that the toxicity of phenol affects not only the secondary producer but to the tertiary producer also. Phenol and ammonia apart from their self toxicity form a toxic unit the heavy metals.

Heavy metals far above the lethal concentration are being regularly added into the river course. So, accumulation of these toxicants will prove to be most detrimental to the river eco-system in due course. Heavy metals impart long ranging toxic effect in the animal food chain. Bioaccumulation of heavy metals is a well pronounced toxicity Table -2).

Water quality

In a fast flowing water course the pollution indicating parameters often produce apparent values making it difficult to identify the causative factors, due to high rate of agitation specially when highly complex industrial effluents are admixtured and the bed is highly permeable due to thick sand layer. However, the data on water quality as presented in table 3 is self explanatory. It is evident when the flow is arrested in a reservoir, the water quality depicts a definite indication of sharp deterioration.

Plankton

These micro-organisms being deprived of their own locomotion do not usually depict the state of pollution in a water course. A detail account as depicted in table 4 indicates dominance of pollution resistant species in the watercourse with low diversity index which reveals that the biotic community thriving under pollution.

Benthos

The benthic organisms which are integral part of the biotic community and a vital component of the fish food chain mostly harbour on the river bed but are highly sensible to ecological changes. The Damodar river bed being blanketted with oil mixed fly ash do not support proper growth and multiplication of wide variety of benthic flora and fauna. The predominance of olegochaets and chironomids over the entire stretch indicates the toxic nature of the bed (Table 4).

Fish and fishery

River Damodar has never been a potential fishery resource and commercial fishery exists only in the lower valley. But, at present the fish community as a whole in the entire riverine stretch is under serious threat, due to the septic condition of the river course. Table 5 depict a sharp decline in their species diversity and gradual dominance of non-commercial pollution resistant species. A total of 89 species of fish belonging to 20 families with 25 species of commercial importance existed in the river prior to DVC, have declined to only 56 species belonging to 21 families with only 16 species of commercial importance. Results of situ bioassay studies provide in depth location specific evaluation of toxicity of the river water and justifies the extinction of Indian Major carps over the riverine stretch upto Durgapur. More over, the external examination of test fishes in the stretch reveal that fish succumbed to respiratory stress due to deposition of coal dust particles and fine silt over the gills. It has further been evidenced through microscopic studies that the fish gills suffered various deformitie in cellular levels.

Accordingly, it may be concluded upon that the biotic community as a whole over the entire stretch of the river can be considered to be endangered species.

Conclusively it may be inferred that the Damodar, one of the most essential riverwith a country is not only tending towards an ecological desert but the vary existence of the river course is under serious threat only due to anthropogenic indifference.

Table 1. Quantum and nature of effluents expelled into the Damodar by some major industries

Industry	No. of plant	Quantum of effluent Mm^3/d	Quantum of main effluents (Tonnes per day)							
			TSS	TDS	Phenol	Ammonia	Oil & grease	COD	Heavy metals	
Thermal Plant	7	Fly ash 10,000 TPD	300	900	--	--	1.358	39.5	Fe, Cu, Zn, Cd	0.04-0.28
Live coal mine	742	0.2-0.3	--	--	--	--	--	16-20		0.05-0.60
Coal washery	15	0.10*	4.0-12.0	4.0-7.2	0.8-1.2	--	.001-.002	4.8-6.4	Fe, Cu,Zn, Cd, Cr	0.01-0.20
Steel plant	5	0.16	200-300	--	13.0-15.0	5.0-7.0	2.0-3.0	80-100	Fe,Cu,Cr, Zn	.0.02-0.19
Sindry fertilizer & A. C.C.	2	0.02	31.5	11.2	--	4.2	--	40-65	Fe, Zn	0.01-0.08
Asansol Industrial Complex (through nunia Nullah)	-	0.007	1.4	1.4	0.2	1.8	0.5	2.8	Fe, Cu, Zn, Etc.	0.01-0.04
Durgapur Industrial Complex (Through Singran Nullah)	-	0.008	10.5	1.4	0.2	2.6	0.6	3.2	Do	0.08-0.40
Through Tumla Nullah	-	0.12	49.3	18.3	1.6	2.3	1.2	41.6	Do	0.08-0.40
Domestic effluent	0.08		-	-	(47.459 TPD of BOD	-	-	-	-	-

*7000 MT/Yr solid rejects

Table 2. Heavy metal concentration in the Damodar river water

Location	Season	Iron mg/l	Copper mg/l	Zinc mg/l	Cadmium mg/l	Lead mg/l	Chromium mg/l
Upper Stretch (Hazaribagh Dist.)	M	0.066	ND	0.053	0.016	0.027	0.035
	S	0.021	ND	0.014	0.010	0.013	0.018
Middle stretch (Dhanbad Dist)	M	0.578	ND	0.103	0.011	0.148	0.035
	S	0.124	ND	0.091	0.008	0.006	0.009
Middle stretch (Durgapur industrial belt)	M	0.261	0.109	0.076	0.012	0.027	0.035
	S	0.189	0.071	0.383	0.008	0.031	0.010
Lower stretch (Burdwan Town)	M	0.121	0.043	0.029	0.006	0.026	0.042
	S	0.017	0.001	0.158	0.006	0.018	0.004

M= Monsoon, S= Summer

Table 3. Water quality of the Damodar during 1993-95

Zone	Year	Temp. 0 °C	Turbidity (mg/l)	pH	DO mg/l	TSS mg/l	Phosphate mg/l	Ammonia mg/l	Nitrate mg/l	COD mg/l	Phenol mg/l	Alkalinity mg/l
Zone I (Rajarappa to Tenughat avg. of four (4)points	1993	S 31.0	400	8.0	7.8	44	0.04	Trace	0.48	-	-	104.0
		M 30.0	900	7.2	7.2	60	0.06	0.56	0.81			64.0
	1994	S 30.0	350	8.2	8.2	38	0.02	0.28	0.29	27.2	-	168.0
		M 30.0	950	7.5	7.5	67	0.06	0.46	0.73	50.5		34.0
	1995	S 31.5	350	7.8	9.0	41	0.03	Trace	0.04	35.5	-	204.0
		M 30.0	1050	6.5	8.4	72	0.06	0.49	0.53	70.1		58.0
Zone II (Below Tenughat to Panchet avg. of 14 points.	1993	S 30.5	700	7.1	7.0	500	0.27	0.84	0.28	98.1	-	60.0
		M 29.5	900	8.2	3.0	950	0.13	2.17	0.84	60.3	-	62.0
		W 23.0	200	7.4	5.9	320	0.30	0.28	0.56	76.0	-	59.0
	1994	S 31.0	300	7.0	6.8	380	0.51	1.70	0.35	58.7	-	55.0
		M 28.0	950	8.4	2.5	1000	0.65	3.70	0.90	100.2	-	66.0
		W 22.5	250	7.1	3.5	280	0.08	1.50	0.08	85.7	-	63.0
	1995	S 30.5	650	7.2	5.3	650	0.38	2.10	0.93	80.3	-	60.3
		M 29.0	900	7.9	1.7	870	0.43	3.21	0.87	80.7	-	61.0
Zone III (Panchet to Durgapur Barrage) avg. of 10 points	1993	S 37.0	450	8.6	8.4	54	0.16	2.5	5.04	1160.0	-	86.0
		M 36.0	600	8.0	9.1	75	0.08	3.6	4.20	937.0	0.54	92.0
		W 23.5	300	7.8	8.0	40	0.60	0.8	6.06	636.0	1.38	120.0
	1994	S 36.5	350	8.4	8.0	48	0.07	3.1	4.08	1120.0	-	62.0
		M 36.0	580	7.8	9.3	61	0.28	3.7	4.76	1000.0	-0.48	68.0
		W 23.0	400	7.8	8.2	44	0.22	1.8	5.12	620.0	-0.48	85.0
	1995	S 37.0	500	8.0	7.8	40	0.21	3.7	6.03	927.0	-1.59	68.0
		M 35.5	550	8.0	8.1	68	0.18	4.1	5.16	830.0	-1.86	66.0
Zone IV (Durgapur to Burdwan) avg.4 centres	1993	S 31.5	680	7.4	7.6	50	0.08	1.40	0.32	1000.0	1.09	94.0
		M 30.5	450	8.0	10.5	96	Tr	0.86	0.32	1085.0	0.82	90.0
		W 23.0	110	8.1	8.1	16	0.02	0.81	0.32	699.0	0.98	123.0
	1994	S 32.0	700	7.8	7.0	47	0.04	1.21	0.27	900	1.27	100.0
		M 30.5	320	8.1	8.9	81	0.02	1.08	0.31	1000.0	0.78	82.0
		W 22.5	90	8.3	8.1	19	0.02	0.92	0.29	562.0	0.82	100.0
	1995	S 32.0	600	8.0	7.6	38	0.02	1.37	0.21	950.0	1.32	120.0
		M 30.0	250	8.3	8.1	96	0.06	1.00	0.32	1050.0	1.00	82.0

Table 4 Availability of plankton & bottom biota from different zones of the river Damodar during 1992-1994

Location	Plankton (unit/l)				Bottom biota		
	Phytoplankton	Dominant sp.	Zoo-plankton	Dominant sp.	Total	Flora	Fauna
1st Zone (Tori to Tenughat	80	*Oedogonium sp.* *Fragilaria sp.* *Spirogyra sp.*	5	*Cyclops sp* *Nauplii*	85	*Spirogyra sp.* *Oedogonium sp.* *Ulothrix sp.* *Melosira sp.*	Oligochaete
2nd Zone (Below Tenughat to Chandrapura)	203	*Oedogonium sp.* *Fragilaria sp.* *Spirogyra sp.* *Oscillatoria sp.*	29	*Cyclops* sp.	932	*Oscillatoria sp.* *Oedogonium sp.* *Spirogyra sp.* *Ulothrix sp.* *Navicula sp.*	*Oligochaete* *Thiara sp.* *Pleurocera sp.* *Gastropod shell* *Chironomid Nymphs*
3rd Zone (Below Chandrapura to Panchet)	363	*Microcystis sp.* *Fragilaria sp.* *Oedogonium sp.*	59	Moina sp., *Cyclops sp.* *Keratella sp* *Arcella sp.* *Diaptomus sp., Filinia sp.*	422	*Oedogonium sp.* *Ulothrix sp.,*	-do- & Mosquito larvae
4th Zone (Below Panchet to Burdwan)	2666	*Spirogyra sp.* *Oedogonium sp.*	166	*Cyclops sp.,* *Keratella sp.* *Monostyla sp.* *Nauplii*	2832	-do-	-do-

Table 5. Changes in species spectrum in different reaches of Damodar river (1992-95)

Commercially important species	Upper (Tori-above Panchet)	Middle (Disergarh-Durgapur	Down (Durgapur-Burdwan)
1. Barillius bola	+	+	+
2. Puntius sarana	-	+	+
3. Catla catla	-	-	+
4. Cirrhina mrigala	-	+	+
5. C. reba	-	+	+
6. Labeo rohita	-	-	+
7. L.calbasu	+	+	+
8. L.boga	+	+	-
9. L. bogggut	+	+	-
10. L. dyocheilus	-	+	-
11. Ompok bimaculatus	+	+	-
12. Wallago attu	-	+	+

3. Mystus seenghala	+	+	-
14.M. aor	+	-	+
15. Clupisoma garua	+	+	+
16. Labeo bata	-	+	+
17. Rhinomugil corsula	+	+	+
NON-COMMERCIALLY IMPORTANT SPECIES			
18. Notopterus notopterus	-	+	-
19. Chela gora	+	+	+
20. Chela sp.	+	+	+
21. Barillius barila	+	+	-
22. B. bendelisis	+	+	-
23. Barillius sp.	+	+	-
24. Esomus danricus	-	+	-
25. Amblyopharyngodon mola	-	+	-
26. Aspidoparia morar	+	+	-
27. Puntius sophore	+	+	+
28. P. conchonius	+	-	-
29. P.ticto	+	+	+
30. P.tigma	+	+	+
31. & 32 Garra spp.	+	-	-
33. Botia spp.	+	+	-
34. Nemachilus spp.	+	+	-
35. Mystus cavasius	+	+	-
34.Glyptothorax spp.	+	+	-
35. Hara sp.	+	+	-
36. Clarias batrachus	-	-	+
37. H. fossilis	-	+	+
38. Xenontodon cancila	+	-	+
39. Channa punctatus	-	+	+
40. C.striatus	-	-	+
41. Glosogobius giuris	+	+	+
42. Ambassis baculis	+	+	-
43. A. nama	+	+	+
44. A.ranga	+	+	+
45. Mastasembelus armatus	+	+	-
46. M. pancalus	+	+	-
47. Amblyceps sp.	+	-	-
48. Dorichthys cunculus	+	-	-
49. Aili coilia	+	+	+
50. Amphipnous cuchia	-	+	-
51. Colisa fasciatus	-	-	+
52.Apocryptis sp.	-	+	+

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ENVIRONMENTAL ISSUES AND SUSTAINABLE FISH PRODUCTION FROM FLOODPLAIN LAKES OF GANGA BASIN

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Introduction

India possesses extensive land and water resources, including highly productive agricultural land and some of the world's major river systems. The total length of the rivers and their main tributaries in India is nearly 28,506 km. The Ganga river system is the largest and the most productive.The river Ganga is 2,525 km long. Within India, it drains about 861×10^3 km^3 catchment along different states covering more than a quarter of the country's total area. Its floodplains spread over mainly in West Bengal, Bihar and to some extent U.P. together cover an area of 1,03,439 ha (Table 1).

Table 1. Wetland resources in three states along Ganga basin

States	Total wetland area (ha)	Floodplain wetland area (ha)
U.P.	225,302	12,832
Bihar	273,395	48,607
West Bengal	344,527	42,000

In West Bengal, the floodplains are associated with Hooghly and Matlah river basins while in Bihar they are associated with Gandak and Kosi basins. Floodplain wetlands locally known as *beels, pats, mauns, jheels* etc. are biologically sensitive ecosystems which play a vital role in the inland fish production of the states along the Ganga river basin. These lakes can yield about 0.2 million tonnes of fish per year. According to the statistics available fish yield from these water bodies is only 100 kg/ha while the potential yield on an average is about 1000 kg/ha. Based on the water circulation pattern the *beels* can be broadly classified into two categories viz. (1) open *beels*, which are retaining their connections with the parent rivers and (2) closed *beels* which are cut off totally from the main stream. The former does not allow macrophytes to flourish while the latter in most cases are weed choked. Any management measures to boost fish production in this ecosystem depends on this classification. Each one keeps its own ecological characteristics.

Beels of West Bengal

In West Bengal, although the *beels* lie mainly in seven districts, nearly half of the *beels* are located in the districts of 24 Parganas, Murshidabad, Hooghly and Nadia. The ox-bow lakes in West Bengal vary widely in size, some are small covering only about 2 ha of water area but some others are quite large covering more than 600 hectares. (Table 2). Medium sized *beels* excel in number and they vary between 20-50 ha in area.

Table 2. Distribution of *beels* in West Bengal

Parameters	Districts			
	Nadia	Murshidabad	Hooghly	24 Parganas (N)
Number of beels	43	43	6	23
Range of effective area (ha)	2-130	7-210	3-75	12-600
Maximum depth (m)	2.5-7.0	3-5	2.5-3.5	3.5-8
Connected river	Ganga, Ichamati, Bhagirathi, Jalangi	Ganga, Sone Canals	Farakka, Ganga	Ichamati
Total water area	15,982	13,161	174	1742

Vass, 1989

Beels of Bihar

The ox-bow lakes in Bihar are spread over in the northern part of the State. These *beels* lie at the basins of a net work of rivers and rivulets *viz.* Gandak, Burhi Gandak, Kosi, Bagmati, Kamla Balan etc. About 12,000 ha of water is spread over in the form of *beels* mainly along the Gandak and Kosi basins. These lakes vary in size ranged from 4-400 hectares (Sinha and Jha, 1997). Information on the *beels* of Eastern Uttar Pradesh is not much available at present.

Fish production of the beels of Ganga Basin

In West Bengal, on an average the fish yield ranges between 107-12,610 kg per month. By planned stocking with suitable species mix of major carps, the production range has increased to 320-440 kg/ha/yr from an earlier average of 150 kg/ha/yr. However, a potential production range of 1000-1500kg/ha/yr is expected if managed scientifically, (Vass,1989).

A study conducted by CIFRI in 18 beels of West Bengal (Table 3) showed that the open *beels* with fluviatile conditions are less productive (42-150 kg/ha/yr) while closed *beels* showed higher production (66-4333 kg/ha/yr). In most cases the potential yield estimated as 1 % of the primary energy is much lower than the actual yield. This is because in *beels*, the huge detritus reserve is contributing more to the fish productivity unlike in other ecosystems (Anon, 2000).

Table 3. Estimation of fish production potential and actual yield of some West Bengal *beels*

Name of the beel	Water spread area (ha)	Production potential (kg/ha)		Total potential yield (kg/ha/yr)	Actual yield (kg/ha/yr)
		Macrophyte chain	Plankton chain		
Closed (weed choked)					
Bhomra	83	190.75	47.63-73.91	238-264.6	690.00
Beloon	200	96.88	13.84	110.72	875.00
Bansdaha	41	123.15	38-61.5	161.1-184.6	1100
Mogra	60	123.9-139.12	23.6-95.88	147.5-235	345.8
Ghurnamani	40	51.18	33.28-208.05	84.4-259.2	650
Nehali	30	22.67	6.7-13.9	29.3-36.5	333.3
Dekole	43	94.5	14.5-18	109-112.5	66.18
Closed (moderately choked)					
Sarasankha	35	58	17-35	75-93	800
Berir Baor	163.6	3.29	196.22	199.5	507.34
Garapota	131	11-22	28-91	39-113	310.6
Haripur	30	14.89	103-158.7	117-173.5	900
Moranadi	35	3.42	20.1-73.5	23.5-76.9	
Akaipur	32	1.86	42-254.3	43.8-256.1	1921.5
Bhaluka	32	1.6	23.95-31.94	25.5-33.54	468.75
Closed (weed free)					
Kola	12	neg.	270-320	270-320	4333.3
Patari	30	neg.	12.8-49.8	12.8-49.8	298.01
Open Beel					
Palda	200	3.99	59-91	62.99-94.9	42.04
Bhanderdaha	400	1.34	30.23	31.57	150

Anon, 2000

Common fishes of the floodplains

In most of the *beels* in West Bengal the fishery is mainly dominated by miscellaneous species and carps (in stocked beels) followed by cat fishes and air-breathing fishes (Table 4). The *beels* where management measures are in vogue, regular stocking is taken place and the resultant catch spectrum is dominated by Indian major carps, *Catla catla, Labeo rohita, Cirrhinus mrigala, Labeo calbasu* and the Chinese carps, *Hypophthalmichthys molitrix* and *Ctenopharyngodon idella*. The miscellaneous fishes constituted the fishery are *Colisa fasciatus, Amblypharyngodon mola, P. stigma, P. sarana , Cirrhinus reba, Nandus nandus, Gudusia chapra, Labeo bata* etc. The cat fishes and air-breathing fishes like *Wallago attu, Mystus vittatus, Heteropneustes fossilis, Anabas testudineus* and *Notopterus notopterus etc.* are also caught.

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

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

In Bihar *beels*, the fisheries is restricted mainly to small and predatory fishes. In shallow lakes shell fisheries is also common. Fish yield on an average is estimated at 40-200 kg//ha/yr (Sinha & Jha, 1997). An overall picture of the fisheries of *beels* of Bihar could be made from the Table below.

Table 5. Percentage composition of fishes from *beels* of Gandak basin

Beels	Miscellaneous	Catfishes	Carps	Shrimps
Manika	34-50	23-43	3-14	3-19
Brahampura	53-58	18-24	3-22	3-8
Kanti	18-22	53-62	8-12	7-10
Muktapur	50-60	10-12	8-10	3-4

Jha, 1989.

The fish species recorded by CIFRI from the beels of Ganga basin are :- *Catla catla, Cirrhinus mrigala, Labeo rohita, Cyprinus carpio, Hypophthalmichthys molitrix, Ctenopharyngodon idella, Labeo calbasu, Wallago attu, Mystus spp., Silonia silondia, Bagarius bagarius, Gudusia chapra, Chanda nama, C. ranga, Puntius sophore, P. ticto, P. sarana, P. chola, P. stigma, Barilius bola, B. bendelisis, Chela laubuca, C. utrahi, Notopterus notopterus, N. chitala, Setipinna phasa, Danio rerio, D. dangila, Esomus danricus, Amblypharyngodon mola, Aspidoparia morar and Cirrhinus reba.*

Environmental issues related to fisheries

Water abstraction

Water abstraction is a major problem in ox-bow lakes. During summer months lake water is depleted through evaporation. To add to this, water abstraction for irrigation of neighbouring agriculture farms also poses problem for the existing biota of *beels* especially in closed ones. The multipurpose dams constructed on the main river limit the influx of water into the open *beels.* The water level fluctuation affect the plants and animals along the marginal areas of the *beels* due to exposure. Those which cannot migrate to the deeper part of the *beels* perish. The hike in temperature due to the depletion of water column upset physiologically the animals living in the water. Water quantity also plays a vital role in diluting contaminants of the ecosystem. Moreover, pen/cage culture activities along the marginal areas of these water bodies are also being affected by drastic level fluctuation in the existing water.

A very important factor which is affected by the abstraction of water in the catchment of main river is the breeding and recruitment of fishes especially Indian major carps whose spawning grounds are situated in the floodplains which are inundated during monsoon. The ox-bow lakes act as sanctuaries for brooders. A flood level between 5-8 m helps the fish to migrate to the spawning ground and a moderate current (0.35-1.6 km/hr) is needed for the smooth drifting of the spawn to down (Jhingran, 1989). The recent surge in construction of embankments along the river as flood control measures has rendered many of the potential flooplain lakes barren and unproductive. The sluice gates provided on embankments should serve the vital purpose of regulating water exchange between the river and the lakes to ensure easy access to breeders to the floodplains for breeding.

Deforestation in the catchment

Turbulent monsoon, discharge 85,000 cubic meters of water per second m in Ganga. Therefore sediment load and heavy soil erosion are characteristic to Ganga system. Deforestation in the catchment and the resultant soil erosion increases the sediment load in the water shed and the lakes get reclaimed causing drastic hydrographic changes detrimental to fish fauna. Changes in the river bed configuration alters the water regime of floodplain lakes. The bottom dwelling animals are also affected by the sedimentation. All these things affect the fish production of the *beels.*

Heavy metal and pesticide pollution

Industrial and urban activities and the modernisation of agriculture cause a lot of heavy metal and pesticide washings into the *beels.* Presently about 10 million tonnes of NPK and pesticides are washed into the aquatic ecosystems annually (Joshi, 1989). Jute, paddy and vegetables are grown all along the shores of these lakes and as a result pesticides are the most prominent chemical poison deposited in the *beels* which stay for quite long time in the sediments. The use of organometallic compounds in agriculture as plant protection chemicals lead to the release of metals into the *beel* waters from the surrounding agriculture fields. Lead from the road surface runoff and mercury from the atmospheric fallout are other sources of metal contamination in the *beels*. In some *beels*, municipal effluents and flyash from thermal plants are being dumped. Dumping of sullage leads to direct contamination of *beels* by heavy metals. The most direct impact of pollution in *beel* ecosystem is mass scale fish mortality. Destruction of habitats for benthic and planktonic communities and toxicity to organisms are other damages the pollutants could make. Some pollutants are present in water in very low quantity but their accumulation in fish tissues can affect the growth and reproduction of majority of aquatic animals. Traces of these xenobiotic substances in fish tissues not only result in low fish ouput but also responsible for transport of toxic metals and pesticides to human body through the consumption of such fishes by human beings. Common pesticides recorded from the water and sediments of ponds in Sunderbans of West Bengal are DDT, BHC, endosulfan and methylparathion.

A comparison of two *beels*, Garapota and Padma of West Bengal suggested that Garapota *beel* was moderately polluted as indicated by higher hardness, chloride values and appreciable levels of metals and pesticides (Table 6). The pesticide residue and metal content in the sediments of Garapota *beel* indicated significant anthropogenic influence (Table 7). Chemical examination of *Cyprinus carpio* from Garapota *beel* indicated appreciable levels of mercury (0.28 μg/g wet wt)) and HCH (0.35 μg/g wet wt) (Joshi, unpublished)

Table 6. Water quality in two *beels*

Parameter	Garapota	Padma
PH	8.3-8.5	8.0
Alkalinity	118-332	101-103
Hardness	141-144	62-63.5
Chloride	16-32	12-16
Phosphate	0.06-0.2	0.02-0.06
Nitrate	0.01-0.04	0.04-0.05
Silicate	2.0-2.1	2.2-3.3
Zinc	0.03-0.12	0.02-0.06
Copper	0.01-0.016	nd-0.013
Mercury	not detected	not detected
Pesticides	0.0002 (HCH)	not detected

All values in mg/l except pH

Effluents from cottage industries engaged in leather tanning, electroplating, pesticide formulation and sewage from villages can be checked by adopting suitable treatments or diverting the waste waters.

Table 7. Chemistry of sediments in two *beels*

Parameter	Garapota	Padma
PH	7.2-7.4	7.2-7.3
Organic C %	2.4-3.3	2.9-3.0
Av. P mg/100 g	4.2-13.4	4.4-11.4
Zinc µg/g	28-64	14-42
Copper µg/g	5.8-14.3	0.8-6.6
Mercury µg/g	0.18-0.37	0.01-0.1
Pesticides µg/g	0.212 (HCH)	0.013 (HCH)

Macrophytic infestation

The annual cycle of runoff from the catchment areas enriches the *beels* with nutrients leading to the growth of undesired macrophytes. This community is very important in the *beel* ecosystem especially in closed ones without sufficient water circulation. Excessive growth of macrophytes often poses serious threat to the ecosystem. They blanket the water surface, preventing penetration of sunlight and thus retards growth of phytoplankton. They compete with phytoplankton for the nutrients of water and soil phase for their unchecked growth. A few negative impacts of macrophytes have direct bearing on fish production of the *beel* ecosystem. Weeds overcrowd and interfere with free navigation and fishing activity in the water body. In weed choked *beels* it is impossible to make use of various types of fishing gear. The overcrowded plants ultimately die and sink to the bottom to create toxic condition. Weeds can interfere with the fish culture activities like pen or cage cultures by damaging the walls of the enclosures by exerting pressure on these structures

Keeping aside their damaging impacts, the weeds to some extent have some positive role also to play in the ecosystem. A large number of animals like insects, molluscs, mites, annelids and other animal groups thrive among the weeds and they are mostly of little consequence to the economic variety of fishes. Weeds act as shelter to some fishes which give eggs under these plants. They can even give a protective cover to the newly hatched fish larvae also.

Macrophytes play an important role in the food chain of *beel* ecosystem. The energy input through macrophytes was 2.66-3.56 % of light and the total biomass of macrophytes in the *beel* ranged from 20.08-37.47 x 10^5 Cal/m^2 in 1981. The bottom deposits was 335-432.5 g/m^2 and thus the detritus energy was 334-435 K Cal/m^2 or 40.44 x 10^5 K Cal/ha. Normally macrophyte chain involves tremendous energy loss as the fishery of weed choked *beels* consists mainly of air-breathing fishes which depend on weed fishes. In Kulia beel of West Bengal, the rate of energy output through autotrophic primary production was only 2500 Cal/m^2/day which increased to 38,050-

1,94,460 Cal/m^2/day resulting 10 times increase of photosynthetic efficiency from a mere 0.12 % after the removal of macrophytes from this *beel.* However, removal of macrophytes from the vast open water system is not a practical idea. But, technology demonstration in Takmu Lake (500 ha) in Manipur has resulted in complete removal of a dense mat of 1 metre high water hyacinth and grass. Application of 2,4D sodium salt formulation has achieved 90 % weed kill followed by Paraquat (Gramaxone) treatment to eradicate the grass. A commercial wetting agent (Dedanol) was mixed with the herbicidal spray solution to facilitate adhesion and spread of solution on waxy and hairy leaf surface.The submerged weeds (*Vallisneria, Hydrilla, Najas* etc) can be controlled by stocking fishes like *Puntius pulchellus, P. dobsonii, Ctenopharyngodon idella* (exotic) etc. However, the free floating weeds mainly water hyacinth (*Eichhornia crassipes*) has to be eradicated.

For weed choked *beels* pen/cage culture also could be advised as a management measure to improve their production. Small area of the *beel* can be cleared off to construct the enclosures. These enclosures could be stocked with prized species like prawns to achieve high profit. A detritus oriented fishery with detritivores like *Cirrhinus mrigala C. reba, Labeo bata etc* is not a bad proposition in beel ecosystem with its huge bottom deposits.

Conclusion

The environmental management in relation to fisheries calls for an ecosystem oriented approach. The fisheries management comprises the conservation of aquatic fauna and flora, natural recruitment, stocking, selective and controlled fishing. The fisheries sector should not be isolated from any conservation/developmental programme which involves the use of water by the Government or any other organisation.

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ENVIRONMENTAL ISSUES AND SUSTAINABLE FISH PRODUCTION FROM FLOODPLAIN WETLANDS OF BRAHMAPUTRA

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INTRODUCTION

Floodplains and the wetlands associated with them are unique ecosystems providing livelihood to millions of people all over the world. This is particularly true in Asia where the low lying fertile valley bottoms adjacent to major rivers are thickly populated and used traditionally by the local communities for agriculture, post-harvest, fishery, livestock farming, navigation and a number of other activities. Wetlands commonly found on the riverine floodplains are evolved over many millennia through natural processes of flooding and riverbed movement caused by extreme climatic and geological events. In the Indian subcontinent, these events are particularly pronounced due to the effects of monsoons. Floodplain wetlands play a vital role in the maintenance of stability in lowland ecosystems, facilitating effective retention and release of floodwater as well as absorption and cycling of nutrients. However, due to man-made physical modifications, many of the floodplains have been lost or reduced often leading to more catastrophic events such as extreme flooding and even loss of human lives. Floodplain wetlands are biologically sensitive areas as they provide breeding and nursery grounds for a number of aquatic organisms. Therefore, they should be considered as a continuum of rivers with regard to conservation.

CONCEPTS AND DEFINITIONS

In the fisheries literature, terms like floodplains, wetlands, floodplain wetlands, *etc* are often used loosely leading to ambiguity in expression. Some of the semantic confusion in the use of terminology has been sought to be removed by Sugunan (1997). *Floodplains* are the flat land bordering rivers that is subject to flooding which tend to be most expansive along the lower reaches of rivers (Matlby, 1991). They are either permanent or temporary water bodies associated with rivers that constantly shift their beds especially in the potamon stretches. According to Leopold *et al.* (1964), a typical floodplain will include the river channel, oxbow lakes, point bars, meander scrolls, sloughs, natural levees, backswamp deposits and sand splays. Based on the flow of water, floodplains can be divided into two broad groups *viz.,* the plain (lotic component) and the standing water (lentic component). Further, these are grouped into fringing floodplains, internal deltas, and coastal deltaic floodplains (Welcomme, 1979). *Wetlands,* as defined by Ramsar Convention, include *areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six metres.* In simpler terms, wetlands occupy the transitional zone between permanently wet and generally dry environments. They share the characteristics of both the environments, and yet cannot be classified exclusively as either aquatic or terrestrial (Maltby, 1991).

Wetlands situated on floodplains of major rivers can be designated as *Floodplain wetlands* or *Floodplain lakes* which cover a variety of water bodies in India such as *beel*s, *jheel*s, *maun*s, *pat*s, *anoa*s, *boar*s, *hoar*s, *bowrs*, *etc.* They can be typical oxbow lakes, (*i.e.,* cut-off portion of meander bends), sloughs, meander scroll depressions, backswamps, residual channels or tectonic depressions (Sugunan, 1995), though it is often difficult to establish their actual identity owing to natural as well as man-made modifications to the environment.

FLOODPLAIN WETLAND RESOURCES OF INDIA

The eastern and north-eastern states *viz.,* Assam, West Bengal, Bihar and other north-eastern states have more than 200,000 ha of floodplain wetlands which are mainly associated with the river systems of Ganga and Brahmaputra (Table 1).

Table 1. Distribution of floodplain wetlands in India

States	Distribution	River basins	Local names	Area (ha)
Arunachal Pradesh	East Kameng, Lower Subansiri, East Siang, Dibang valley, Lohit, Changlang and Tirap	Kameng, Subansiri, Dibang,Lohit, Dihing andTirap	*Beel*	2,500
Assam	Brahmaputra and Barak valley districts	Brahmaputra and Barak	*Beel, Howr, Anoa*	100,000
Bihar	Saran, Chaparan, Saharsa, Muzaffarpur, Darbhanga, Monghyr and Purnea	Gandak and Kosi	*Maun, Chaur, Hoar*	40,000
Manipur	Imphal, Thoubal and Bishnupur	Iral, Imphal and Thoubal	*Pat*	16,500
Megha-laya	West Khasi Hills and East & West Garo Hills	Someswari and Jinjiram	*Beel*	213
Tripura	North, South & West Tripura	Gumti	*Beel*	500
West Bengal	24 Parganas, Hooghly, Nadia, Murshidabad, Dinajpur, Malda, Cooch Behar, Howrah and Medinipur	Hooghly and Matlah	*Beel, Bowr*	42,500

ENVIRONMENTAL ISSUES

Balance between the environment and biotic communities determines the health of an ecosystem. Harvestable living resources in any ecosystem comprise the populations belonging to nekton, which form only a section of the community at large. The abundance and distribution of these target populations depend on a very complex community metabolism by which the solar energy trapped at primary producer level passes through different communities of organisms before a fraction of it finds its way to the terminal phase. Community succession is series of rhythmic but predictable changes in the structure of the component populations in a community, determined by a number of habitat variables. Environmental stresses inflicted upon any component population affects the community metabolism and succession and will be reflected in the entire community and ultimately impairs the production at fish level. Therefore, the habitat constraints, which have no direct bearing on fish, can also affect the fish productivity indirectly. Conservation of the whole community, rather than the specific economic species, is therefore imperative in preserving the biological wealth from floodplain wetlands.

Ill effects of anthropogenic changes in the riverine ecosystem are well chronicled, especially from public health, aesthetic and economic angles. They include sedimentation, river course modifications, creation of hydraulic structures and effluxion. Since floodplain wetlands are in integral part of the river continuum (Sugunan, 1999), all these environmental changes are equally relevant to the *beel*s. The major source of environmental perturbations in the floodplain wetlands can be summarized into the following heads

i) Sedimentation
ii) Soil erosion
iii) Water abstraction
iv) Embankments
v) Hydraulic structures and
vi) Effluent discharge

Sedimentation

Three modes of sediment transport are transport of bed load, transport of suspended load and the wash load. Bed load consists of rolling and saltation of particles, the suspended load is transported by the turbulence mechanism in the fluid and the wash load is a portion of sediment load, which had an upstream origin. In a river, as the flow passes, several forces like *lift, pressure drag*, and the *surface friction drag* are exerted on the individual particle. In response to these forces, the particle rolls or slides over the neighboring one and consequently, the motion is initiated. When the lift force exerted on the particle exceeds the submerged weight of the particles, the particle is taken up into the flow, the drag forces helping their forward transport. When the turbulent velocity fluctuations are inadequate, the saltating particle may be carried further up into the flow and maintained in suspension. Thus, in the bed load transport, three types of motions viz. rolling or sliding, saltation and suspension can be discerned.

The rate of suspended load transport has a relation to the vertical distribution of the concentration of sediment particles at the column of water. It is apparent that the suspended load concentration decreases from the bed towards the water surface and that the mixing process must therefore result in the upward movement of suspended particles for transport. Thus, the transport of bed load, suspended load and the wash load are dependent mainly on the velocity and gradient.

Soil erosion

Erosion of topsoil in the catchment area is the main man-made factor that leads to increased sediment load in rivers and associated wetlands. Vegetative cover on the slopes acts as an adherent of topsoil during the surface runoff. Removal of forest cover in the slopes for logging, grazing of cattle or for urban needs make the soil susceptible to erosion, thus adding to the sediment load in the river. Soil erosion results in raising of riverbeds and thereby restricting water renewal in the wetlands. This could lead to obstruction of fish movements and accumulation of waste in the floodplain lakes.

Water abstraction

Diverting water for agriculture, irrigation, industries and drinking water purposes pose serious threat to the stability of the delicate floodplain wetland ecosystem. Environmental changes associated with water abstraction manifest themselves through velocity, depth, width of the channel and solid transport, each of them having its own impact on the biotic communities. A fall in water level may physiologically upset the process of normal community succession and lead to a decrease in species diversity. A common ill effect is the excessive colonization of aquatic macrophytes, which disturbs the normal phytoplankton-based chain of energy transformation, retarding productivity.

Embankments

With constantly changing velocities and volumes of flow, rivers are bound to have different quantum of energy at different times. This, in turn, results in bank erosion. Main purpose of embankments is to safeguard the adjoining towns, roads, railways, fields, etc. Protection of banks also becomes necessary to control floods, to facilitate construction of hydraulic structures and to facilitate navigation. Most of the embankments created on the floodplain wetlands are the river revetments, which smoothen the banks by masonry or other structures to prevent the river from excoriating its banks. However, embankments often have deleterious effects on the living aquatic resources like fishes as they hinder the movements of organisms and water renewal pattern.

Hydraulic structures

Effects of dams, barrages weirs and other hydraulic structures on the riverine portion of the floodplain wetlands are manifested in three ways viz., i) reduced discharge, ii) habitat destruction due to impoundment and iii) obstruction of migratory pathways of fishes and other organisms.

Effluents discharge

As the human activities in the river basins are increasing day by day, discharge of wastes into the water bodies is fast becoming the single largest cause of environmental degradation. The wastes that find their way to the floodplain wetlands can be grouped into i) domestic wastes, ii) industrial effluents and iii) agricultural wastes. Among them the domestic and agricultural wastes are more common in floodplain wetlands.

Specific impact of a habitat constraint on the biotic communities is difficult to assess, as the different parameters that exert pressure on the ecosystem are closely interrelated. It is not even possible to prescribe safe limits in respect of any of the chemical pollutants. In fact, the practice of prescribing safe limits is no longer valid, as the main emphasis is now shifted to a balanced ecosystem, rather than to prevent fish kills. To protect the ecosystem from gradual degradation, we must provide criteria that will protect the entire life cycle of the desirable species as well as the food chain on which these species depend. While dealing with the multiple effluents, not only the specific knowledge on the effluents but also a knowledge on the potential chemical and physical changes is imperative. In addition, we must comprehend the potential of combined stress on aquatic life, the effect of which cannot be explained on the basis of a single contaminant. The problems involving pH and metal toxicity are common where toxicity increases due to decrease in pH values.

SUSTAINABLE DEVELOPMENT

Sustainable development, according to the FAO (1997), *is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations.* Such sustainable development should be environmentally non-degrading, technically viable and socially acceptable. Sustainability, as applied to fisheries development is relevant to both capture and culture systems and their products, which are designed to maintain productivity and usefulness to society without any time limits. However, compared to the intensive aquaculture, capture and culture-based fisheries provide management options, which are more compliant with the norms of sustainable development. In practice, sustainable fisheries projects should be site specific and programmed judiciously to integrate technologically, economically and ecologically viable practices (Gopalakrishnan, 1999). Sustainable fisheries management entails a proper understanding of the objectives of the programmes, technology to be adopted, long term impact of the operational activity on the environment as well as other species and the society at large.

Most of the open waters, which contribute substantially to fish production such as *beels*, *boars*, *chaurs* etc, are managed on the basis of culture-based fisheries or various other forms of enhancement, which are intermediate to culture and capture fisheries norms. These modes of fishery management offer relatively eco-friendly options for sustainable management of resources.

CONSERVATION OF BIODIVERSITY

Any development plan for floodplain wetlands has to consider the rich biodiversity of this ecosystem and its conservation. The UNCED Conference in Rio de Jeneiro (1992) has defined biodiversity as *"the variability among living organisms from all sources including* inter alia, *terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."* Thus, biodiversity not only refers to protection species but also covers the whole spectrum of the natural environment. The importance of biodiversity stems from an array reasons/arguments such as precautionary, moral, indicative, aesthetic and economic.

The precautionary argument is based on the premises of our inadequate knowledge to make definite judgment on how much loss of biodiversity can be sustained without causing irretrievable damage to the balance of nature. A more utilitarian argument is the commercial value of plants and animals, particularly the risk of losing valuable genes from the pool if due care is not taken to preserve them. According to the moral argument, mankind should act as a trustee to look after the natural environment, improve it and hand over to the next generation with pride. The indicative argument stresses on the ability of biodiversity to act as an indicator or barometer of the health of an environment since a change in the biodiversity is often the first indicator of environmental change. Aesthetic and cultural arguments are less appealing to many a developing societies. They are based on the premise that the biodiversity of landscapes and natural ecosystems and the species they support can provide solace and a feeling of homeliness.

Many developing countries are facing the challenge to feed their large human populations that are growing at a faster rate than food production including fish production. The dilemma faced by these countries is whether to feed the hungry millions today or to preserve their biological diversity for the posterity. Unless the philosophy of global partnership through redistribution of technologies and wealth to areas of need (as enshrined in the Agenda 21 of Rio declaration) is followed in letter and spirit, it is difficult to achieve a balance between these two needs. Another probable way out is sustainable use of biological resources, wherever possible. A key element in this direction is the accurate determination of the carrying capacity of the habitat.

Sustainable fishery management norms suitable for floodplain wetlands

A range of management practices is collectively known as enhancement. FAO (1997) defines fisheries enhancements as *technical interventions in existing aquatic resource systems, which can substantially alter the environment, institutional and economic attributes of the system*. This is the process by which qualitative and quantitative improvement is achieved from water bodies through exercising specific management options. The common forms of enhancement which are relevant to inland water bodies of India are stock enhancement, species enhancement, environmental enhancement, management enhancement and enhancement through new culture systems. Culture-based fishery is the most common mode of enhancement being followed in the floodplain wetlands in India. When the fish harvest in an open water system depends solely or mainly on artificial recruitment (stocking), it is generally referred to as culture-based fishery.

It has been recorded that 1.4 million t of fish is produced through inland aquaculture in India (Gopakumar, 1999). The remaining 0.8 million t of inland fish is attributable to different types of inland open water systems. Although the breakup of catch from rivers, lakes, floodplain wetlands and reservoirs are not recorded, it is generally believed that the capture fisheries of rivers and estuaries contribute very little to their total inland catch. Bulk of production from open waters emanates from reservoirs and floodplain wetlands. The main focus of management in these water bodies is culture-based fisheries and fisheries enhancement. The following management options have been evolved for sustainable fisheries of the floodplain lakes as a result of research on their ecology and fishery management.

Recent studies conducted in West Bengal have proved beyond doubt that *beels* can yield much more fish than the conventional 1 % of the energy at primary producer level due to accumulated carbon at the bottom (CIFRI, 2000). 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 affect 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.

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

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.

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

Taking appropriate measures for gear selection prevents the growth over-fishing. Adjustments in quality and quantity of fishing gear are an essential component of capture fishery management. Common strategies followed are summarized as:

i) Increase the minimum mesh size.
ii) Increase or decrease the fishing effort.
iii) Observe the close season to protect the brooders.
iv) Strict adherence of the restriction on the minimum size at capture.
v) Diversity of the gear.
vi) 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 of fish. 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:

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

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 1). This has been tried in many places of the country with certain degree of success.

Fishery options

i) *Fishery based on Indian major carps*
ii) *Fishery based on indigenous fishes*
iii) Fishery based on pen and cage culture

Beels also can be part of an integrated system including navigation, bird sanctuary, post harvest, aquaculture and open water fisheries. A proposed scheme of closed *beel* (Fig 2) has been shown as an 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 material. The Central Inland Capture Fisheries Research Institute has standardized methods for culture of freshwater prawn, *Macrobrachium rosenbergii* in pens. These include site selection, pen size and design, selection of pen material, pen preparation, deweeding, liming, water and soil quality management, species selection, stocking size, stocking density, stocking ratio, growing period, feeding, harvest size, and harvesting methods.

CONCLUSIONS

Beels are the ideal water bodies for practicing 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 to their better growth performance and high yield. 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.

It is well recognized that depletion of wild stock of fish and the resultant erosion of traditional inland fisheries in the floodplain wetlands are unavoidable to a great extent due to the man-made changes that have already taken place. It is equally obvious that all water bodies cannot be preserved for the purpose of biodiversity conservation, without neglecting the genuine developmental needs. It is also necessary to meet the pressing need faced by many developing countries to increase fish production from all kinds of inland water bodies in order to alleviate the problems of malnutrition and poverty. Thus, we have a delicate task at hand to dovetail the twin objectives of conservation as well as development of aquatic biological resources for human needs. There is a growing realization that the enhancement of fisheries in floodplain wetlands can emerge as a possible solution to resolve the conflicts by combining environmental concerns with the growing aquacultural ventures.

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Summer School on ***Environment Impact Assessment of Inland Waters for Sustainable Fisheries Management and Conservation of Biodiversity***
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BIOLOGICAL MONITORING TOOLS FOR INLAND FISHERIES RESOURCES.

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Introduction

Our inland waters have a particular facination for us . The expanses of lake waters surrounded by hills , and the unique of the corridors through which the streams and rivers flow towards the sea , evoke a sense of timelessness and feeling of contentment. But the aquatic environment is showing signs - many of them unwelcome - of man's activities. And our freshwater fisheries have not escaped the effects of the main problem - the discharge of chemicals and wastes.

Conditions of fish growth

Water is essential for all forms of fish and other aquatic animals which require require oxygen for their growth and survival. The water supply is only source of this oxygen for most of the species, although there are exceptions like air-breathing fishes, such as *Ophicephalus* spp. and *Clarias* spp.The availability of dissolved oxygen to the organisms depends on the amount of dissolved oxygen entering the aquatic system and / or processes within the system itself. The relative importance of these two sources is highly dependent on condition of system . The systems with short water residence times rely heavily on in-flowing water to supply the dissolved oxygen requirements to the biological communities. In this situation , the carrying capacity (amount of fish biomass that can be held) is determined by the respiratory requirements of the population and their physiological tolerance to low concentrations of dissolved oxygen in relation to the supply of dissolved oxygen in in-flowing water. A water inflow to the system can be an important source of harmful toxins but it is also an important medium for receiving and dispensing excretory products and other waste materials generated with in the system, which may prove harmful on a long term basis. The time scale changes in physical and chemical conditions of the water and sediments of the system play an important role in physiological behaviour and overall growth of fish populations.

Biological monitoring

Biological monitoring for detectable changes has the attraction that aquatic organisms will be reacting to the totality of the inputs, both in-terms of the variety of chemicals present and the range of their concentrations. In this respect, the measurement of biological responses has a distinct advantage over a chemical monitoring programme. There is a long history to the development of methods of measuring changes in the structure of aquatic communities, particularly in response to nutrient loadings. Some organisms are apparently sensitive to reduction in the DO of the water, whereas others are more tolerant ; however, it may be more accurate to say that the changes recorded are associated with changes in the DO because it is possible that there are other factors in complex organic effluents which are responsible in part for the effects on the organisms. These effects can be analysed in two basic ways : the presence or absence of "key" species that span the spectrum of sensitivity to organic load , and the change in species diversity which is a reflection of the smaller number of tolerant species that are able to live in polluted water. Of these two approaches the identification of key species is the less time-consuming and this is important for routine monitoring programmes.

Biomonitoring tools

Many approaches could be used to understand the ecosystem changes at species , community and physiological level, to evaluate the gravity of the impact so that suitable mitigation plan could be formulated . Some of the approaches are indicated below :

A. Eco-taxonomical approach

Indicator species	**Community structure**
Score system	Species diversity index
Algal index	Dominance index
Trent biotic index	Eveness index

Similarity index

B. Physiological & Biochemical approach

Biological function analysis	**Toxicity testing**
ATP	Short-term acute
Primary production	Long-term
Chlorophyll	Avoidance studies.

History of biological monitoring

The biological surveillance of fresh waters started with the development of Soprobian system at the turn of the twentieth century (Kolkwitz and Marsson, 1902, 1908, 1909). But early attempts to use biological information to detect pollution utilising both flora and fauna were made by Butcher (1928 , 1946) in U.K.. But gardually among all flora and fauna it was macro-invertebrates which assumed increased importance (Hawkes1956; Hynes 1959). It was , however, the publication of the Trent Biotic Index (Woodiwiss 1964) a method based entirely upon macro-invertebrates , establishing its utility for routine biological surveillance of pollution. Subsequently , the Trent Biotic Index (TBI) has been modified in many European countries for their local use. In U.K. the appearance of TBI was followed by a proliferation of score and index systems based on macro-invertebrate. Many of these were developed for limited geographic areas but recent one , Biological Monitoring Working party (BMWP) score , was devised by a committee of freshwater biologists for national use (Chesters 1980 ; Armitage et al., 1983).

Bioindicators

Biomonitoring can not yet completely replace chemical monitoring where detailed inventories of pollutants are required. Nevertheless , the shifts in the species composition and abundance of biotic assemblages may indicate pollution where the chemical cause such as a brief discharge or spill of material , has passed undetected. The organisms , species , populations and assemblages that can be used for biomonitoring are many and varied (from attached and planktonic micro-algae to macrophytic vegetation; from Protozoa to Fish). Many argue that while the condition of a river or lake is reflected most noticeably in the appearance of water (algal bloom ; turbidity) , organisms associated with sediments and other surfaces may provide the earlier indication of change in quality.

By definition , the ecology of best indicators of ecosystem quality or health is well established (planktonic *Anabaena* (eutrophic) and *Asterionella* (mesotrophic-eutrophic) benthic invertebrates from Plecoptera (many species indicating " pristine " water), to Chironomidae, Oligochaeta and larval Diptera (organic pollution) ; acid indicating diatoms) . Some of the best indicator organisms are also reasonably abundant and relatively easy to detect. In this connection , communities of organisms such as benthic invertebrates which are attached to , or loosely associated with surfaces , are perhaps more convenient than planktonic species (blue-green algae and diatoms on sandy and stony stream bottoms and lake shores).

Changes in organism morphology (algal size due to grazing pressure , fish caudal ray deformities due to acidification), in addition to shifts in the abundance of a species itself , can be used as *indicators of change*. Care must be exercised at all times in interpreting the indicator potential of a change in a population or assemblage.

Biomonitoring schedule

All zones of an ecosystem harbour biota that are , or have the potential to be , *indicators of water quality* (open water plankton , littoral zone , epipelic diatoms (on mud surfaces), epipsammic forms (on sand grains) , epiphytic species (on submerged plant leaves) and filamentous green algae (*periphyton*) loosely attached to submerged plants. Habitats and communities must be assessed (e.g, by stratified random sampling , transects or quadrats) to ensure repeatability and comparability of data that may be collected by different operators and / or at different times , otherwise the significance of a change or lack of change can not be assessed.

In addition to focussing on major pollution events (industrial discharges , strom runoff of sediment), sampling schedules must take account of the life cycles and generation times of the organisms of interest (daily sampling e.g., phytoplankton , protozoa and rotifera ; weekly for crustacean zooplankton ; seasonal for macrophytic vegetation and benthic invertebrates ; and possibly yearly or even less frequently for certain fish populations). Schedules may well need to be altered in order to chart events such as the recovery of a fish population following a kill due to pollution or disease.

Limitations of biomonitoring

Biomonitoring can also *fail* for a number of reasons. One of these can arise due to statutory authorities reluctance or inability to respond rapidly enough to reports on the appearance of pollution if plankton , especially algae , are taken as indicator species. If biomonitoring establishes the presence of a nuisance organism or an increase in its numbers to *undesirable* levels , the ecosystem is already in decline. Secondly , inadequate temporal and / or spatial sampling can lead to false interpretation as to the state of a water body. Dense , but patchy aggregations of surface-blooming blue-green algae which are very noticeable , may be perceived as *serious* even though such populations are likely to be very moderate if expressed on a lake-wise basis. An extremely dense and well mixed diatom populations can pass relatively unnoticed since they simply impart a general cloudiness to a water . Dense populations of organic pollution indicators are restricted to the immediate vicinity of a *spill*. The third shortcoming of biomonitoring stems from the lack of knowledge about the potential indicator value of many organisms (numerous chrysophycean species , the colonial green alga *Botryococcus braunii* and *Euglena* producing striking blooms of orange and red colour) .Fourthly , there is the problem of the very identity of organisms recorded , and fifthly , among very small (*pico*) plankton , some are likely to be completely overlooked even when present in enormous numbers , e.g., *Synechococcus* (Cyanobacterium) .

Inspite of the fact that biomonitoring reflects the sum-total of physico-chemical changes in an aquatic ecosystem due to various environmental stresses yet at times it does not give conclusive mathematical evidence regarding positive or negative impacts on an ecosystem as can be provided by chemical monitoring. Despite a variety biological indices and the often vigorous debate on their relative merits , the principle underlying all of them is effectively the same. Each individual taxon can be attributed a score , value or category that is indicative of its tolerance to environmental stress . An integration of the scores of all taxa present at a site provides a measure (index) of the extent to which the site is , or has been , stressed.

Effectiveness macro-invertebrates in biomonitoring

Employing macro-invertebrates in biomonitoring has been found to be very effective in comparison to drifting plankton populations. Many workers have stressed it importance
(Hellawell 1977 ; Hellenthal 1982). Recently a forecasting model has been developed in U.K. by using macro-invertebrate monitoring. Some of the advantages are :

- The wide diversity and abundance of species in almost all freshwater habitats
- Their relatively sedentary habit which allows the presence of most taxa to be related directly to environmental conditions at their place of capture.
- The length of life-cycle of many species which provides a perspective of conditions which pertain to at a site over several months.
- The ability of invertebrate communities to integrate and to respond to a range of environmental stresses simultaneously.
- Many species are important accumulators and concentrators of toxic substances
- Qualitative sampling is easy and inexpensive.

Use of biomarkers

One of the main areas of emphasis in current bio-marker research is the application and validation of markers to assess toxic effects of aquatic pollutants in the field.The histopathological investigations have proved to be a sensitive tool to detect direct toxic effects of chemical compounds within target organs of fish in lab experiments (Wester & Canton,1991; Schwaiger et al., 1996) and in field investigations (Hinton et al., 1992; Teh et al., 1997). In addition to assessing toxic effects, a further aim of the histopahological approach is to identify histopahological alterations which may occur from environmental stressors other than contaminants (Teh et al., 1997) which are known to occur as a consequence of adverse environmental conditions (Snieszko,1974; Moller,1985; Anderson, 1990).Such alterations which occur in fish living in polluted environments are in most cases described as " pollutant – associated " rather than " pollution – induced " (Overstreet,1988).Histopathological investigations have the capacity to differentiate between organ lesions induced by diseases and other environmental factors from those lesions due to pollutant exposure.The histopathological changes have to be evaluated vis-à-vis total limno-chemical changes in the system. Similar approach was investigated at CIFRI during environmental evaluation in Ganga river system in West Bengal by (Vass et.al., 1998 ; Mohanty & Vass 1998) and valuable information in this regard has also been generated by (Shantnau , 1999).

In order to evaluate effects of pollutants on the abundance, production and persistence of populations, communities and ecosystems , a variety of methods have been developed from the (sub) cellular (Aregese et al., 1994) to the ecosystem level (Hall et al., 1985). With every increase in level of biological organisation , the degree of ecological relevance and realism increases , but repeatability and interpretation of the observed effects become more difficult (Persoone & Janssen, 1994). Ecosystem – level assessment methods have the advantage of studying effects which may not always appear at the organismal or population level (e.g., changes in the structural or functional properties of communities), but they face practical problems (e.g., long exposure times) and are therefore expensive (Suter,1992). Unfortunately, these bio-marker endpoints usually suffer from lack of ecological relevance and are therefore difficult to interpret in environmental impact assessments (Giesy & Graney, 1989).

A number of theoritical principles have been developed linking effects at the (sub) organismal level with population level effects (Kooijman & Metz, 1984; Nisbet et al., 1989). The "metabolic cost " hypothesis as reviewed by Calow and Sibly (1990), suggests that toxic stress induces metabolic changes in an organism, which might lead to a depletion of its energy reserves resulting in adverse effects on growth and reproduction. In this context recently developed technique , the Cellular Energy Allocation (CEA) assay , is used to evaluate the effects of toxic stress on the metabolic balance of test organism (De Coen et al., 1995). Using this approach , energy reserves available (Ea) and energy consumption (Ec) are quantified bio-chemically and integrated into a general stress indicator. Energy consumption is estimated by measuring the electron transport activity (ETS) at the mitochondrial level , while the energy reserve available for metabolism is assessed by measuring the total lipid, protein and sugar content of the test organism. The difference between Ea and Ec represents the net energy budget of the test organism.

Although this technique was initially developed and validated with *Daphnia magna* , the CEA methodology can also be used with other invertebrates and vertebrates. Indeed, in a series of fish early life stage tests (ELS) with *Clarias gariepinus* , it has been recently demonstrated (Nguyen,1997 Mss) that the CEA criterion was predictive of long term effects on growth. Further research is presently going on to refine the methodology and to establish more quantitative relationships between the sub-organismal endpoints and population level effects.

Conclusion

Biomonitoring at whatever level it may be conducted , is an important tool in evaluating likely impacts on production functions in an ecosystem in an EIA investigation of any development project utilising natural resources directly or indirectly. This important tool has evolved , is being constantly standardized and refined inspite of various shortcomings inherent in dealing with biological species / communities. By and large biomonitoring based on macro-invertebrates is proving to be very effective in a general surveillance programme while physiological and biochemical indices of test populations in ecosystems are being developed to pinpoint the stress induced damages on organisms due to positive or negative environmental impacts.Therefore , biomonitoring will have greater role in future EIA programmes.

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BIOLOGICAL METHODS FOR THE ASSESSMENT OF WATER QUALITY AND PRODUCTIVITY OF AQUATIC BIOTOPES

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Introduction

The environment, in an aquatic biotope, embodies the total physico-chemical factors that exert an effect upon the biotic communities including fisheries. Development of inland water bodies is becoming difficult due to environmental stress posed by anthropogenic activities. Environmental pollution is essentially a biological phenomenon, but the water quality is generally understood in terms of chemical parameters. The deterioration of water quality by human activities may change rapidly the physico-chemical characteristics, necessitating appropriate biomonitoring. Advantage of biological monitoring of water quality is that it can integrate many different environmental factors over a long period of time. On many occasions, chemical monitoring is ineffective either due to combined effects of the pollutants or the concentration being too low to be detected. In determining water quality in relation to fish, biological monitoring assumes greater significance, since it gives a direct measure of the biological qualities conducive to fish productivity.

Methods of biological assessment

There are many methods for biological assessment of water quality and productivity of aquatic biotopes which are depicted in Fig. 1.

Trend biotic index, various score systems and the species diversity indices are more useful in biological monitoring. Primary productivity analysis by light and dark bottle method is also very useful for assessing the productivity status of a water body *vis a vis* to identify environmental stress of the ecosystem. However, it is important to note that most biotic indices and saprobic indices can not be translated into each other, they all have their own values. It is generally found that any single index would not satisfy all requirements, so a number of indices may be used in conjunction for proper assessment of water quality and productivity. For environmental impact assessment work, it is

Primary production

Primary productivity study is very useful for assessing the productivity status of a water body *vis a vis* to indentify environmental stress on the ecosystem. Phytosynthesis by green plants, phytoplankton or algae adds chemical energy and organic matter to ecosystems a fraction of which becomes available to consuming organisms. In most ecosystems organic matter is produced by primaryproducers (autotrophic organisms) and is degraded to carbon dioxide and nutrient by heteroteophs mainly animals and bacteria. In any system the flow of energy coming from the sun's radiation is unidirectional and most of it is transformed to heat within the system. Nutrients such as carbon, nitrogen, phosphorus, silicon and many others brought into the aquatic environment with in flowing water, rainfall,sewage etc. may cycle within the system before they are exported from it.

Primary productivity in an open water body depends on sunlight, turbulence, turbidity, nutrient concentration as well as on environmental stress. In Hooghly estuary Ghosh *et al* (1980) conducted primary productivity study in relation to industrial pollution. They found lower primary production during summer and monsoon season around the outfall of pulp and paper mill (Soda process). Ghosh *et al* (1977) also observed that primary production was significantly lower at the outfall of sulphite pulp and paper mills.

Bagchi and Nath (1998) studied the primary production of Hooghly Matlah estuarine system with special reference to pollution in Hooghly estuary during 1982-93. They recorded minimum primary production at Nowabganj centre nearBarrackpore.This zone is having many industrial units along the banks which discharged their untreated effluents into the estuary which adversely affected the primary production at this centre compared to other centres (Table 1).

Table 1. Mean primary production (mgC/m^3/hr) at different centres of the Hooghly estuary (1982-93)

P. P.	**Nabadwip**	**Medgachi**	**Nowabganj**	**Uluberia**	**Kakdwip**	**Frazerganj**
Gross	52.3	45.3	36.7	51.4	59.4	65.3
Net	29.5	32.5	20.1	32.5	33.3	34.4

The first author studied the impact of hot water discharge on primary productivity in Rihand reservoir. Estimation of Carbon assimilation employing 14C technique revealed wide fluctuation of primary productivity within various sectors of the reservoir. In Inlet Bay the primary production was moderate (Av. 21.01 mgC/m^3/hr) which declined to 0.38-4.8 mgC/m^3/hr in hot water channel which recorded higher temperature showing an average range of 6.65 ^{0}C. The productivity improved in Waidhan Bay (2.21-91.58 mg C/m^3/hr) where the temperature is lower than hotwater channel.

Primary productivity study may be employed as a useful tool for classifying the fish ponds. The primary production was trace (Nil-6 $mgC/m^3/hr$) in a pond having acidic soil reaction (pH 3.5) which was found to be unsuitable for fish culture (Nath 1986). Primary production ranged between 200 and 432 $mgC/m^3/hr$ in Jalpaiguri ponds having acidic soil reaction (pH 5.8-6.2) while at Malda having neutral soil reaction (pH 6.9-7.2), the primary production was significantly higher ranging between 526 and 762 $mgC/m^3/hr$ (Nath et al, 1994, Nath and Tripathi,1997)). In fact Malda ponds were very productive compared to Jalpaiguri ponds. In India, significant improvement in the water quality and primary productivity rate has been observed in Kanpur (Ganga) due to the positive impact of diversion and treatment of the effluents, prior to their release in the river since 1987 (Jhingran, 1991).

Thus, primary productivity estimation of natural water bodies is an useful tool for biomonitoring studies. A sudden decrease of primary production in a zone of a system indicate industrial pollution or other stress in that zone. On the other hand, very high primary production also shows excess nutrient load, particularly phosphate and nitrogen, which may lead to algal bloom in that zone. Excessive algal bloom is not conducive for natural water bodies. The ultimate and best solution to the problem of eutrophication is removal of nutrients from the source water of any water body, but this may be very costly affair in most cases. So, efforts may be focused to develop ways in which the water bodies can assimilate higher quantity of nutrients without becoming obnoxiously degraded. Efforts should be made to develop more efficient food chains, so that high productivity of eutrophic water bodies may be converted into desirable fish protein. The addition to lakes of suitable fungi and viruses which attack blue green algae has been suggested as one means of keeping undesirable algal growth in check.

Das and Bandyopadhyay (1998) have identified the bioindicators of pollution in respect of phytoplankton (*Oscillatoria chlorina, Pandorina morum, Anbistrodesnus falcatus, Phacus, longicaudata, Scenedesmus quadricaudata, Microcystis aeruginosa, Synedra ulna, Ceratim hirundinella, Nitzschia acicularis)* and zooplankton *(Vorticella convularia, Rotatoria rotatoria, Morina brachiata, Brachonus rubens, Daphnia carinata*) from the papermill effluent discharge site in Kole Beel, West Bengal.

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MICROBIAL COENOSES OF AQUATIC ECOSYSTEMS WITH REFERENCE TO PRODUCTIVITY MANAGEMENT

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INTRODUCTION

Indian inland fisheries has a dominance of carps and related fish species that are sustained by both the photosynthetic and detritus food chains (Fig.1). The aquaculture practices are largely organic-based, compatible with other agro-based farming systems in terms of utilisation of by-products as manures and/or feeds for sustaining the photosynthetic and heterotrophic food chains. Further, intensification of aquaculture systems has caused a rise in the level of inputs like chemical fertilisers, raw feed material, etc., that often result in eutrophication, reduced ecological efficiency and diversity rendering the waters low productive. Microbiological studies delineate the trophic interactions and define the nutrient and energy flow patterns providing specific tools for environmental modifications as also products that could be substitutes for chemical inputs or mechanical devices. Biofertilizers, processed organic materials and biofilters are some of the inputs with high potentials of application in aquaculture systems.

TROPHIC SIGNIFICANCE OF MICROBIAL COMMUNITIES

Aquatic production processes are sustained by two food chains, viz., photosynthetic food chain and the heterotrophic food chain. In the former, photosysthetic bacteria and algae from the basis of the ecological pyramid and energy transfer is mediated by different levels of secondary producers, consumers or grazers, while in the latter, decomposers and saprotrophs play a major role in breakdown and utilisation of the dead and decaying organic matter by the trophic components. Aquatic habitats contain diverse microbial communities like bacteria, fungi and actinomycetes that greatly contribute to these processes (Table 1). The techniques for enumeration of bacterial communities and quantification of bacterial biomass in aquatic environments include direct counting of specifically stained bacterail cells - epifluorescence and immunofluorescence; indirect counting by dilution and growth techniques - plate counts and most probable number (MPN) determinations; chemical methods of measuring a unique bacterial components like lipopolysachharide or muramic acid, adenosine triphosphate, etc. and measurements of metabolic potentials of bacterial populations as indicated by activities like sulphate uptake, substrate disappearance, hydrocarbon utilisation potentials, heterotrophic activities, etc. (Table 2).

Studies in Indian freshwater fish ponds under different management practices like organic manuring and inorganic fertilisation have shown gross primary production levels of 2-6 g C/m^3/day, comprising high proportious of net production, with photosysthetic efficiencies of 0.90 - 2.95% of incident light energy. The fish production efficiencies based on photosynthetic energy fixation and total carbon input at production levels of 4-6 tonnes/ha/yr work out to about 1-3%. Assessment of intensities of heterotrophic food chain has indicated the trophic importance of the detritus or finely decomposed organic matter with high nutritive values, the quantities being as high as 4 g/cm^2/day, contributing upto 80% of the energy in the systems.

Aquatic habitats contain diverse microbial communities and their role in detrial food webs and organic mineralisation, particularly through bacteria has been well studied. In studies on freshwater fish ponds under different managemnt practices, gross primary production levels of 2.01-6.01g C/m3/day comprising high proportions of respiration (31.12-139.82%) were observed, with photosynthetic efficiencies of 0.90-2.95% of incident light energy. The fish production efficiencies based on photosynthetic energy fixation and total carbon input were 0.97-2.94% and 0.90-2.33%, respectively. With heterotrophic bacterial populations of 0.51-157.07 x 10^3/ml water and 0.36-15.03 x 10^6/g sediment, the studies brought out the significance of the heterotrophic food chain in fish pond ecosystem, further evidenced by the energy contribution levels. With mean levels of 1.36-6.42 mg detritus/cm^2/d, the percentage contribution of energy from detritus was in the range of 76.21-90.62%, as compared to 9.38-23.79% through plankton.

Use of microbial communities for processing organic wastes and production of single cell protein and use of bacterial inoculants as silage additives for increasing microbial biomass have been proposed for improving production potentials. While production of SCP from different organic sources has been discussed in the context of improvement of trophic potentials, use of bacteria (*Streptococcus, Lactobacillus*) and fungi (*Coprinus, Pleurotes*) in ensiling paddy and wheat straw has been worked out by several workers. The nutritive qualities of microbial communities as feed components of carp fry were evaluated, using pure microbial culture (*Bacillus subtilis* and *Aspergillus flavus*) and processed substrates (mixtures of wheat bran and groundnut oilcake in equal proportions fermented with 2% yeast powder and water hyacinth processed with 10% cowdung and 2% urea). Crude protein levels (percentages on dry weight basisi) in various feeds, *viz*., bacteria, fungus, plankton, wheat bran-groundnut oilcake mixture (1 : 1), fermented bran-cake and processed hyacinth were 43.63, 47.27, 42.91, 20.09, 36.37 and 14.53, respectively. The corresponding energy values were (k cal/g dry weight) 2.98, 4.03, 3.78, 3.02, 3,68 and 3.01. The study showed the significance of microbial communities as trophic components of filter-feeding fish, as also the possibilities of their better utilisation for carp rearing through medium enrichment or diet incorporation.

ORGANIC DECOMPOSITION AND PROCESSING OF ORGANIC MATTER

The degradation of organic matter regulates a number of important functions like nutrient recycling, food production for detritus feeders, production of regulatory ectocrine substances and modification of inert material(Fig.2). Decomposition of organic substrates has been studied both as a means to assess the decomposition potentials of the different types of ponds, as well as to recycle the organic matter into carp culture, that enhances the detritus pathway. The mean daily loss rates of cow manure, biogas slurry, poultry manure, water hyacinth, *Salvinia, Azolla*, filter paper and silk, the last two provided as cellulose and protein substrates were 0.99, 2.06, 2.83, 2.21, 1.65, 2.70, 1.51 and 1.05% of initial weights on dry weight basis. The corresponding nitrogen release rates worked out to 0.83, 1.06, 1.19, 0.69, 0.48, 1.25, 0.64 and 1.21%. With significant differences in the daily decay loss rates, the nitrogen release as well as the decomposition rates wee related to the nitrogen content of the substrates.

Studies on processing and utilisation of the problem weed, water hyacinth, with a view to recycle it into carp culture as a manure and/or feed were conducted with inocula of cowdung/poultry manure and urea. A period of 2-3 weeks was observed to be adequate for treatment, considering the changes in its nutrient compartments, bacterial populationa and the effects on water quality. High organic processing potentials (5 g $C/m^2/d$) and primary production sustenance capabilities (4 g $C/m^2/d$) were demonstrated. Biomanipulation of the environment of shortening food chains, achieved through both the application of processed hyacinth and maintenance of high fish densities, increased the efficiency of the vegetation-fed and detritus-based carp culture sysem.

Microbial pre-conditioning of organic matter in the biogas plants improves the nitrogen conservation in the resource and its application was found beneficial at different stages of carp culture. The specific growth rates of catla spawn reared for a period of 15 days with cowdung at 10 t/ha, biogas slurry at 15 and 30 t/ha and the latter supplemented with feed were 2.14, 3.13, 4.82 and 6.72.Fry-rearing experiments with cowdung at 10 t/ha and slurry at 30 t/ha gave respective growth rates (SGR) of 1.14 and 1.40.With manurial treatments of cowdung at 10 t/ha/yr and biogas slurry at 15 and 30 t/ha/yr in ponds stocked with catla, rohu, mrigal, silver carp, grass carp and common carp fingerlings at a density of 6000/ha, the respective mean net fish production rates were 2.2, 3.3, 3.7 t/ha/10 months. With corresponding mean primary production levels of 3.19, 3.21 and 3.29 g $C/m^2/d$, the respective production efficiencies were 2.18, 3.45, and 3.65. Based on the total carbon input, the efficiencies worked out to 1.88, 2.98 and 3.02%. An application rate of 30-45 t/ha/yr of biogas slurry is recommended for carp culture.The savings in fertilization practices with biogas slurry over the recommended manurial schedule in carp culture amount to around 30%.This assumes great significance in view of the increasing costs and scarcity of inorganic fertilizers as also the suitability of the biogas plants for processing and recycling several natural organic resources like aquatic macrophytes and agricultural by-products that otherwise are 'wastes'.

NITROGEN FIXATION AND BIOFERTILISATION

The significance of biological nitrogen fixation in aquatic ecosystems has brought out the utility of biofertilization through application of heterocystous blue-green algae and related members. This assumes great importance in view of the increasing costs of chemical fertilizers and associated energy inputs that are becoming scarce as also long term environmental management. *Azolla*, a free-floating aquatic fern fixing atmospheric nigrogen through the cyanobacterium, *Anabaena azollae*, present in its dorsal leaves, is one of the potential nitrogenous biofertilizers. Its high nitrogen-fixing capacity, rapid multiplication as also decomposition rates resulting in quick nutrient release have made it an ideal nutrient input in farming systems.

Azolla is a heteosporous fern belonging to the family Azollaceae (Salviniaceae) with seven living and twenty extinct species. Based on the morphology of reproductive organs, the living species are grouped into two subgenera, viz., *Euazolla (caroliniana, A. filiculoides, A. microphylla, A. mexicana, A. rubra)* and *Rhizosperma (A. pinnata, A. nilotica).* Proliferation of *Azolla* is basically through vegetative propagation but sexual reproduction occurs during temporary adverse environmental conditions with the production of both microsporocarp and megasporocarp.

Though *Azolla* is capable of absorbing nigrogen from its environment, *Anabaena* meets the entire nitorgen requirements of *Azolla-Anabaena* association. The mean daily nitrogen fixing rates of a developed *Azolla* mat are in the range of 1.0 - 2.6 kg/ha and a comparison with the process of industrial production of nitrogenous fertilizers would indicate the efficacy of biological nitrogen fixation. While the latter carried out by the enzyme nitrogenase, operates with maximum efficacy at 30°C and 0.1 atm, Haber-Bosch process employed by the fertilizer industry requires reaction of nitrogen and hydrogen to form ammonia at temperature and pressure as high as 300°C and 200-1000 atm respectively.

The normal doubling time of *Azolla* plants is three days and one kilogramme of phosphorus applied results in 4-5 kilogrammes of nitrogen through *Azolla*, i.e. about 1.5 - 2.0 t of fresh biomass. It may be mentioned that *Azolla* can survive in a wide pH range of 3.5 to 10.0 with an optimum of 4.5 - 7.0 and withstand salinities of up to 10 ppt. With a dry weight range of 4.8 - 7.1% among different species, the nitrogen and carbon contents are in the range of 1.96 - 5.30% and 41.5 - 45.3% respectively. *Azolla* is useful in aquaculture practices primarily as a nitrogenous biofertilizer. Its high decomposition rates also make it a suitable substrate for enriching the detritus food chain or for microbial processing such as compositing prior to application in ponds. Further, *Azolla* can serve as an ingredient of supplementary feeds and as forage for grass carp too. Studies made on *Azolla* biofertilization have shown that the nutrient requirements of composite carp culture could be met through applicaltion of *Azolla* alone at the rate of 40 t/ha/yr providing over 100 kg of nitrogen, 25 kg of phosphorus and 90 kg potassium along with 1600 kg of organic matter. This amounts to total substitution of chemical fertilizers along with environmental upkeep through organic manuring. A saving to the extent of 30-35% over the recommended manuring schedule is estimated through *Azolla* biofertilization.

BIOFILTRATION AND TREATMENT OF BILOGICAL WASTES

Reduction of ammonia and nitrite-nitrogen contents in the water medium assumes great importance in intensive aquaculture operations, particularly in prawn farming. Biofilters, biodrums, bioreefs, the variants of the substrates provided for immobilisation of the nitrifying bacterial communities (*Nitrosomonas, Nitrobacter*) have been used for the purpose. These were further demonstrated to be economical and effective substitutes for mechanical processes like aeration and agitation that are energy-intensive.

Long-term operations of carp hatcheries result in problems of low hatching and survival rates due to development of biofilsm oand bacterial flora that ae often hazardous. With high metabolite and bacterial loads, application of antibiotics does not give the anticipated effects on many occasions. In this regard, UV-irradiation of water medium was found effective at a dose of 5.4 x 10^6 μw.sec/m^2 or a flow rate of 20 l water per minute in a layer of 3 cm with an exposure from a single UV lamp of 40 w capacity was shown to disinfect 1 m^3 of water for hatchery operations.

Biological treatment of waste waters, already occurring in nature, but stadardised with introduction of specific microbial inoculants or scaled-up designs, is a potential area compatible with freshwater aquacultue. The objectives of using sewage for fish culture are two-fold: utilisation of nutrients in the waste water for fish production being the earlier concept, and using aquaculture as a tool for treatment of sewage and other waste waters being the recent trend. With production rates of 5.4-7.0 t/ha/yr achieved in sewage-fed carp culture practices, the aspect of integrated farming is also being considered as low-cost and low-input technologies, where excreta of several animals like poultry, sheep, pigs, rabbits, apart from cattle, are applied into fish ponds. Further, the aspect of reduction of nutrient and bacterial loads through fish culture has been considered and shown effective with regard to counts of total and faecal coliforms, faecal *Streptococci* and *Salmonella.*

SEWAGE TREATMENT THROUGH AQUACULTURE

Several variations of models of aquaculture for treatment of domestic sewage have been proposed. Employing the biotic components such as bacteria, algae, duckweeds, macrophytes and fish/shellfish in an aquatic ecosystem, the principle of all models has primarily been dilution, oxidation, and reduction of the suspended solids along with nutrient recovery in terms of biomass. Both autotrophic and heterotrophic food chains operate in these systems, rendering the effluent nutrient-deficient and less harmful to the environs to which they are discharged.

Fish ponds serve as facultative ponds for sewage treatment, also providing oxygen input from the photosynthesising algae and macropohytes. The macrophytes also serve as nutrient pumps, reducing the eutrophication effects that the sewage is likely to cause in the natural waters. It has been demonstrated that ponding reduces the bacterial loads by 2-3 log units and bacteriophage loads by 3-4 log units even at a sewage loading of 100 kg COD/ha/d. With no evidence of a build-up of the concentration of excreted microorganisms in pond water with either an increase in organic loading or time, it has been shown that the faecal coliform concentrations reduced by 4 log units within 24 hours of retention in the ponds.

Studies have shown that about 1 million litres per day of domestic sewage could be treated over an area of one hectare through water hyacinth, reducing the BOD and COD by 89 and 71% respectively, along with removal of nitrogen and phosphorus to the extents of 89 and 50%. Aquaculture being a product-oriented practice, public health concerns are being raised with regard to the suitability for consumption of fish/shellfish from such systems. This pertains to the microbial load of the produce, possibilities of harbouring human pathogens, accumulation of pesticide residues and heavy metals, etc. Accordingly, the sewage-fed aquaculture models are being modified with the incorporation of plant cultivation prior to application of wastewaters in fish ponds, also followed by necessary depuration measures and a system has been developed by the Central Institute of Freshwater Aquaculture, Bhubaneswar, in the recent years (Fig. 3). Duckweeds serve as nutrient pumps, reduce eutorphication effects and provide oxygen from their photosynthesising activity. Aquatic macrophytes used for treatment of domestic sewage were *Azolla spp., Spirodela spp., Wolffia spp.* and *Lemna spp*. The approximate growth rates of individual weeds in the sewage-fed culture system were *Azolla spp*. - 160 g/m3/d, *Spirodela spp.* - 350 $g/m^3/d$, *Wolffia sp.* - 280 $g/m^3/d$ and *Lemna spp.* - 275 $g/m^3/d$. The harvested weeds could be used for feeding grass carp (*Ctenopharyngodon idella*) in the marketing ponds. Excess of weeds could be used for composting, which is further applied in fish ponds, agricultural and horticultural fields, etc. Polyculture of carps (catla, rohu, mrigal, silver carp, common carp and grass carp) is preferable over monoculture in sewage treatment systems.

Distillery effluents are also a major resource in the country with about 150 distilleries producing 900 million litres of alcohol annually, resulting in 10,000 million litres of spent wash. The efficacy of aquaculture, as a tool for treatment of such wastes, has been demonstrated at Madras, where the effluent after undergoing the biomethanation process, is fed into fish ponds. With production rates of 50 tonnes per hectare per year, about 6 hectares of land area have been shown to be adequate for treating 100m3 of effluents. This has opened avenues for utilising a variety of agro-based industrial effluents as also for treating them through aquacultue practices, largely based on microbial processes, in terms of oxidation or nutrient removal through algae and other macrophytes.

In terms of solid wastes also, the resources in the country are huge in terms of agro-residues amounting to 321 million metric tonnes per year. As already mentioned, on bioconversion of these lignocellulosic wastes, they can be applied to fish ponds as manure/feed, which also results in usable products like single cell protein and biogas.

Microbial technology for aquaculture comprising aspects of biofertilization, microbial processing of organic matter, use of probiotics and enhancement of feed digestibility, detritus enrichment and shortening of food chains for better energy traqnsfer rates, genetic upgradation of bacterial strains, biofiltration and waste recycling as also techniques pertaining to post-harvest technology hold great promise in environmental management as also optimising aquatic productivity on a sustainable basis.

Table 1. Microbial communities in a pond ecosystem

MICROBIAL COMMUNITIES

Bacteria

Autotrophs

Nitrifiers, Aerobic & anaerobic, Sulphur oxidisers, Photosynthetic sulphur bacteria

Facultative autotrophs

Iron & manganese oxidisers, Methane oxidisers

Heterotrophs

Ammonifiers, Nitrogen fixers-aerobic and anaerobic, Dinitrifiers, Phosphorus solubilizers, Sulphate reducers, Amylolytic bacteira, Cellulose decomposers-aerobic and anaerobic, Methane producers, Protein decomposers

Fungi

Molds

Phycomycetes

yeasts

BACTERIA (Classification based on different criteria)

Distribution

- Free floating (Planktonic)
- Adhering to suspended particles
- Attached to submerged solids supports (epiphytic and epilithic)
- Sediment bacteria

Nutrition

- Photosynsthetic autotrophs
- Chemosynthetic autotrophs
- Heterotrophs

Oxygen requirements

- Aerobic
- Anaerobic
- Facultatively anaerobic
- Microaerophilic

Temperature preference

- Psychrophilic
- Mesophilic
- Thermophilic

Morphological

- Bacilli
- Cocci
- Coccobacilli
- Filamentous rods

Structural

- Spore bearing/Sporeless
- Capsulated/bare
- Flagellate/Aflagellate

Table 2. Enumeration melthods of aquatiac bacteria

Methods of enumeration

Direct counting of specifically stained cells	Chemical methods of measuring a unique bacteria component	Measurements of metabolic potentials	Other methods	Indirect counting by dilution and growth techniques
Epifluorescence Immunofluorescence	Lipopolysachharide or muramic acid Adenosine triphosphate	Sulphate uptake Substrate disappearance Hydrocarbon degradation heterotrophic activities	Turbidimetry Nephelometry Enzyme activity measurements	

Direct microscopy using membrance filters

Filter 5-10 ml of water on 0.2 μm millipore filters, air-dry, stain with phenon - erythrosin, air-dry and observe under oil immersion, Count the number of bacteioplankton and compute for unit quantity of the sample

Plate counts

(Standard dilution plate count technique)
In petridishes using agar media Count the number of colony forming units and compute the bacterial number in unit quantity of sample

Dilution counts

(Most probable number methods)
In test tubes using liquid media Observe growth, count the number of positive tubes and determine the MPN of bacteria

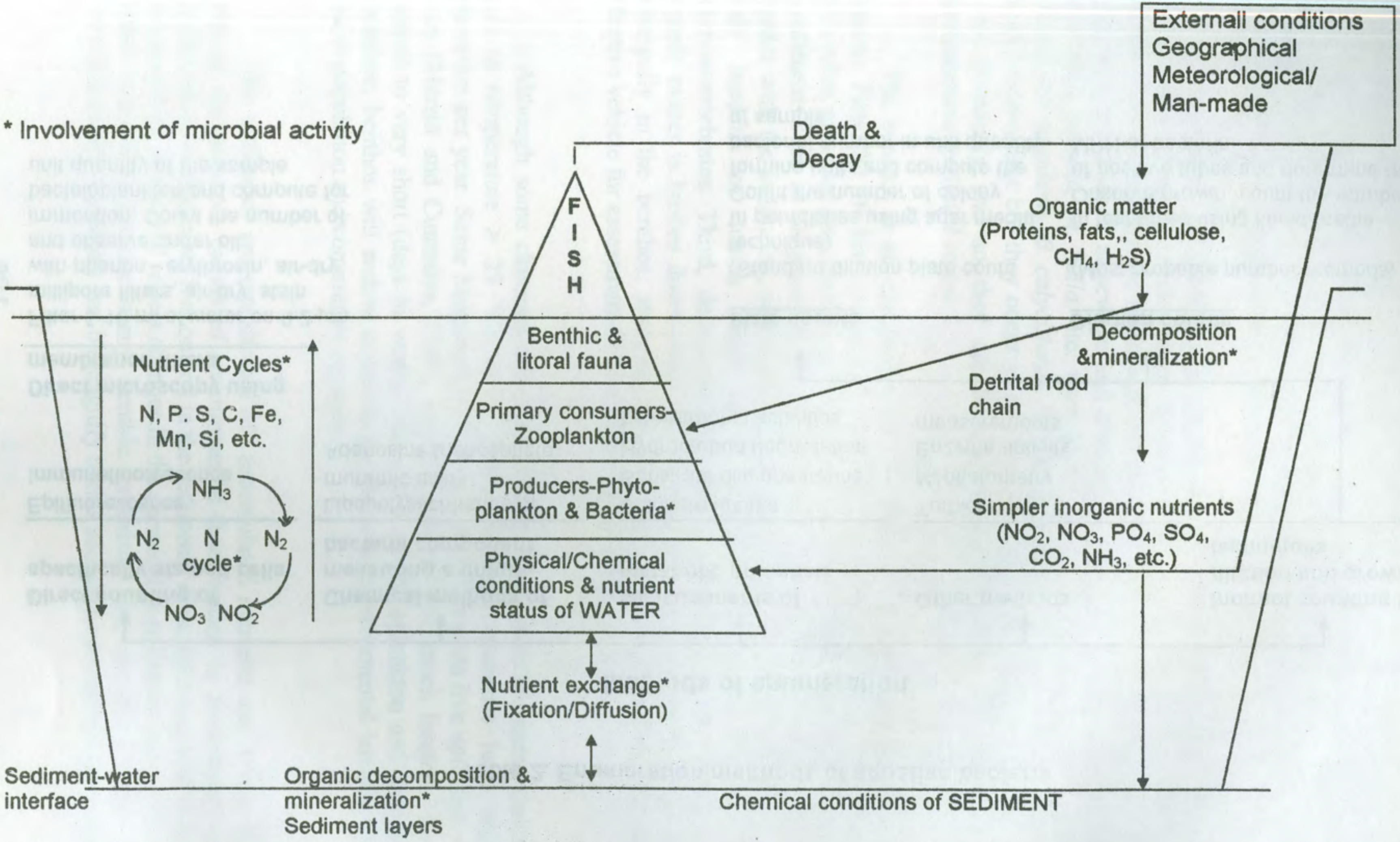

Fig. 1. Significance of microbial activity in aquatic trophic interactions

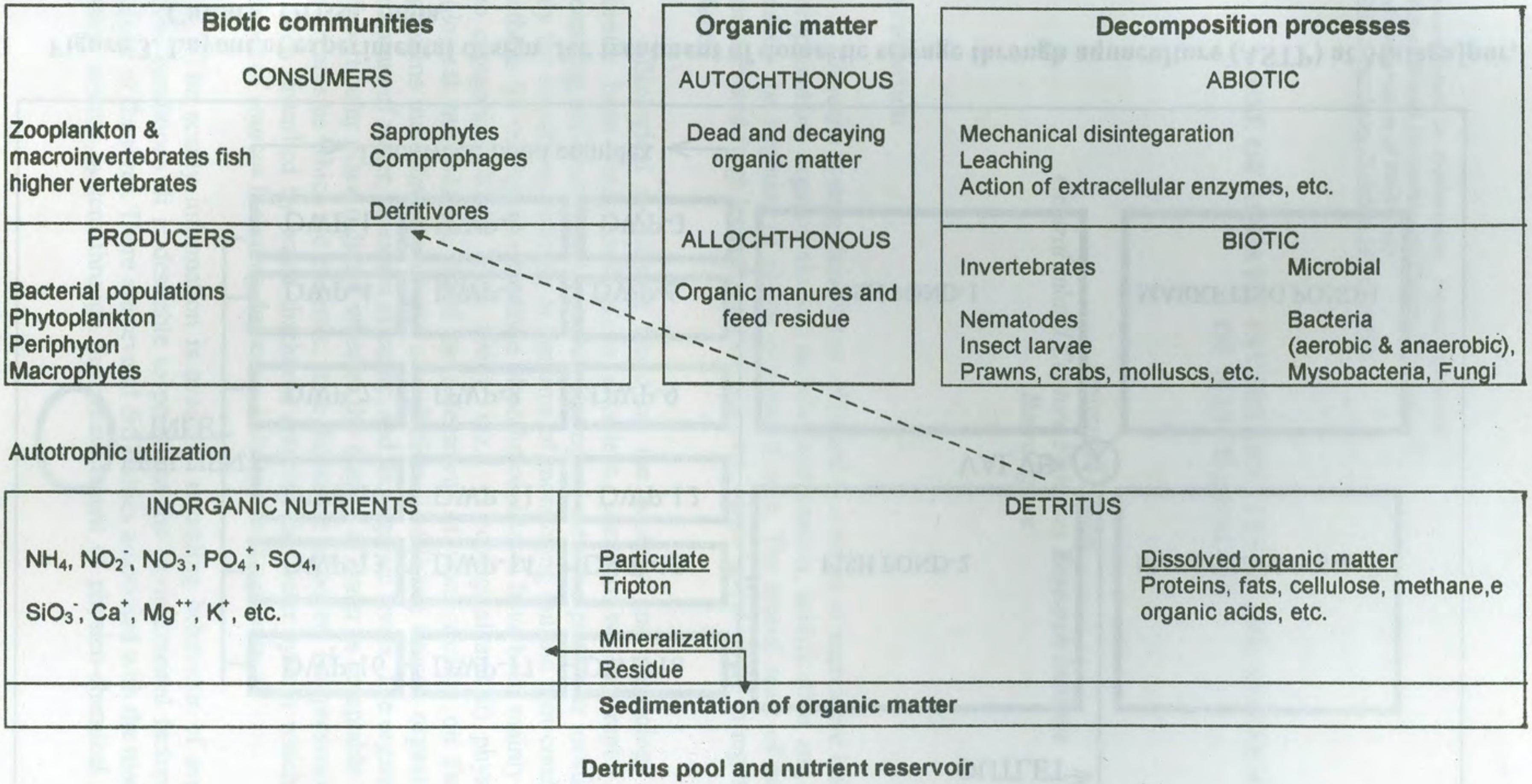

Fig. 2. Significance of decomposition processes in nutrient recycling and detritus food chain

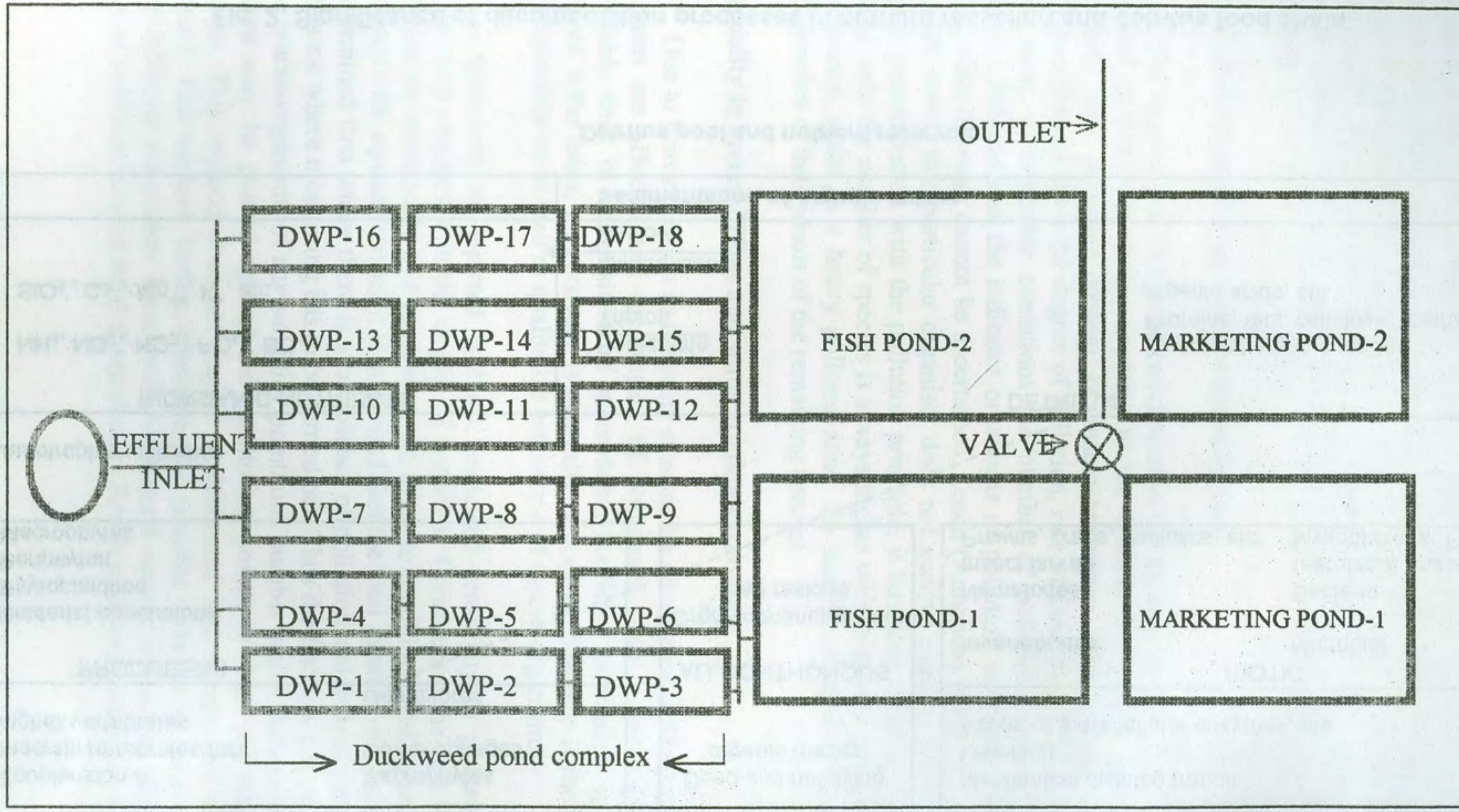

Figure 3. Layout of experimental design for treatment of domestic sewage through aquaculture (ASTP) at Matagajpur, Cuttack, Orissa, India.

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USE OF AQUATIC INVERTEBRATES IN THE ASSESSMENT OF WATER QUALITY

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Introduction

Aquatic systems have been subjected to a series of successive insults, including eutrophication, organotoxin and metal contamination, acidification and perhaps, most recently the begining of global climatic change. The spatial scale of perturbation has been elevated from local disruption of lakes, streams and rivers to regional and global effects.

Biological monitoring based on the ecology and physiology of fauna has recently been recognized as an excellent, unexpensive and rapid technique for measuring pollution levels in water. Biological data at a particular location reflects not only the conditions existing at the time of monitoring but the past conditions as well. Methods for biological estimation of pollutional level have been mainly classified into two categories (Wood Wiss, 1964) viz., i) ecological and ii) physiological. The ecological methods are based on assessment of water quality on the basis of the organisms indicating the degree of pollution. The living aquatic organisms determine the nature of water, its extent of purity, and its hygienic levels. The organisms present at any particular place indicate whether the quality of water is acceptable or not as such the organisms which are endemic, state the nature of water. The presence of organisms is often disturbed by waste discharge entering the water system which come from a number of sources including domestic, industrial and agricultural.

The scanty information is available regarding behaviour of organisms under Indian conditions. It is desirable to point out the environmental factors affecting the ecology of the river. There are several difficulties associated with the monitoring of any natural aquatic system through the measurement of physico-chemical and biological parameters. The dynamic interaction between animal kingdom, plant kingdom and human beings is very complex. Similarly, the impact of physical environment on biotic environment is not yet well understood. The measurement of physico-chemical parameters is fairly accurate but time consuming and costly. The measurement of biological parameters are straight forward and quick and could be adopted as a source of first hand information regarding the level of pollution and in this context the aquatic invertebrates are adequatly good source to assess the water quality of natural inland resources.

Effects of water quality on aquatic invertebrates

The organic and inorganic enrichment in the aquatic system causes decrease in dissolved oxygen and sludge deposits in the bottom. In general, this affects the respiratory and digestive system of macro-organisms. The extent of anaerobic conditions depend upon the degree of pollution, rate of fluid flow and its temperature. Under these unfavourable conditions the number of pollution intolerant species is drastisally reduced and the indicator organisms of pollution vanished. Therefore, the exact quality of water cannot be ascertained. Leech (Annelida) is the only indicator of the fresh water; this particular organism does not survive even in the least polluted zone. In corroboration with the pollution principle, it has been observed that in a less polluted zone the number of species is always higher with relatively few individuals of each species, while in a heavy polluted zone, the number of species decreases with larger number of individuals of the remaining species.

Seasonality in invertebrates and water quality assessment

Due to heavy dilution in the rainy season, the abundance and variety of macro-organisms are affected and the impact of pollutional load is not significant. An appreciable shift in composition of macrofauna confirms uncertainty in individual members. After rains, the recovery is generally noticeable. Summer is the best period for the quantitative as well as qualitative estimation of macro-organisms.

Crustaceans as depicted in Fig.1. indicated sensitivity to pollution and its concentration changes with the degree of pollution. Considering the fact that macro-organisms are sensitive to soil conditions, the climatic conditions, and other parameters associated with aquatic system, it is suggested that the total number of crustaceans may be determined first where there is total absence of pollution and then at other points of importance where monitoring has to be carried out. Thus the fraction, i. e., total number of the macro-organisms of any sampling point/total number where there is no pollution obtained may be plotted against the monitoring points, to find out the degree of pollution. This method does not require sophisticated instruments and well trained personnel. This method, further, eliminates the possible variation in macro-organisms due to different parameters associated with natural aquatic ecosystem. Wherever the degree of pollution is considered unsatisfactory further monitoring may be carried out.

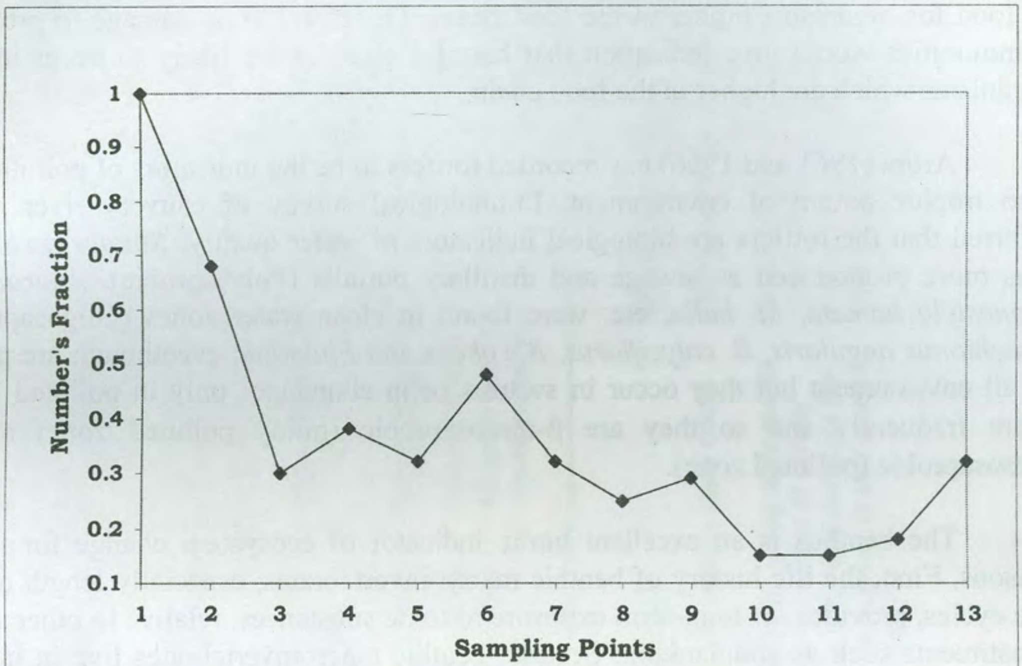

Fig : 1 Crustecea at Various Sampling Points

Practical utility of bio-indicators

There are certain intrinsic advantages in using biological indicators as compared to chemical analysis for studying effects of individual compounds. Biological indicators are screening agents in that they respond to many different compounds, and they are integrating devices in that they show the cumulative effects over a period of time or over some spatial area; but their primary advantage is that the bio-indicator directly measures the property that we are really interested in-is there something in the air or water that is harmful to life ? (Patrick, 1949 and Goldstein, 1972). Several workers have evidently exploited a variety of bacteria, fungi, algae, protozoans, nematodes, arthropods, annelids, molluscs, fishes, etc., as biological indices to measure the severity of pollution. Curiously, most of them choos multicellular organisms to ascertain the characteristics of aquatic media and the effects of different polluting substances caused by the unchecked discharge of man-made wastes.

Protozoans being ubiquitous in nature and single cell systems would be among the first to be affected by contamination of an aquatic ecosystem since they have only a plasma membrane and a permeable outer covering between their living cytoplasm and their environment. Furthermore, in aquatic ecosystems, protozoan communities are designated as "primary consumers". Among them ciliated forms are characterised as "filter feeders", in other words, they ingest small particulate food such as bacteria, yeast, algae and other microorganisms. Protozoans in turn are part of zooplankton which serve as food for organisms higher in the food chain. Therefore, toxic damage to protozoan communities would give indication that harmful changes are likely to occur in those organisms which are higher in the food chain.

Arora (1961 and 1966) has recorded rotifers to be the indicators of pollution and also trophic nature of environment. Limnological survey of cauvery river system inferred that the rotifers are biological indicators of water quality. *Rotatoria rotatoria* was more pronounced at sewage and distillary outfalls (Polysaprobic). *Anuraeopsis, Monostyla hamata, M. bulla,* etc. were found in clean water zones (Oligosaprobic). *Brachionus angularis, B. calyciflorus, B. robens* and *Philodina* eventhough are present in all environment but they occur in swarms or in abundanc only in polluted waters more frequently and so they are β-mesosaprobic (mildy polluted zone) and α-mesosaprobic (polluted zone).

The benthos is an excellent biotic indicator of ecosystem change for several reasons. First, the life history of benthic macro-invertebrates, especially length of their life cycles, provides for long-term exposure to toxic substances, relative to other system constituents such as zooplankton. Second, benthic macroinvertebrates live in intimate contact with the sediments, which enhances their contact with many pollutants. Thus, body burdens of toxins build up to easily detectable levels in benthic macroinvertebrates. Third, decomposition, the fundamental process where in dead organic matter is broken down into CO_2 and simple inorganic molecules, takes place principally in the benthos; studying rates of decomposition, therefore, provides an effective vehicle for assessment of ecosystem functioning.

Although some chironomidae and culicidae have short life spans (around 20 days at temperature > 25 °C), many benthic macroinvertebrates have only one generation per year. Some Megaloptera, Odonata, and Plecoptera live upto four or five years (Merritt and Cummins, 1984), and crayfish can live much longer. This is in contrast to very short (days to weeks) life cycles of phytoplankton and zooplankton. Therefore, benthos will endure sustained exposure to environmental hazards that can lead to population and community changes.

The sediments are repositories of accumulated nutrients and toxins that are some of the principal causes of environmental deterioration in freshwater systems. Benthic macroinvertebrates live on and in the sediments. This tight coupling means that the zoobenthos likely will reflect changes in the chemical or pollution status of a lake or stream, especially because many benthic organisms are sessile. Benthic macro invertebrates bioaccumulate and biomagnify toxins such as heavy metals and pesticides.

Furthermore, benthic macroinvertebrates can affect cycling of a contaminant in freshwater ecosystems through bioturbation and sediment resuspension (Reynoldron, 1987).

Environmental risk assessment

The amount or quantity of the chemical including the forms and site of such releases must be clearly understood through ecotoxicological studies. The ecotoxicology of any chemical may be considered as a sequence of interactions and effects controlled by the toxicity and physico-chemical properties of the chemical. The chemical may be transported geographically into the biota and perhaps chemically modified or transformed and degraded by abiotic processes (eg. Hydrolysis, photolysis) or more often by microorganisms present in the environment. The ecosystem of aquatic species can react in a variety of structural and functional ways. Changes may occur in species diversity or in their interactions or in energy flows. Thus, water quality may be assessed with the help of aquatic invertebrates and environmental risk assessment, in nutshell it can be understood as is depicted in Fig. 2.

Diversity index and measures used in rapid assessment

Species diversity is a function of the number of species present (species richness or species abundance) and evenness with which the individuals are distributed among these species. The concept of species diversity is based on the theory that aquatic communities living in a pollution free habitat are characterised by occurrence of a wide variety of species but only by a moderate number of individuals. A change in biotal community structure resulting in less species but greater abundance of selected tolerant ones indicating onset of an environmental stress. Staub *et al* (1970) suggested a scale of polution in terms of species diversity which is as under.

Species diversity	Pollution Status
3.0-4.5	Slight Pollution
2.0-3.0	Light Pollution
1.0-2.0	Moderate Pollution
0.0-1.0	Heavy Pollution

Measures being used in rapid assessment protocols may be summarised under following heads:

1. **Richness measures**

Macroinvertebrates are separated into presumed species groups. The number of distinct taxa is counted. Taxa richness generally decreases with decreasing water quality (Weber, 1973; Resh and Gradhaus, 1983).

2. **Enumerations**

Number of individuals, ratio of EPS (Ephemeroptera, Plecoptera and Trichoptera) to Chironomidae, ratio of individuals in numerically dominant taxa to total number of individuals (=% dominant taxa) and ratio of non-dipterans to total number of individuals (= % non-dipterans) should be worked out. Perhaps, it is that chironomidae are perceived to be pollution tolerant relative to pollution sensitive EPT. A community dominated by relatively few species would indicate environmental stress (Plafkin *et. al.* 1989).

3. **Community diversity and similarity indices**

i) Shannon's index - Calculated as : $\sum_{i=1}^{s} pi \log 2\ pi$,

where pi is the proportion of individuals in the ith species.

ii) Pinkham-Pearson community similarity index- Pinkham and Pearson (1976)

Calculated as:

$$B = 1/k \sum_{i=1}^{k} \frac{\text{minimum}\ (x_{ia},\ x_{ib})}{\text{maximum}\ (x_{ia},\ x_{ib})}$$

Where k is number of comparisons, x_{ia}, x_{ib} is the number of individuals in the ith species at the reference site (a) or the study site (b).

Communities will become more dissimilar as stress increases and accordingly species diversity decreases with decreasing water quality.

4. **Biotic indices**

Texas are identified to predetermined levels (usually family or genus) and comprise the "systematic units" for special faunistic groups (e.g Placoptera, cased trichoptera). A biotic score is based on total number of systematic units and number of units in different faunistic groups. This index reflects richness of the benthic macroinvertebrates community and gives weighted scores reflecting richness in various indicator groups.

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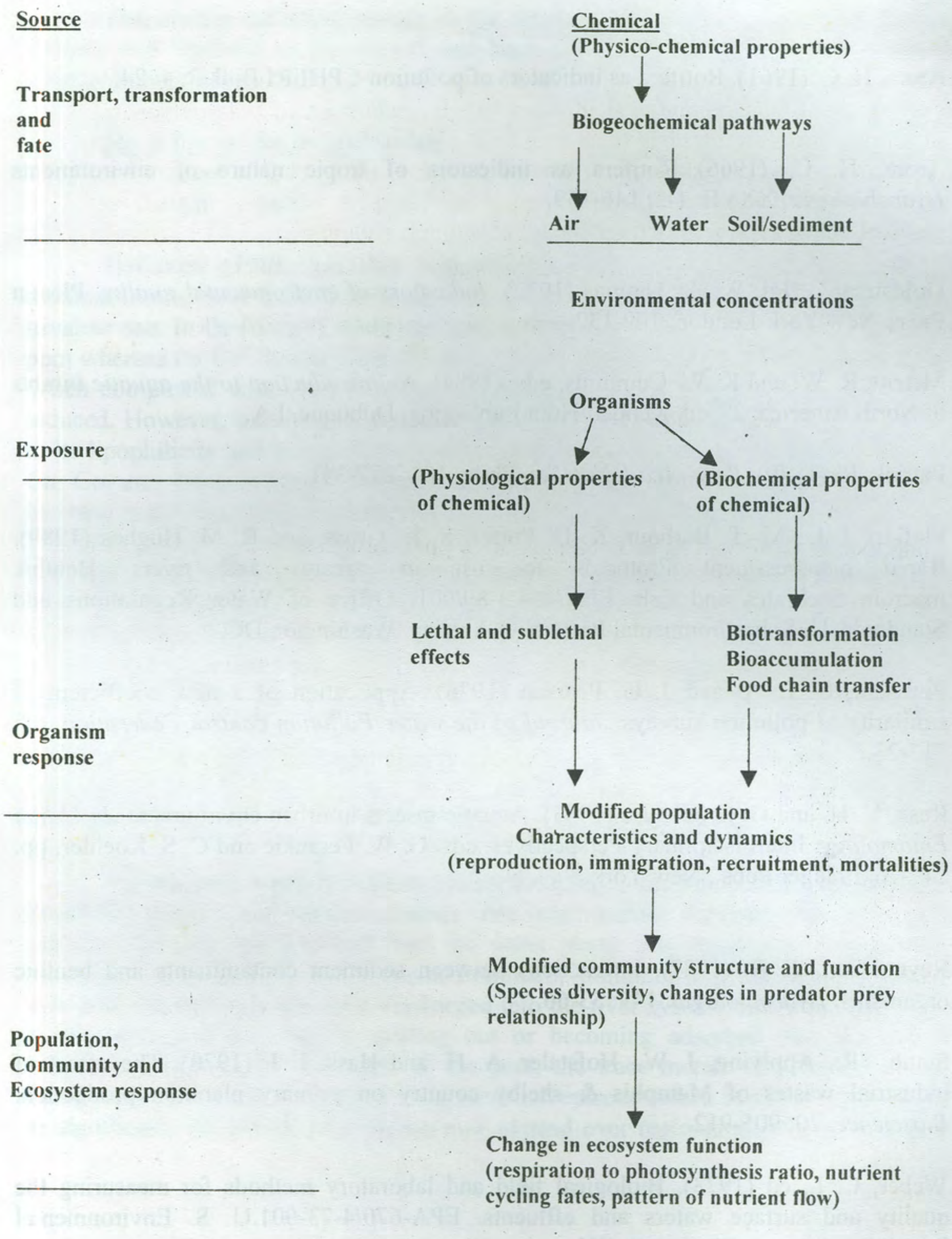

Fig. 2. The sequence of events leading to the effects of a chemical at different levels of organization

*Summer School on **Environment Impact Assessment of Inland Waters for Sustainable Fisheries Management and Conservation of Biodiversity***
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IMPACT ASSESSMENT OF HEAVY METALS IN INDIAN RIVERS - RIVER GANGA

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Introduction

The metals with specific gravity of approximately 5 or more are considered as heavy metals, *e.g.* Cr, Mo, Mn, Fe, Co, Ni, Cu, Ag, Zn, Cd, Hg, Pb, *etc.* Many of these are essential to the biological organisms (*viz.*, Cr, Mo, Mn, Fe, Co, Cu, Zn) in traces, but when get accumulated in excess amounts in an ecosystem, these cause harm to the inhabitants. This is one of the factors involved for the low productivity in rivers and canals (0.64 - 1.04 kg/km/year) in India. Realising the importance of heavy metals, the United States Environmental Protection Agency (US EPA) monitors the level of Cr, Ni, Cu, Zn, Cd, Hg, Pb and As (not a true metal) as routine parameters.

In an ecosystem the heavy metals may accumulate from any of the sources *viz.*, weathering of rocks and minerals, washings of open cast mines, effluents of industrial and domestic origin, washings from agricultural fields with fertilizer in use, atmospheric fall-out, washings of dumped industrial wastes, *etc.*

The toxicity level changes widely depending upon the type of metal, its oxidation state, ligand attached to the metal, pH of the medium, phase in which it is present, route through which it enters the organism, regulatory mechanism present in the organism, *etc.*

The toxicity of heavy metals in the form of their chlorides, experimented by Oshima and reported by Doudoroff and Katz (1953) on eels and cyprinodont fish *Orizias latipes* as under :

$$\begin{array}{lllll} Hg > & Cu > & Sn > & Fe^{+2} > & Mn \\ & Zn & Ni & & \\ & Cd & Fe^{+3} & & \end{array}$$

Hellawell (1988) has also reported a nearly similar order of toxicity. The trivalent iron is more toxic than bivalent one, hexavalent Cr causes more harm than the trivalent one. In the former USSR, maximum allowable concentration of Cr^{+6} was 0.001 ppm whereas for Cr^{+3} it was 0.5 ppm. As a rule, the ionic form of a metal is most toxic. When complexed with organic acids like fulvic and humic acids, toxicity is greatly reduced. However, in case of Hg, the dialkyl derivative accumulates in food chains due to its lipophilicity and is highly toxic than the ionic form. The metals *viz.,* Fe, Mn, Zn, Cu, Co, *etc.,* become more soluble at low pH and thus, are more harmful. With the increase in pH and hardness, the metals form carbonates and toxicity is greatly reduced. The toxicity level of Cu to fish, as per US EPA, is 0.005 ppm at 10 ppm hardness, 0.02 ppm at 50 ppm hardness and 0.04 ppm at 100 ppm hardness. The metals present in the water phase, enter into fish through gill than those present in the sediment or in food and are much toxic also. The acute LC_{50} 96 h of water borne Hg on *Oreochromis mossambicus* was 0.0722 ppm. However, when administered through food, even @ 10 g/kg of food (on dry weight basis of food) mortality was notably absent. Some metals, *viz,* Cu and Zn, due to good regulatory mechanism, are not biomagnified in fish. However, for Hg, the body burden in fish is found to increase linearly with size, suggesting an upper limit in the rate of excretion. Thus, the long lived speciman *viz.,* tuna, soard fish, shark, *etc.,* accumulate highest concentrations of Hg.

The metals present in solution phase are quickly adsorbed on to the suspended particulate organic and mineral matters with large surface area and high adsorption capacity and thus, are removed from the water phase. An experiment conducted by Konhauser *et al.* (1997) in the rivers Brahmani, Baitarani and Mahanadi of Orissa indicated that the trace elements discharged into the river system tend to be short lived in the water column, rapidly settling out or becoming adsorbed into the bottom sediment. Although for most part of the year, the trace metals may remain locally incorporated at bottom sediment, during monsoon episodes when bed load transport can be significant, the effects of pollution may expand over regional distances. In another experiment conducted by Jain and Ram(1997) on the adsorption behaviour of Pb and Zn on bed sediments of river Kali of Western UP indicated that the optimum contact time needed to reach the equilibrium is only in the order of 45 minutes for both the metal ions. The extent of adsorption ceases with an increase in pH. They also stated that the geochemical phases consisting of iron and manganese oxides act as active support material for the adsorption of metal ions.

The first widely recognised impact of health hazard to human being from aquatic environment was the instance that occurred at Minamata, Japan. By late 1974, one hundred seven death was reported amongst some 798 officially verified patients. The fish kill and bird mortality in the area was noted in early 1950s, and was followed in 1953 by the outbreak of a "dancing disease" in the local cat population. Dog and pig were also affected. Initial investigations considered the possibility of bacterial or viral infections and a range of heavy metals (Th, Pb, Mn) as being causal agent. Latter it was discovered in 1958 that the causal agent was methyl mercury. The local chemical factory Chisso was using $HgSO_4$ as catalyst for acetaldehyde and vinyl chloride production during 1932-1971 and the relatively nontoxic chemical was released with the effluents. That form of Hg was getting transformed to methyl mercury. Now it is well known that under aquatic environment a number of fungi and bacteria in anaerobic or aerobic condition can produce methyl mercury. Fishing in Minamata bay is now highly restricted and it is estimated that about 400 ton of mercury has been accumulated in the bottom of the bay, close to the original source of effluent disposal area.

Gouda and Panigrahi (1992) reported the level of Hg in the effluent of a Hg cell chloroalkali factory along with its content in the Rushikulya estuary water and sediment, also in fish and shellfish. The effluent water contained as high as 0.672 ppm, estuary water up to 0.013 ppm (with respect to European Community Environmental Quality Standard of 0.0005 ppm) and sediment 4.96 ppm; in fish muscle up to 2.14 ppm (against WHO recommended limit of 0.5 ppm) on wet weight basis and in shell fish up to 2.02 ppm of Hg. Thus, adequate preventive measures should be taken to check the pollution load.

Impact assessment of metals in Indian context :

Although the available literature indicate the metal levels in water, sediment and fish of different Indian rivers, only a few describe the impact. Varma (1995) reported that the heavy metals Cu, Pb and Zn in water, algae and fish of the river Subarnarekha at Ghatsila were at a very high level. This might have caused the apparent reduction in the number of fish fauna. Joshi (1994) stated that the high Zn bearing waste from Gwalior Rayon Factory near Harihar, Karnataka has caused complete wiping out of mollusc population in the discharge area in river Tungabhadra. As per the study of Banerjee *et al.* (1990) the metropolitan effluent of Calcutta containing high amount of metals, Zn, Cu and Cd might have exerted toxic effect on the microbial population of the Kulti estuarine ecosystem, West Bengal, resulting in low oxygen consumption by the group of organism. It is similar to the report of Stones (1976).

Impact assessment study of heavy metals in the river Ganga is only a few. One report, made by Ghosh *et al.* (1983), indicated high level of Zn (0.63-7.2 ppm), markedly low pH (3.0-7.2), alkalinity (0-108 ppm) and dissolved oxygen (DO minimum of 1.9 ppm) at the outfall of the rayon factory, Kuntighat; the occasional presence of high Cr (BDL-20 ppm) and low DO (minimum of 1.8 ppm) at the outfall of the tannery industry, Batanagar; occasional low D.O. (minimum of 2.8 ppm) with presence of Zn (BDL-1.7 ppm) and Cr (0.5-0.6 ppm) at the outfall of the rubber factory, Sahagunj; markedly low DO (1.8-3.9 ppm) with presence of Zn (BDL-1.0 ppm) and Cu (BDL-0.2 ppm) at the outfall of paints and varnishes industry, Shalimar, and presence of Cr (BDL-0.28 ppm) at the outfall of cotton textile industry, Garden Reach of Hooghly estuary are attributable to reduction in plankton abundance at the various outfalls. Summer conditions were more critical for multiplication of planktons, since the metal toxicity was intensified at high temperature (effluent max. 40^o; water max. 37^o) with low DO (effluent 0 -2.4 ppm; water 0 -3.2 ppm) and hardness (effluent 40-100 ppm; water 58-90 ppm).

The levels of Zn, Cu and Cd in water, sediment and fish flesh of the river Ganga are presented in the Table 1. It is not clear which zone (upstream, midstream or downstream) has maximum load of heavy metals. This is because, in the mid and down streams, the metal is a point source pollutant and since metal gets adsorbed or precipitated very quickly on particulate matters, its zone wise effect has not been observed. The high pH level (>7.5) also facilitates metal precipitation in the Ganga river system in addition with heavy silt load. Since fresh silt is also deposited every year, the cumulative impact of metal accumulation in the sediment phase is not observed. However, among the point source pollutants, Joshi (1991) reported that the samples below the outfall of Pandu nallah and tannery effluent, Kanpur, exhibited the highest concentration of all the heavy metals, Zn (285 $\mu g\ l^{-1}$), Cu (178.9 $\mu g\ l^{-1}$), Cr (200 $\mu g\ l^{-1}$), Cd (13.7 $\mu g\ l^{-1}$), Pb (26.1 $\mu g\ l^{-1}$) and Hg (1.3 $\mu g\ l^{-1}$). In the downstream of Ganga, although the zone is heavily industrialised, the high tidal flushing activity is not also allowing the metals to accumulate at alarmingly high levels.

Although no specific impact of heavy metal pollution from the river Ganga is available, the likely impacts may be as under :

Relatively non-tolerant species will show symptoms of toxicity at different levels. Those, having migrating capability, may move to the fresh location, such as fish. But, in this process the breeding ground of organisms may be lost and thus, their population may suffer due to recruitment failure. Under extreme cases the organism may die and disappear from the food chain causing change in biodiversity.

The tolerant species may accumulate the metal directly from the environment (bioconcentration) and may or may not undergo morphological changes. The metal may gradually increase in concentration along the food chain due to biomagnification. In many cases, the sublethal level of the metals cause more harm due to persistant or chronic effect, which may go unnoticed and the anthropogenic slow poisoning activities continue. In case of acute toxicity, effects are sudden and noticeable, so care is taken and thus anthropogenic activities may be stopped to save the ecosystem.

From the aforesaid discussion, it may come in mind that probably the river water is most polluted with respect to heavy metals. It is not the case. A study conducted by Pathak et al (1994) with 1094 number of water samples from 326 springs, 207 streams, 183 dugwells, 151 piped supplies, 90 tube wells, 75 hand pumps, 60 rivers and 2 lakes, collected from 8 northern and 6 north-eastern districts of India showed the following ranking in relation to the heavy metal content : hand pump > dug well > spring > stream > river water.

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Table 1 : Heavy metal content in water, sediment and fish of the river Ganga at upstream,midstream and downstream.

Location	Water metal content(μg l^{-1})			Sediment metal content(μg g^{-1})			Fish flesh metal content(μg g^{-1})			Source
	Zn	Cu	Cd	Zn	Cu	Cd	Zn	Cu	Cd	
Upstream	75.4-156.6	8 -16.8	BDL-10.9	26.3-48.3	4.1-17.9	0.8-29.4	----	----	----	Saikia *et al* (1988)
	71.6	7.2	BDL	----	-----	----	----	----	----	Joshi (1991)
	6 - 20	BDL-2.0	BDL	26.4-27.1	4.8-7.3	BDL-3.2	10.8-22.3	0.8-1.0	1.4	AUW (1997)
Midstream	12.7-48.6	----	----	64.7-96.3	----	----	BDL-32.8	----	----	Singh *et al* (1993)
	285	178.9	13.7	-----	----	----	80.9-189.6	11.8-36.4	0.4	Joshi (1991) (on dry weight)
	6 - 40	BDL - 8	BDL -1	21.6 -179.3	3.8-46.0	1.1-2.8	1.2-22.7	BDL-1.3	1.3-2.4	AUW (1997)
Downstream	BDL-7200	BDL	----	----	-----	----	7.5-22.5	BDL-4.0	----	Ghosh *et al* (1983)
	37.1-248	6.4-38.1	BDL-10.3	----	----	----	----	----	----	Joshi (1994)
	10 - 90	BDL - 7	BDL - 1	27.5-64.7	9.2 -18.2	0.4-3.1	6.9-19.2	BDL-0.9	1.8-2.2	AUW (1997)

BDL = Below Detection Limit of Instrument   AUW = Author's Unpublished Work

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POLLUTION IN INLAND WATER AND POSSIBLE MITIGATION ACTION PLAN

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Introduction

Concern for water quality and rational management of water resources are receiving wide attention throughout the world. Adequate knowledge of the existing nature, magnitude and sources of pollution load in water bodies is must for formulating water pollution control policies measures, in India.

The inland water in India needs thorough monitoring in the light of above mentioned parameters for its conservation and purity. The studies should include physico-chemical analysis of water, phytoplankton with special reference to pollution indicator species, primary productivity, heavy metal analysis at source and various other related components. Water quality index of rivers also need to be evaluated to know the significance of various parameters.

There are 14 major rivers in India (Ganga, Bramhaputra, Brahamani, Cauveri, Godavari, Indus, Krishna, Mahanadi, Mahi, Narmada, Periyar, Sabarmati, Subarnrekha and Tapti). Covering 83% of the drainage basin and account for 85% of the surface flow. Bramhaputra, Ganga, Indus and Godavari basins cover more than 50% of the country's surface flow. Apart from these, there are 44 medium and 55 minor rivers which mostly originate from the coastal mountains.Only 4 out of 14 major rivers are perennial . These are Bramhaputra, Ganga, Mahanadi and Brahamani with a minimum discharge of 0.47 M m^3 km^2-yr^{-1}, six others namely Krishna, Indus, Godavari, Narmada, Tapti and Subarnrekha have average discharge of 0.26 M m^3 km^2-yr^{-1}. The remaining four (Cauveri, Mahi, Sabarmati and Perriar) passes through low rain fall areas and have an average discharge of 0.06 M m^3 km^2 yr^{-1}.

Fresh water lakes and streams together estimated to cover about 0.20 % of the earth surface and have a volume of 2.04 % X 105 km^3. A perusal of literature with respect to river water pollution indicate that much emphasis has been laid on characterization of effluent water, quality of river water, sediment and the role of effectiveness of plankton in order to the mitigate to the pollution. Considerable literature is available with regard to effluent characterization that flows into various Indian rivers and many rivers such as Cauveri, Damodar, Kapila, Moosi, Purna and Ulhs have been studied for different heavy metals. Similarly, estuaries like Adyar, Ambika and Hooghly have been thoroughly investigated on the above aspects. Sediments of various Indian rivers have also been examined with respect to heavy metals. Many species have been identified as bio-indicators for specific pollutants, too.

Physico-chemical factors

Physico-chemical aspects of natural water are one of the important areas of study, since, they influence river biota significantly. Temperature plays a vital role in bio-chemical reaction and self purification of aquatic systems. Organic matter that gets oxidized is supposed to be highly influenced by water temperature. Thus, self purification (break down of organic matter) is more rapid during summer months compared winter seasons leading to oxygen consumption in the river environment. Effluents with higher temperature from various industrial sources alter the natural condition of the river as the oxygen consumption of aquatic fauna nearly doubles itself for each 10°C rise in temperature.

pH maintenance (buffering capacity) is one of the most important attributes of any aquatic system since all the biochemical activities depend on pH of the surrounding water. It is well established that the pH of the natural water is controlled to a greater extent by the interaction of hydrogen ions resulting from the disassociation of carbonic acid and from hydroxyl ions arising from the hydrolysis of bio-carbonate .

Turbidity is a function of increasing suspended particles, soil particles, effluents discharge, decomposed organic matter, total dissolved solid as well as the microscopic organisms. The turbidity of water interferes with the penetration of light. The increased turbidity during rainy season is attributed to higher rate incidence of soil erosion from catchments besides massive contribution of suspended solids from sewage canals, surface runoff and domestic wastes. The correlation coefficients recorded between chemical oxygen demand (COD) and turbidity manifest that organic matter is an important factor in increasing turbidity values. Suspended solids cause ecological imbalance in an aquatic ecosystem by mechanical abrasive action. High load of suspended solids cause a significant deterioration in the survival conditions for aquatic organism. Suspended solids may be in the form of coarse, floating, settable, fine or colloidal particles as a floating film. The dissolved solids in a stream depend on various factors such as geology of the watershed, rainfall and the intensity of surface runoff.

Alkalinity of water is a measure of weak acid present in it and of the cations balanced against them. In water, cations of strong bases are present in negligible concentrations, the only anions that need to be considered are those of carbonic and boric acids. However, in polluted system OH released from chemical factories plays an important role in increasing the pH of the system. Alkalinity and acidity play important roles in controlling enzyme activities. Chloride is one of the important indicators of pollution. Chlorides are present in sewage, sewage effluents and from drainage and, remain unaltered during the purification of sewage.

Nutrient enrichment leading to eutrophication is a major concern of many Indian rivers. Discharges from domestic sewage, septic tanks, runoff, industrial waste contribute to the nutrients enrichment and accelerate eutrophication. Existance of phosphorous, both in inorganic and organic forms, is essential for the growth of algae, but is usually present in low concentration in unpolluted rivers. Ammonical nitrogen comes to the stream through diverse sources, major contributors being: domestic waste, piggeries, dairies, chemical industry etc. Presence of ammonical nitrogen in river water is important in the sense, its role in fish mortality, even, when present in lower concentration. Moreover, its toxicity is enhanced by the pH value of the medium. Seasonal variation of ammonical nitrogen, monitored in the river has indicated higher values after the onset of rains, owing to organic matter coming through domestic drainage. Among various forms of nitrogen, nitrites are found to be in very low concentrations in river water. Nitrate concentrations depend on the activity of nitrifying bacteria, which in turn get influenced by the presence of dissolved oxygen.

Concentration of dissolved oxygen is one of the most important parameters indicating water purity and determines the distribution and abundance of various algal groups. The importance of dissolved oxygen for its role in various metabolic activities of organisms has been discussed by many ecologists. Different workers have pointed out various factors influencing oxygen level that include discharges from industries, water current, velocity and biota. BOD (bio-chemical oxygen demand) determination is a most useful technique to assess the level of organic pollution in a river system. BOD values of most of the rivers were noticed to be higher than the prescribed ISI limit. Peak values for BOD found to occur during monsoon and lower values during winter. COD represents chemically oxidisable load of organic matter in water.

A number of environmental factors namely heat and light, water body morphology, morphometry and substrate, rate of grazing and availability of nutrients have definite influence on the regulation of primary productivity. The effects of water depth, hardness of water, light penetration and supply of carbon-di-oxide, organic matter and solar radiation on the standing crops of primary producers on different habitats have also been considered to influence primary productivity. Besides temperature, quality and quantity of light and wind are important for aquatic primary productivity.

Heavy metals

Metals get contaminated into aquatic systems as a result of various natural activities (weathering of soil and rocks from volcanic eruption) and from a variety of human activities involving the mining, processing or use of metals or substances. Some metals such as, Manganese, Iron, Copper and Zinc are essential micro-nutrients, while others such as Mercury, Cadmium and Lead are not even required in small amounts by any organisms. All metals including the essential micro-nutrients are toxic if, exposure levels are sufficiently high. Cadmium, Chromium, Copper Mercury, Nickel and Zinc are of particular relevance to fresh water. The increased circulation of toxic metals in recent times has resulted in the inevitable build up of toxic substances in the human food chain.

Since, metals are rapidly absorbed to particulate maters (e.g. detritus, plankton, suspended sediments) and assimilated by living organism, the available concentration of metal in the water phase may give a highly misleading picture of the degree of metal pollution. Metal adhering particulate materials could be absorbed by an organism in the process of pumping water through its gill or in the process of filtering water to obtain food. There is paucity of information on the toxicity of suspended metals to most aquatic organisms.

Inland water bodies are polluted due to mixing of organic constituent both from natural and man made sources but drinking waters standard were established in accordance with toxicity data obtained for human clinical investigations and other like experiments (ISI, EPA, WHO). Therefore, there is an urgent need to formulate new indices keeping in view the organic contents too.

The significance of sediment in assessing the conditions in an aquatic system is well established in the lacustrine environment, since, fresh water lakes have been the centre of important cultural development ever since the earlier base of civilization. Sediment analyses of all main rivers in India reveal the presence of traces of Manganese and other transition metals in significant amounts. Levels of Cadmium , Cobalt, Chromium, Copper, Iron, Manganese, Nickel, Lead and Zinc in the water and sediments of Yamuna river have been monitored by this Institute. The transportation of several metals, i.e. Arsenic, Chromium, Mercury, Lead and Zinc contained in effluents, discharged by several industries into the Damodar has increased the level of Arsenic and Mercury in the sediments of the river to alarmingly high values. This is highly dangerous to aquatic denizens and their users in the region of Durgapur.

Data on sediments of various Indian rivers had revealed that Copper levels were highest in Naravagedda stream sediments (47.5 – 527.1 ppm) followed by Kaveri River system (72.0-153.0 ppm) and Ulhas river sediments (70.5-99.5 ppm).

Possible mitigative action plan

The increasing stress in inland waters has resulted in sharp decline in the overall fish production associated with a qualitative shift in species. The prized commercially important fishes have given way to uneconomic species. A general deterioration of water quality as compared to that of 1960 calls for immediate corrective measures. Some of the possible mitigative actions described below are necessary for reviving the fisheries of the inland water of our country:-

1. The management policies should involve planning of land use within the river basin as a whole. A system which links fisheries management, agriculture, forestry to agro- industries and hydro-electric units will facilitate recycling of nutrients, optimization of river basin production and minimization of pollution, eutrophication and toxic contamination that arise consequent to the changes in hydrological and socio culture regime.

2. Urgent actions need to be taken to evolve viable standards for various parameters, stretch-wise and to ensure that standards are strictly followed by the agencies concerned *viz*. industries, municipalities *etc*. A direct monitoring of ecosystem by the enforcing agencies is urgently needed. This will restore quality of river water and abate pollution .

3. Sewage discharge by municipalities should be treated before its discharge. The treated sewage water can be utilized for sewage – fed aquaculture based on the technology developed by CIFRI.

4. Prevention of deforestation and promotion of afforestation along the cathcment areas of the river and its tributaries will gradually reduce silt load in the river.

5. Training of rivers for controlling floods and some wild areas are to be maintained (in-situ conservation) and these should be treated as sanctuaries in the planning criteria for the river basin.

6. Removing of bundhs and opening of sluices for a few days where fish seed accumulate in the outfall channel . Securing access of water and fish to off river water bodies (behind the levees) such as flood plain lakes and constructing fish ponds in abandoned places.

7. There should be a total ban on the juvenile exploitation from the entire river system. Juveniles trapped in the water bodies like creeks, and gullies which become severed from the main river with the recession of flood level may be salvaged and restocked in the river.

8. Breeding of major carps and maintenance of minimum level of water at downstream during the dry season must be considered while determining the quantum of water to be released from dams and barrages. Assessment in terms of threshold volume of flow and other hydrographic parameters conducive to ecological wealth of the river required serious consideration.

9. Strict regulation of closed season and areas, type of gears used and their mesh size and the minimum capture size at various species have already been delineated. These need be implemented strictly. State governments need to adopt uniform policies in this regard with proper enforcement of regulation.

10. Rehabilitation of the hilsa fisheries in the upstream of Farakka barrage through artificial propagation and re-stocking is urgently needed. Similarly, for fast recovery of dwindling Mahaseer fisheries in upland waters of the country is needed.

11. Resource conservation through revision of existing fisheries laws and regulations based on the results of biological investigations of commercial fish species and strict implementation of laws through an efficient enforcement machinery shall prove beneficial. A close linkage with wild life sector in each state could be useful for logical interaction and enforcement.

12. There should be proper coordination among the state governments concerned through inter-state working groups for monitoring and implementation of conservation and management measures. A well defined national riverine policy needs to be evolved for optimum utilization and conservation of fisheries resources of the inland waters.

13. A quantitative data on specific cause and effect, relationship is needed for evolving remedial measures prior to any activity which may result in a change in river habitat. In case, information on such relationship is available in the form of specific case studies, they should be examined and tested for wider application. This will enable a proper EIA of the developmental projects at a very early stage of the project planning.

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IMPACT OF ANTHROCENTRIC ACTIVITIES ON FISH AND ENVIRONMENT WITH SPECIAL REFERENCE TO XENOBIOTICS

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Introduction

The chemicals that are strangers to the biosphere are termed as 'xenobiotic' compounds ('xenos' meaning foreign). However, the term xenobiotic should not be restricted for compounds foreign to the life systems only, as pointed out by many. But it should equally be used for all other chemical compounds that are released to the environment through various anthropogenic activities (greak term 'anthropo' meaning man) and occur in excess than natural or expected level of their occurrence. This broad definition of xenobiotic compounds is normally referred to in the literature. The xenobiotic compounds may accumulate in an environment and their foreignness may generate apprehension for harmful effects on living system.

Many of the insecticides, pesticides, halogenated aliphatic and aromatic compounds have drawn most of the attention with respect to xenobiotics because they are poisonous compounds and hence potentially toxic. It is thus demanded that these compounds be excluded from the environment. On the other hand, many such compounds have immense social and economic overtones and their elimination from the biosphere may not seem possible. It is, therefore, felt that appropriate research and development (R&D) activities be directed towards the biodegradability of these compounds to observe how these toxic materials can be degraded and eliminated from the environment.

Of the xenobiotic compounds, the insecticides and pesticides draw major attention since they have become an important component of the modern agriculture to protect standing crops from insects and pests and for safe in storage of the harvested grains. Besides, these compounds also save lives of millions in developing and underdeveloped countries affected by several diseases caused by insect vectors like malaria, plague, sleeping-sickness etc. A many-fold increase in the use of such compounds in recent years indicates their significance in the modern day society.

The average consumption of pesticides in India has increased drastically from 3.2 g/ha in 1953-54 to 336 g/ha in 1980. The consumption has further risen in another two decades, bringing the figure much higher in the new millennium. However, even this level of consumption is considered lesser than the levels consumed in United States of America (1490 g/ha) and Europe (1870 g/ha). The use of pesticides has increased to about 40-fold in past three decades in the U. S. A. only. These xenobiotic compounds have occupied almost every segment of the environment currently and remain no more localized to their place of application. A glaring example is the reported presence of DDT, an organochlorine, in North Pole snow where this was never used.

It has been pointed out that the atmospheric fumigants and pesticides are brought back to the earth's crust by rainfall. The xenobiotic compounds after application eventually find their way to the aquatic ecosystems via a number of ways including industrial run-offs, city and municipal drain-offs, agrifield run-offs as well as atmospheric fall-outs through rainfall. They are detected in groundwaters making the water contaminated and in bottom sediments also. The xenobiotic compounds exhibit their effects on target species as well as numerous non-target species. The target species succumbs to death, that is wanted (insects, pests, rodents etc.) but the most unfortunate observation is that these compounds threat and make the life hell for non-target species and among them the fishes are the worst affected in the open water aquatic ecosystems. The effects may range from alteration in growth, development, reproduction etc. to mortality as well. The changes in physiological and biochemical processes in fish depend on factors like the physical and chemical properties of the xenobiotic, their concentration or their transformation to products in water; duration, type of exposure (acute, chronic etc.) and the ability of the fish to biotransform the absorbed compounds. One of the very probable causes for sudden large-scale fish mortalities in many parts of the globe may be attributed to the ever-increasing concentration of the xenobiotics in natural open waters. Many interacting physical, chemical and biological factors of the aquatic ecosystem complicate the process and the eventual response of a fish to them. Even an unnoticed characteristic of environment may exhibit a differential response in fish.

After being accumulated in the aquatic ecosystem, a portion of the xenobiotic undergoes breakdown and transformation, which depend upon the physico-chemical factors of water. Simultaneously, another fraction enters into the biotic communities including fish and exibiit responses that not only depend upon the nature and concentration of xenobiotic but on the time of persistence in the body too. The water-soluble xenobiotics are readily transported to fish than the hydrophobic ones. The water-soluble ones enter the fish body by way of body surface, gills or mouth-cavity. These compounds in fish food get ingested by the fish and absorbed through the alimentary canal. Thus the xenobiotics get entry singly or through multiple routes. The route of entry and the duration of exposure has in fact, great impact on the adsorption, distribution, physiological actions and finally the bio-transformation of these compounds.

Classification of xenobiotics

The xenobiotics are usually classed based on their actions on target organisms. This way, they are classed as insecticides, herbicides, pesticides, fungicides, rodenticides, weedicides, molluscicides, algaecides etc. Also, they are more systematically classed based on the chemical nature of the compounds like organochlorines, organophosphates (OP), carbamates, pyrithroids etc. A few classes of these compounds are as under:_

i) Organochlorines - DDT, aldrin, dieldrin, heptachlor, toxaphene, gammaxene (BHC), chlordane, endosulphan, lindane (HCH), endrin, polychlorinated biphenyls (PCB) etc.

ii) Organophosphates - Malathion, parathion, diaginon, dimethoate etc.

iii) Carbamates - Carbaryl, carbofuran, sevin, baygon, aldicarb, perimicarb. etc.

iv) Pyrithroids - Allethrin, permethrin, cypermethrin, decamethrin etc.

Bioaccumulation

The xenobiotics are absorbed by living aquatic resources, directly from water as well as through food chain and are accumulated in the body. Bioaccumulation in fish is seen to depend upon physico-chemical nature of the xenobiotic and the sex, age and physiological status of fish. The rate of uptake is seen to depend upon the nature and concentration of the compound in water, the solubility of the compound, ambient temperature, the species of fish and their physiological activity. Water-insoluble compounds usually bind with suspended organic matter of water and bottom sediments. Low water solubility affects the affinity of these compounds to partitioning between water and lipid materials, thus making them able to get accumulated in various tissues of the fish.

Water insoluble or less soluble compounds are more readily absorbed by fish than the water-soluble compounds. It has been reported that absorption through the intestine is a slow process. Carbamates and organophosphates having higher water solubility are taken up in lesser amounts and eliminated quicker than organochlorines. The time for obtaining highest uptake and extent of organophosphate residue in fish is directly related to the persistence of otrganophosphates in water. Xenobiotics are mainly absorbed (passively) through gill and body surface. This uptake continues till an equilibrium is reached. In some fishes, highest concentration is observed in the gastro-intestinal tract and least in skeletal muscle. For some, retention in liver in found to be longest. Xenobiotics, whether ingested through food or absorbed via gill or body surface, afterwards appear in blood circulation and distributed to various body tissues where they are retained as such for a prolonged period (OC) or biotransformed and eliminated from the body (OP and Carbamates).

Physiological action and the bio-transformation of the compounds

Mode of action

The mode of action of organochlorines (OC) and their analogues is related to their molecular size and shape. Less is known regarding the precise mode of action of the organochlorines. Systems of poisoning in insects as well as in vertebrates include loss of movement followed by convulsion and death, indicating clearly that these xonobiotics act on the nervous system and probably upset the sodium and potassium balances. It is well known that Na^+-K^+-ATPase is the key enzyme that is implicated in active transport of sodium ions by biological membranes. The principal mode of action of organochlorines lies in blockade of this enzyme. The enzyme is also inhibited in gills and kidney. Thus, the disruption of ionic balance in nerve and non-nerve cells results. The secondary mode of action involves suppression of the thyroid activity and uptake of iodine by the organ. Since thyroid hormones are involved in reproduction, osmoregulation and oxidative metabolism, suppressed thyroid activity due to organochlorines appear extremely deleterious. The organochlorines are very persistent lipophilic (fat-liking) molecules which are not readily biodegraded and tend to accumulate in fatty or adipose tissues in the biotic community as well as in the environment.

The organophosphates, on the other hand, effect their toxic action by inhibiting the physiologically important 'acetyl cholinesterase' (AChE), enzyme in the nervous system. This enzyme serves to breakdown acetylcholine formed at the synaptic nerve connections, when an impulse is transmitted. Toxic effects are noted when about 70-90% of this nerve enzyme is inhibited. These xenobiotics (OP) are so effective in inhibiting the acetylcholinesterase that 1μg/g body weight can cause complete *in vivo* inhibition of the enzyme. AChE controls hydrolysis of acetylcholine generated at nerve junctures to choline. In absence of effective acetylcholinesterase, the liberated acetylchloline accumulates and prevents the smooth transmission of nerve impulse across the synaptic gap at nerve junctures. This causes loss of muscular coordination, convulsion and ultimately death of the target species as well as non-target organisms like fish.

The carbamates, however, are closely related in mode of action to those of organophosphates in inhibiting the acetylcholinesterase enzyme system. The carbamates are the third major group of xenobiotic compounds and like organophosphates, are now used as organochlorine substitutes to reduce the environmental load of pollution. They are biodegradable like organophosphates and consequently do not persist for prolonged number of days; hence do not exhibit accumulation in the ecosystem for long.

The pyrithroids, both natural and synthetic, that find wide application in public health programmes to control houseflies and mosquitoes usually employ the well-known compound 'allethrin' or its allied compounds in aerosols, sprays, mosquito-coils and mats. These compounds exhibit rapid knockdown on target organisms like flies and mosquitoes and are used in vector control. Whereas DDT shows little knockdown action and is ineffective in bite inhibition, the mode of action of these pyrithroids involve deterring the entry of vector from outside to the area of application, expelling the vectors, interfering in host-finding, inhibition of bite, knockdown and kill. The modes of action of these pyrithroids are on the nervous system. They alter nerve membrane ionic permeability on the axon of peripheral and central nervous system by interfering with sodium channels. The symptoms these group of xenobiotics exhibit, range from immediate tremor to paralysis within a short period. Non-target organisms like fish exhibit extreme toxicity, particularly at the early life-stages. The pyrithroid fumes are released to the atmosphere, rainwater bringing them to the aquatic bodies ultimately.

Bio-transformation

The bio-transformation of the xenobiotics is perhaps the most important aspect. This is seen to depend largely on the species, size, sex etc. of the fish as well as the chemical nature of the xenobiotic, route of administration and duration. Like mammalian systems, liver is reported to be the main site of biodegradation in fish, although blood plasma, kidney etc. also play roles in detoxification processes. In many fishes, extra-hepatic metabolism is seen to be more than the hepatic metabolism.

The bio-transformation is usually carried out by the enzymes with relative low degrees of substrate (xenobiotic) specificity. These less specific enzymes for biotransformation recognize the functional group within the compound, rather than recognizing the whole molecule. The entire biodegradation is carried out in two parts. In part I, the xenobiotics are transformed by oxidative, reductive and hydrolytic enzymes etc. In the part II, the end products of part I are conjugated with some polar molecules of endogenous origin. Part I, produces transformed materials with high polarity while the part II, accenuates the excretion of the degradables. In some cases, the products of part I are seen to be more toxic than the original xenobiotic. For example, a degraded product paraxon is more toxic than the parent xenobiotic, parathion.

Xenobiotics are degraded by the microsomal enzymes called cytochrome P-450 dependent 'monooxygenases'. Marine fishes have lesser levels of these mixed-function oxygenases called MFOs than the freshwater fishes. Obviously, freshwater fishes are somewhat more resistant and hence less susceptible to xenobiotics. The MFO activities are demonstrated in liver, kidney, gill, GI tract as well as in other tissues of fish, the maximal activity being present in liver followed by kidney. In some fishes, tissues other than the hepatic tissue contribute towards biotransformation of the xenobiotics by MFO enzyme systems. Since fishes are poikilotherms, temperature is expected to play a role in modulating MFO system. This has been verified experimentally. Conversion of DDT to the breakdown product DDE in trout is double at 18 ^{o}C than at 2^{o}C. In general, the optimum activity of MFOs in fish is reported to be at 25^{o}C. In some fishes, MFO system is most active between 22^{o}C-26^{o}C. Sex related differences in hepatic MFO activity have also been reported. Probably sex steroids play an important role in modulating the induction of MFO activity towards the xenobiotic compounds.

Apart from the oxygenase enzyme systems stated above, reduction, methylation and hydrolysis etc. also breakdown the xenobiotic compounds. Reductive enzymes are generally present in the liver microsomes. Parathion nitroreductase activity and hydrolysis of esters and amides by several hydrolytic esterases have been demonstrated in a number of fish. The hydrolytic enzymes are diverse, being present in liver, kidney and blood plasma. Hexachlorobenzene (HCB) and polychlorinated biphenyls (PCB) are mainly degraded by hydrolytic enzymes.

The biodegraded products are either excreted directly or excreted after conjugation with some polar molecules of cellular origin, like the activated glucuronic acids, sulphates etc. These conjugates (degraded products together with polar molecules) are more readily excreted than the original lipophilic xenobiotics, like the organochlorines. Thus, the excretion of metabolites of xenobiotics by forming conjugates constitutes the principal mode of xenobiotic elimination from fishes. The conjugated products may be of different types, like the glucuronates, sulphates, amino acids, acetylated compounds etc.; the glucuronates being the most versatile in binding of the biotransformed products.

In glucuronate conjugation, the enzymes involved are dehydrogenases and transferases that are present in liver although their presence in other organs is also reported. In sulphate conjugation, a hepatic microsomal sulphotransferase enzyme is involved. Sometimes, amino acid conjugates are formed between an endogenous amino acid and aromatic or aliphatic carboxylic acid. In some conjugation, acetylation is seen in the excretion of xenobiotics.

Elimination

In fish, the biotransformed products of xenobiotics are eliminated through the urine, faeces, biles or by diffusion through gills. The gills are reportedly poorer channels for elimination. The elimination of polar metabolites (conjugates) through urine has been reported in various fishes including the trout. Elimination of xenobiotic metabolites through kidney has been well documented. Based on the radioactive tracer-technique, it has been reported that bile is one of the principal routes of elimination of lipophilic metabolites. In fish, bile in fact is suggested to serve as the excretory fluid for certain lipid-soluble xenobiotics, like the organochlorines.

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PRINCIPLES GOVERNING BIO-ASSAY AND METHODS OF ESTIMATION OF TOXICITY OF POLLUTANTS

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Toxicity determination may be classified as short term acute toxicity tests and long-term or chronic biological responses. These methods are essentially bioassays based on response on short or long application times. The former measures the immediate biological disruption, the latter evaluates the mechanisms of successive blockage or disruption of biological processes over the period of exposure.

The principle of toxicity test is based on the recognition of response of living organisms to the presence (exposure) of toxic agents in relation to the dose (exposure level). Utilising this principle, aquatic toxicity tests are designed to describe a concentration-response relationship. In acute toxicity the evaluation is of concentration-response relationship for survival, whereas, chronic studies evaluates sublethal effects such a growth, reproduction, behaviour, or biochemical effects.

Acute toxicity tests

Acute toxicity tests are much concerned with the determination of the condition which produces a 50% mortality. In other words, the value for median lethal response on median tolerance limit (TLM) is determined through the acute toxicity tests. Such an approach may be applied equally to the effect of toxic gases, liquids, solutions, solids and suspensions, and also environmental parameters as light, temperature etc.

In aquatic studies, toxicity is expressed in terms of the concentration of applied toxicant in the surrounding waters. The median values of the toxicant is termed as median lethal concentration (LC50, TLM) or the median effective concentration (EC50). Some toxic materials, such as acids and detergents, act primarily on the external epithelium. In such situations, the matter of whether such application of material should be regarded as LD50 or LC50 in polemical.

Acute toxicity measures effect on survival over a 24 to 96 hour period. Such period is decided on the nature of toxicant and also the type of test organisms. In general, the larval stages are exposed for a shorter period and on the other the biodegradable toxicants are exposed for comparatively less time considering the fast changing toxic characters of the same.

Methods for acute toxicity bioassay are mainly of two types, static and flow through. Based on characteristics of the toxicants and also conditions of the site of toxicity studies, suitable method of these two is applied.

Static toxicity tests

Static toxicity tests are performed without replacement of the experimental media. Mostly acute toxicity tests are performed in static system. Test organisms of smaller size like daphnids, mysids etc. are generally exposed to toxic elements under static condition for acute toxicity tests. Depending on the characteristics of the toxicants and also the requirements of the test organisms the test media are renewed at an interval of few hours to a day. Effluents of quick degradable nature, sediments and dredged materials are often tested in renewal acute toxicity study system.

Static and static renewal tests are usually not appropriate if the material is unstable, sorbs to the test vessles, is highly volatite, or exerts a large oxygen demand. A flow through system is prefered in such situations.

Flow through toxicity tests

Principally the flow-through system is designed to replace the toxicant and dilution water either contineously or intermittently through regulatory mechanisms. Different types of fabrications are designed suitable to the effluents and also the test organisms. By and large effluents with high biological oxygen demands are tested in flow-through toxicity bioassay system.

Dose/concentration/dilution selection

In toxicity testing selection of doses/concentrations/dilutions need logistic and scientific approach. Initially rapid or exploratory tests are performed using doses/concentrations of wider range for a period of 24 hours. Following the results, the actual doses/concentrations are selected as per the standard chart accepted all over the world.

Selection of experimental concentrations based on progressive bisection on intervals on logarithmic scale.

Column 1	Column 2	Column 3	Column 4	Column 5
10.0	-	-	-	-
-	-	-	-	8.7
-	-	-	7.5	-
				6.5
-	-	5.6	-	-
-	-	-	-	4.9
-	-	-	4.2	-
-	-	-	-	3.7
-	-	-	-	2.8
-	-	-	2.4	-
-	-	-	-	2.1
	-	-	-	1.55
-	-	-	1.35	-
-	-	1.8	-	-
1.0	-	-	-	-
-	-	-	-	1.15

Toxicological end points

In acute toxicity tests, end points include a determination of the LC or EC50 value, an estimate of the acute no observed effect level, and behavioural observations. These end points can be determined from the data on mortality percent over the exposure period by a number of statistical approaches. The Litchfield-Wilcoxen approach is most often used, which consists of plotting the survival and test chemical concentration data on log-probability paper, drawing a straight time through the data, checking goodness fit of the line with chi-square test, and reading the LC or EC50 value directly off the graph. Various computer programmes are available to perform this calculation. Other common methods include the moving average and binomial method.

Biological monitoring

Any toxicological test needs shorting out reasons and manifestations of stress on the test organisms. Methods for detecting stress have been developed as per the requirements of the physiologist, biochemists and so on. First hand information on the stress effect is considered the behavioural changes in the organisms. Biochemical changes are also evaluated for detection and also confirmation of the pollutional hazards.

Biological conditions like mortality, immobilization, reduced cell count etc. are often being used for evaluating the toxiciiy impact on the test organisms.

Chronic toxicity test

Unlike rapid damage causing death to the organisms of poising in acute toxicity, chronic toxicity tests consider the subacute toxicity influencing the ability of the organisms to reproduce, grow or behave normally, but probably is not often a direct cause of death in nature.

Importance of chronic toxicity test is more than acute toxicity test since the former forms the basis of finding "safe concentration" for the toxicants in respect of lives likely to be under the exposure. Laboratory studies of growth, reproduction, and other related biological functions are most difficult and time taking. The influence of toxic substance on growth can be studied in laboratory. Evaluation of toxic effect on reproduction, permitting study of development of gametes, fertilization, embryonic development, hatching and survival of young is difficult and not possible for all the organisms, since many of them do not mature and breed in cofinement.

End point monitoring

In chronic toxicity test, the end points most often measured include egg hatchability, growth and survival. Hatchability is observed visually; growth is determined photographically and by weighing and measuring the organisms physically at the termination of the study. In partial and full life cycle studies, the end points of interest are expressed, relative to concentration, as the non-observed effect level (NOEC) and the lowest observed effect level (LOEC). The geometri mean of these two values has tradionally been referred to as maximum acceptable toxicant concentration (MATC). The approach for assessing these end points is based upon an appropriate statistical test for comparing each concentration level to the control.

Application of bioassay results

The acute and chronic bio-assay which aim at finding out application factor provide measures of protection for valuable population that must exist in waters receiving toxic wastes. This protection is intended only to prevent possible toxic effects of materials in wastes being dis-charged. Waste often contain materials whose harmful actions are not toxic; excessive enrichment, oxygen depletion, or physical alteration of the aquatic environment. The use of application factors, by requiring greater dilution of wastes in receiving water may reduce harmful effects of the toxicants, and save the lives of ecological values and human importance.

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CONCEPTS OF STRESS AND METHODS OF STRESS DIAGNOSIS IN FISH

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Introduction

Fishes live in water under dynamic chemical and physical conditions. Although fishes may be adapted to these conditions but very often they have to spend a lot of energy. The homeostatic control system of fishes are thus constantly effected by the demands of the aquatic environment they inhabit. In addition to this there may be the effects of adverse environmental conditions or intensive farming practices. All of these singly or together, can impose a considerable load or stress on the homeostatic mechanisms of fish. Stress that exceeds physiological tolerance limits will eventually be lethal. Stress, which is less severe will limit physiological systems, reduce growth, predispose to infectious disease when pathogens are present and reduce ability of fishes to tolerate additional stressors.

Definition of stress

The term stress or stressor or stress factor is defined as the force or challenge in response to which there is a compensatory physiological change in fish. Thus, an environmental or biological stress is of significance if it requires a compensating response by a fish, population or ecosystem.

General Adaptation Syndrome (GAS)

The various physiological changes that occur, as a fish respond to stressful stimulus, are compensatory or in other words these are adaptive in nature and are required for acclimation. Collectively these phenomenon have been termed as *General Adaption Syndrome*.

Conceptual Frame work of Stress response

The conceptual frame-work is to consider the stress response in terms of primary secondary and tertiary changes.

i) *Primary response :* Following perception of a stressful stimulus by the central nervous system the stress hormones *viz.,* cortisol and epinephrine are synthesized and released into the blood stream.

ii) *Secondary response :* Changes in the blood and tissue chemistry and in the haematology occur, such as elevated blood sugar levels and reduced clotting time. Diuresis begins followed by blood electrolyte losses and osmoregulatory dysfunction. Tissue changes include depletion of liver glycogen and interrenal Vit. C, hypertrophy of interrenal body.

iii) *Tertiary response :* Manifest in reduction of growth, resistance to diseases, reproductive success and survival. These may decrease recruitment to succeeding life stages as a result population decline occur.

Use of the physiological response as indicators

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

Methods for stress diagnosis

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

Primary stress response

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

Secondary stress response

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

The haematological parameters also provide useful information about an animals tolerance to stress.

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

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

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

The physiological tests of importance and their interpretations are given in Table 1.

Tertiary stress response

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

Metabolic rate : It is a fundamental aspect of animals performance and is affected by stress.

Reproduction : Detrimental effects on reproduction as manifested by oocyte atresia, spawning inhibition and decreased fecundity and hatching success are taken into consideration for assessing stress response.

Disease : Incidence of fish disease is an important indicator of environmental stress. Fish disease is actually the outcome of the interaction between the fish, their pathogens and the environment. If the environment deteriorates stressed fish is unable to resist the pathogens that they normally can resist. Certain diseases are proving to be useful indicators that tolerances of adverse environmental conditions have been exceeded.

Conclusion

Thus it is apparent that knowledge of the tolerance limits for acclimation to the single or cumulative effects of various biotic and abiotic stress factors is an important part of the data base for species habitat relationship needed for effective fishery management. Such information will solve many problems ranging from prediction of the tolerance fish will have for proposed habitat alterations to evaluation of the effects on fish health exerted by modern intensive fish culture.

Suggested reading

Stress and Fish. *Ed.* A.D. Pickering, 1981. Academic Press, London

Table 1 : Recommended physiological tests to assess the tolerance limits of fish for abiotic and biotic stress factors (compiled from Passino 1984; Buckley *et al.,* 1985). The interpretations of responses listed are general but not necessarily universal; investigators should be aware that there may be some stressful situations that do not evoke a change in one or more of these physiological conditions.

Physiological test	Interpretation if results are	
	Low	High
Blood cell counts	**Blood variables**	
Erythrocytes	Anemias, hemodilution due to impaired osmoregulation	Stress polycythemia, dehydration, hemoconcentration due to gill damage
Leucocytes	Leucopenia due to acute stress	Leucocytosis due to bacterial infection
Thrombocytes	Abnormal blood-clotting time	Thrombcytosis due to acute or chronic stress
Chloride, plasma	Gill chloride cell damage, compromised osmoregulation	Hemoconcentration, compromised osmoregulation
Cholesterol, plasma	Impaired lipid metabolism	Chronic stress, dietary lipid imbalance
Clotting time, blood	Acute stress, thrombocytopenia	Sulfonamides or antibiotic disease treatments affecting the intestinal microflora
Cortisol, plasma	Normal conditions	Chronic or acute stress
Glucose, plasma	Inanition	Acute or chronic stress
Hematocrit, blood	Anemias , hemodilution	Hemoconcentration due to gill damage, dehydration, stress polycythemia
Hemoglobin, blood	Anemias, hemodilution, nutritional disease	Hemoconcentration due to gill damage, dehydration, stress polycythemia
Hemoglobin, mucus	Normal conditions	Acute stress
Lactic acid, blood	Normal conditions	Acute or chronic stress, swimming fatigue
Leucocrit	Acute stress	Leucocytosis, subclinical infections
Blood osmolality, plasma	External parasite infestation, contaminant exposure, hemodilution	Dehydration, salinity increases in excess of osmoregulatory capacity, diuresis, acidosis
Blood total protein, plasma	Infectious disease, kidney damage, nutritional imbalance, inanition	Hemoconcentration, impaired water balance
	Tissue variables	
Adenylate energy charge, muscle and liver	Bioenergetic demands of chronic stress	No recognized significance
Gastric atrophy	Normal conditions	Chronic stress
Glycogen, liver and muscle	Chronic stress, inanition	Liver damage due to excessive vacuolation, diet dtoo high in carbohydrates
Interrenal hypertrophy, cell size and nuclear diameter	No recognized significance	Chronic stress
RNA : DNA ratios, muscle	Impaired growth, chronic stress	Good growth

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STRESS SENSITIVE PARAMETERS OF FISH DUE TO BIOTIC AND ABIOTIC FACTORS

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Introduction

Disease outbreaks are generally hypothesized to start from the stressed condition of the animal, which is known to lower the ability of the host to resist pathogens and succumb to infection. Environmental stress is an inescapable aspect of life in aquatic environment which is constantly under the threat of viable biotic and abiotic factors eg. pH, temperature, dissolved oxygen, sediment load, insecticides and pesticides, adverse light level *etc.* The stress factors exerts pressure on the organisms to adopt their body physiology to sustain relatively. Immediate responses to any stress occur over a time span of few seconds to few hours. When the changes exceed the threshold level, a state results, showing significantly reduced chance of survival which is known as 'morbid-state'

The biotic and the abiotic stress factors in fish and shellfish impair the normal biological activities, reduce the immunological status and often cause considerable loss of production and in certain cases mass mortalities.

Abiotic factors

Stretching the production capacities of ecosystems beyond a point can lead to environmental problems. It can also lead to disease out breaks and its rapid spread from one system to the other. This seems to have happened in certain pockets of brackishwater in our country- Non-infectious factors including nutritional imbalances and genetical disorders have not received much intensive

study although disease experts clearly recognize their importance. Their importance are often down played because clinically they are difficult to sort out and because their effects are considered to be less significant than those of the infectious processes.

Fish live in an aquatic environment where some of the most essential parameters such as **water level, temperature, pH, oxygen, carbondioxide etc.** fluctuate widely and may become lethal at times. Metabolites get accumulated in the system and come in inimical contact with the vital organs of the fish such as gills, skin, buccal cavity *etc.* Due to increased use of organic manures, fertilizers, feed etc. Some of the gases such as **hydrogen sulphide, ammonia, carbon dioxide etc.** are formed which are lethal to fish at 0.1, 0.03 and 30 ppm respectively. Some eco-biological components of the pond ecosystem play a major role in the production of such gases. Sometimes as a result of temperature fluctuations the fish are put to lot of stress beyond their normal tolerance limit The stressful environment for fish becomes congenial environment for the disease producing agents where they increasingly flourish.

Out break of disease is the function of three interacting factors i.e., **environmental stress, virulent pathogen and susceptible fish species.** However, environmental factors or stress is the most potential factor among the three. The stress induced changes are source specific and do not occur due to a single cause but rather multiple. It has also been the convention to describe environmental stress as either acute or chronic. Stress due to netting, grading, handling, prophylactic treatment and hauling etc. are all **acute** in nature where as over crowding, viable water quality parameters, exposure to novel environments are examples of **chronic** stress factors.

Fish live inside water and out of sight, as a result, detection of any disease at its early stage becomes difficult. Out break of disease is considered to. be the result of some basic environmental problem. Until therapy and corrective measures are taken up simultaneously, **fish** disease out breaks are difficult to control.

Biotic factors

Almost all forms of acute and chronic stress are capable of increase in the susceptibility of the host to a wide range of common pathogens such as virus, bacteria, fungus and parasites many of which would not normally cause disease problems. Presence of pathogens alone does not result in epizootics unless they are present in overwhelming numbers or there exists unfavourable environmental conditions compromising the host defense system. Thus, infectious diseases are not single causal events rather are the outcome of the continuing interactions between several aquatic environmental parameters. If the host-environment pathogen relationship is balanced and are maintained in equilibrium, good growth and survival occur, but if it is poorly balanced disease problems may begin to become evident which in turn reduce growth and survival.

The stress mediated diseases seem to have the most adverse effect as indicated in freshwater environments are those due to facultative bacterial fish pathogens which are continuously present in most natural waters.

Infectious diseases are often the most dramatic in terms of their high mortality rates. Over the past two decades there has been a rapid expansion of aquaculture in our country as well as Asia Pacific regions which has been accompanied by out brakes of serious diseases in finfish and shellfish. Thus, since past one decade the nature of the causative agents have been intensive. To date there are known to be more than 20 cutaneous and systemic bacterial diseases, more than 30 viral diseases and more than 100 external and internal parasitic diseases of commercially important finfish species.

Studies on diseases of fishes were carried out during the 1930-1940 in this country which were mainly concentrated on marine fishes from Gulf of Mannar. Communicable diseases are of more common occurrence and many of them at times assume epizootic proportions causing devastating effects. Epizootic ulcerative syndrome (EUS) in fish and white spot disease in brackishwater prawns have become serious concerns for aquaculture practices. These two diseases have caused substantial financial losses to fish farmers and aquaculturists in India and Asia - Pacific regions. Although notable leads have been achieved at CIFA through development of CIFAX for treatment of EUS, there is no definite therapeutic approach for white spot disease. It is noteworthy that there are some active efforts towards development of PCR probes for detecting the virus. However, there is an urgent need to develop field diagnostic kits based on ELISA/PCRILATEX BEAD. This would go a long way developing early warning systems both in freshwater as well as brackish sectors.

Innumerable diseases are caused in fishes due to **bacterial** pathogens and several of these are reported in Indian literature. They occur in nursery, rearing and growout ponds causing serious concern to fish farmers. Some of them often wipe out the entire population of fish. **Fin-rot** and **tail rot** in fishes have been reported in Indian literature as early as 1939 where both young and adult fishes were affected. Other bacterial diseases include **dropsy, eye disease, generalised septicemia** and skin and muscle lesions. Ulcerative disease in Indian major carps and catfishes have been reported where bilateral ulcerations of opercula, muscle tissue and head are observed. Species of *Aeromonas and Pseudomonas ware* found to be the causative organisms. Another major disease of similar dermal ulcerative condition has also been reported in Indian major carps and exotic carps and the causative organism has been identified as *Flexibacter columnaris.* **Myxobacterial** organisms have been attributed to a condition known as gill hyperplasia.

Protozoan parasites are common pathogens in fish causing marked loss of weight and growth retardation. Some workers have observed the correlation between environment and protozoan parasites leading to diseases in fish. **Myxosporidia** are one of the most important group of pathogen capable of producing disease in fish causing heavy loss in juvenile as well as young ones. Some other protozoan parasites affecting **fish** under **myxozoan** genera are **Thelohanellus** and **Henneguya** affecting the gill and skin. Renal myxosporidiasis affecting tubules of kidney has also been reported. Other important protozoan infections are due to **Trichodina** and **lchthyopthirius.** Incidence of 'White spot' disease caused by lchthyophthirius sp. in fingerlings of Indian major carps have been reported. Presence of numerous pinhead shaped white spots on the skin, fins and gills are the common diagnostic features.

Fishes are infected on their gills and skin by many species of **monogenetic trematodes.** The most important among them are **Gyrodactylus** and **Dactylogyrus** spp. They infect mainly the gills and skin causing wounds. The fish becomes very weak and prone to secondary infections. Similarly, the metacercarial stage of **digenetic trematodes** are extremely harmful for the fish. The metacercarial bodies get encysted in any part of the body like skin, muscle, abdominal cavity, liver, eyes and brain. These parasites belong to **diplostomatidae, echinostomatidae, clinostamatidae** and **opisthorchidae.** The fry and fingerlings of Indian major carps, silver carp and common carp are observed to get infected with the disease.

Besides these **Cestodes** like *Ligula intestinalis* infect the carp and live in the abdominal cavity. The infected fish especially the catla show softening of the muscle tissue probably due to accumulation of body fluid. In case of heavy infection the abdomen bursts resulting in death of fishes. *Ergasilus* spp. Infect the gill lamellae causing severe wounds and haemorrhages. **Crustacean** parasites **Argulus** or fish louse have been reported to infect cultured finfish. These parasites inhabits the skin, fins and gills of the host causing extensive pathological lesions over the skin specifically. These lesions promote secondary infections with fungi and bacteria.

There are several **fungal** pathogens also eg. *saprolegnia, Achyla*, Aphanomyces, Branchiomyces, Aspergillosis etc. which pose problems as biotic factors responsible for causing diseases in fishes. Fry, fingerlings and adults of Indian major carps may be affected with fungal attack after mecahnical injuries or bruises during netting operation or transportation.

Managernent of the aquatic environment

Proper and efficient management of the aquatic environment is very important for health point of view. Therefore, maintenance of a high quality environment is of utmost importance in the prevention of many diseases. Depending on the situation, periodic application of chemicals and monitoring of health status from time to time help as prophylaxis against many possible disease outbreaks. An aquaculturist need to adopt timely measures for maintaining healthy stock through out the culture period.

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ENVIRONMENTAL PERTURBATIONS AND AQUATIC BIODIVERSITY

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Introduction

The word biodiversity has become very popular in recent time with dramatic growth in its usage in scientific literature, popular articles and newspaper columns. The word, in fact has exploded as a vocabulary of importance, especially after the Earth Summit in Rio de Janeiro in 1992. The pertinent question is as to what does this word actually mean? Whether it is just a linguistic jugglery, where the old concept remains unchanged, or it is just an effort to create a fear psychosis for attracting international attention and more funds, or does it refer to certain fundamental issues in science? Besides these the point of argument is whether biodiversity is a property, which needs conservation and effective measurement. If it is so, then as to how, when and what way one should respond to the emerging situation in order to conserve the ecological integrity of an ecosystem?

Approximately 75% of the earth's surface is covered with water amounting to about 1.4 billion km^3, 96.5% of the total water stock is stored in seas followed by 1.77% as icecaps & glaciers, 1.70% as groundwater, only a meager 0.03% as freshwater accessible to human use and 0.001% as water vapour in the atmosphere.

The problem is more acute as the world, today, is passing through a critical phase of ecological transition and the blue planet Earth has limited freshwater resources. It is a paradox, however, that the critical freshwater resource available for human usage has brutally been assaulted in recent past, in the face of reckless developmental activities of various dimensions. The fact remains is that the aquatic systems have developed symptoms of disintegration and the biodiversity is the worst hit in the whole gamut. Biodiversity, being the biological wealth intimately associated with the welfare of mankind besides necessary for overall maintenance of ecological health of an ecosystem. It is imperative, therefore, to make all efforts towards their conservation for safe guarding the economic, aesthetic and cultural values linked to the survival and growth of human civilization on this planet.

Water Habitats

Freshwater ecosystems, the lakes and streams in particular, cover an area of 2.5 million km^2, which is approximately 02% of the Earth's surface (Wetzel, 1983) and together with soils these ecosystems contain only 0.014% of the total water stock available on it. The freshwater ecosystems are highly diverse in terms of physical structure and biodiversity composition. The freshwater resources are linked to the surrounding terrestrial habitats through the exchange of water and the material dissolved in it. These are also exposed to impacts via atmospheric pathways even from distant regions.

The aquatic habitats can broadly be classified into:

- *standing water,*
- *running water,*
- *soil & groundwater,*
- *wetlands*, and so on.

<u>Standing water</u>

The properties of standing waters, the lakes, ponds, pools, puddles etc., depends and linked to their origin, size, catchments characteristic, geological factors and the climate. Most of the present lakes, available throughout the world, are relatively younger from geological perspective (10,000 to 20,000 years old), except lake Baikal and lakes of East African rifts, being tectonic or volcanic in origin and much older. The old lakes often exhibit relatively higher species diversity and relatively higher degree of endemism. Many species, which inhabit these lakes, are found nowhere else in the world.

Freshwater biological communities are composed of microscopically small organisms called plankton, which have the characteristic to remain passively suspended in the water. An assemblage of plankton consists of phytoplankton, bacterioplankton and zooplankton. The biological cover or periphyton is another important assemblage of microscopic plants and animals, attached to submerged substrata. The biological covers have indicated greater dominance of diatoms (algae) and protozoa (animalcules). The normal littero-benthic communities include mollusc, oligochaetes, insect larvae and bacteria. The availability of freshwater fish depends on the quality and quantum of grazing chain besides the limno-chemical features of a particular water body. Water temperature and dissolved oxygen, for instance, play as the most vital limiting factor in regulating the distribution of fish fauna. The productivity status of inland waters linked to the characteristics of drainage basin and also the intensity of human influences of various dimensions.

Running water

The running water resources of the world, the streams and rivers, hold a meager 0.004% of the total liquid freshwater available on the surface of the Earth. Fish and sessile-organisms that can adjust with the changing current pattern dominate the normal biotic communities prevalent in running water. Moreover, the dominant running water species generally have flattened body and attachment mechanisms. Plankton can also frequent such waters, but more common in slow-moving lowland stretches. The riverbed flora generally predominate by sessile algae and higher aquatic plants. Water insects play a dominant role amongst the animals. The allochthonous input remains as the major source of nutrients in a running water.

The conditions for biotic communities change with the change in *temperature; lowering of oxygen concentration, increase in turbidity with greater ingress of dissolved and particulate organic substances*. However, the whole range of environmental variables change, when human starts interfering with the system.

Soil & groundwater

The content of water in soil besides the groundwater varies with its type and found fluctuating between 10 and 400 liters per cubic meter. Biological communities, inhabiting the soil-water-interface is very important for the stability of a terrestrial ecosystem besides maintenance of the nutrient cycle. Biota prevalent in soil phase, are generally heterotrophic in nature and are dependent on organic substances for sustenance. Photosynthesis is not possible in the absence of light, except certain bacteria, which can produce their own energy using special chemical reactions. The common forms prevalent in this habitat are fungi, blue-green algae, isopods and many other invertebrates. In recent years, however, the texture of biotic communities at this habitat have also changed or at the threshold of being changed due to aberrations in soil and groundwater, in the face of increased human interferences. This may have a very serious consequence, because the entire nutrient balance might be disturbed affecting the whole aquatic biodiversity adversely.

Wetlands

Wetlands resource has an estimated expansion of 5.6-86 million km^2 of the Earth's surface and account for 4-6% of the total water on this planet (Mitsch et al., 1994). Wetlands, the transition between land and water, are known as the most productive systems amongst the freshwater ecosystems and are considered as the repository of biodiversity. These are the favoured habitat for amphibians, waterfowl and shorebirds besides a host of micro and macro organisms including fish fauna. Endemism is also common in wetlands, but threatened in recent time due to large-scale modifications in their physical expansion. In India Ganga and Brahamputra floodplains have the maximum concentration of wetlands, supporting huge and diverse biological wealth.

Biodiversity of freshwater Ecosystems

Biodiversity or biological diversity refers to the richness of an ecosystem in plant and animal species, genetic variety and ecological processes. Evidently, it is the diversity of ecological functions and linkages within and between biological communities (Heywood & Watson, 1995). In recent time the biodiversity of many aquatic systems has taken a definite shift, owing to progressive degradation of ecosystems, which in turn has prompted the need of their conservation on priority basis on a global scale. However, as things stand currently, our knowledge on aquatic biodiversity is still in its infancy. We know precious little about the biotic resources from aquatic systems in their totality. The talk on conservation of aquatic biodiversity, therefore, appears to be self-defeating and an exercise in futility. The question is conservation of what and to what extent? The essence of argument is, as to why should we conserve the biodiversity? The fact remains is, that we neither have a comprehensive inventory of aquatic biodiversity nor we know much about the general role of biodiversity in the functioning of an ecosystem. In spite of these shortcomings, however, the biodiversity needs to be conserved from precautionary angle till we understand fully, as to what and how much damage the loss of biodiversity can inflict to a system. On a broader perspectives it must be conserved in view of the following (Perrings, 1995):

- *The biodiversity needs to be protected in order to maintain the services and utilization functions of an ecosystem for the welfare of mankind on a sustainable basis.*

- *The biological communities are a mix of microorganisms, flora and fauna and the interaction between them. All of these together constitute and ensure healthy functioning of an ecosystem, hence must be protected.*

- *The resilience or the elasticity of an ecosystem determines the response to external influences, including human impacts. The biodiversity is known to perform an important function in preserving this elasticity and accordingly must be conserved.*

Status of Aquatic Biodiversity

According to WCMC (1992), the inland ecosystems contain more than 1000 species of vascular plants and approximately 40% of total fish fauna (8,400 species). It has been estimated that the mean number of species in freshwater is much higher than the average number of species available in all other habitats. The Indian inland waters contain more than 150 species of aquatic plants and about 930 species of fish.

It is believed that the aquatic ecosystems, including seas, contain about 10,000 different species of phytoplankton, of which only 10% has been described so far (WCMC, 1992). In India about 4269 species of algae including phytoplankton (890) belonging to 653 genera have been described, of which 3023 species have been recorded from freshwater, 1222 species from marine waters and 24 species common to both the environments. The freshwater ecosystems have wide variety of phytoplankton but there is paucity of research on this aspect, barring some scattered information. The pelagial strata of lakes exhibit a complex biotope and as such it has been termed as '*paradox of plankton*' (Hutchinson, 1961), which need to be looked into in Indian context.

It was assumed in the past that species diversity increases with the maturation of ecosystem (Odum, 1971), but it has been established now that the variability of environmental factors over the time and accelerated in recent years, is responsible for producing new conditions and accordingly permitting new species to coexist (Sommer, 1985). The evolution of new species, therefore, is a function of time and this is the reason why geologically ancient ecosystems often exhibit high species richness and more endemism.

Threats to aquatic biodiversity

Freshwater ecosystems and the biodiversity thriving therein are exposed to a number of threats originating mainly through human interventions. In recent years the threat perceptions have increased manifold due to increasing population pressure at a very rapid pace. Accordingly, most of the freshwater ecosystems have developed aberrations of various nature. Population pressure has a great bearing on the quality of aquatic systems and the texture of biodiversity. Man-induced interferences have many facets affecting the biodiversity adversely. The following omissions and commissions related to human activities have been found detrimental to natural biodiversity:

- *excessive abstraction of water for irrigation, potable and industrial use,*
- *higher rate of siltation owing to denudation of forest coverage and other anthropogenic activities in the catchments,*
- *irrational disposal of domestic or industrial effluents, leading to eutrophication/pollution*
- *more ingress of agricultural runoff containing chemicals and pesticides*
- *large-scale river valley modifications with more incidence of dams and check-dams across various rivers and streams,*
- *encroachment of water area, either drowned or drained, for human settlement or arable land,*

- *massive growth of unwanted plant and animals*
- *over exploitation of water bodies for getting more biomass of food value, such as overfishing or destructive fishing*, etc.

Miller et al., 1989 have identified five major attributes, in reverse order, for the extinction of fish fauna in North America over the period 1900 – 1984 (Fig.1). They arrived at a conclusion that loss of and change to habitat have inflicted maximum harm to the fish fauna.

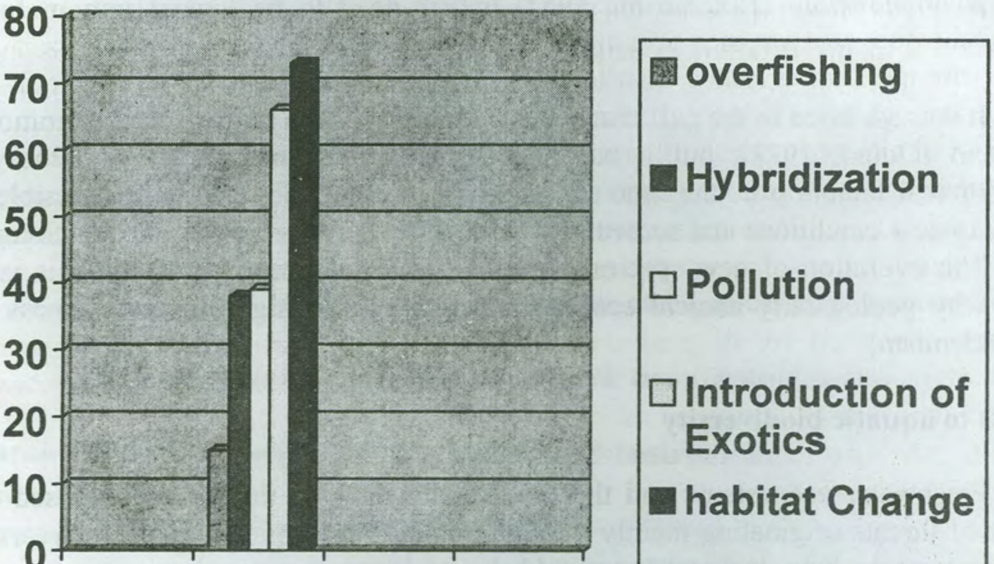

Fig. 1: Threats to aquatic biodiversity and Frequency % loss

Monitoring Aquatic Biodiversity

Periodical monitoring of biodiversity is a must to understand the conservational needs of the diversity of all form of lives for the maintenance of ecological integrity and to hold the utilization function of biological wealth on sustainable basis. The general principle of biodiversity monitoring is as under:

- *we must Monitor to the status of ecosystems or sites such as natural reserves, sanctuaries etc., specially in relation to emerging threats (SIM)*
- *we must Monitor to ensure the quality of such sites or ecosystems (SQM)*

- *we must Monitor to understand the impact of external threats or change in climate on the ecological health of such systems on a long-term perspectives.*
- *we must Monitor to identify the causative factors such as over fishing, pollution, canalization or abstraction of water and other man-induced activities.*
- *we must Monitor to keep a track on the biodiversity shift, specially, endemic endangered or rare species.*
- *we must Monitor to maintain the species richness of a biotope that we value.*

Trends of fish biodiversity in certain freshwater resources in India

Rivers

Recent studies conducted by CIFRI (Sinha et al, 1998) of various major river systems in the country suggest a definite shift in the availability of fish catch structure. The miscellaneous fishes of less economic value have over-taken all the other groups such as Indian major carps and large catfishes. In river Ganga, for instance, the Indian major carp fishery has relegated to third spot, in spite of the fact the Ganga is their original abode. Nevertheless, the total landing of fish has nose-dived alarmingly in recent years, subject to large-scale destruction of habitats on account of man-induced irrational exploitation of both physical and biological resources. The lucrative hilsa fishery of recent past above the Farakka barrage is in total shambles, slides to as low as less than 1% (90s) from a substantial contribution of 14% (70s) in the total catch due to obstruction on their paths of migration from sea to freshwater. Similarly, the mahaseer fishery of Narmada river system is also at the threshold of being collapsed, if corrective measures are not initiated at the earliest. An insight of fish faunal spectrum from the rivers may not be indicative of loss in fish biodiversity in terms of availability of species, but the poor growth performance of prized fishes together with recruitment failure at times do suggest that the biodiversity might have been affected at the genetic and physiological levels, being exposed to stress conditions of various dimensions.

Wetlands

The wetlands are highly threatened aquatic systems owing to various omission and commission by man. The lakes are in a state of advanced stage of eutrophication and tend to become swamps. The rich biodiversity including fish fauna was the characteristics of these water bodies till recently. Unfortunately, however, a very definite shift in fish biodiversity, at the level of population, has taken place. Massive stands of macrophytes have affected the overall biodiversity of these lakes adversely at every level, from plankton to fish (Sinha & Jha, 1997)

Estuaries

Over fishing of estuarine fish stock affecting the fishery of certain important fish species is of common sight. Environmental perturbation, such as construction of barrage and subsequent release of excessive freshwater has been observed in case of Hoogly-Matlah estuarine complex, the largest in the world, resulting into downward pushing of the estuarine area. Accordingly the post Farakka phase has witnessed a definite shift in the fish composition. Incidentally the overall catch from estuary has increased manifold due to the enlargement in fish spectrum due to the surfacing of many freshwater species.

Issues before biodiversity assessment & conservation

- *Strengthening of database in relation to inventorization of aquatic biodiversity from micro to macro organisms*
- *Strengthening of skilled manpower to promote taxonomic aspects of biodiversity assessment*
- *Conservation of biodiversity for conferring stability, productivity and sustainability to ecosystems specially to serve to causes related to human welfare.*
- *Quantification of biodiversity for effective management and sustainable development*
- *Efforts to study biodiversity loss at genetic and physiological levels*

Research options for biodiversity assessment and conservation

- *Collection of time series data besides compilation of existing information on various freshwater resources for placing before the user groups to motivate them on rational utilization of the limited resource.*
- *Studies on the structural and functional interrelationship between the communities in freshwater ecosystems and the adjacent habitats for assessing impact to anthropogenic disturbances and the susceptibility of ecosystems to external threats.*
- *Studies on the likely impacts of introduction of exotics, such as fish and invasion of unwanted non native biota by any means, on the structure, function and freshwater ecosystems with high endemism. so as to understand the system as a whole and to assess the intensity of external pressure.*
- *Immediate initiation of research on biodiversity with reference to genetic and ecological diversities for determining the importance of biodiversity in biotic responses to external influences.*

Concluding remarks

In the backdrop of accelerating extinction rates following increasing man-induced interferences on aquatic systems, quantification of biodiversity is emerging as a new spotlight on the global scale. The legitimate scientific quest is learn to prepare, as quickly as possible, a complete inventory of biological diversity. *All Taxon Biodiversity Inventory* (ATBI) is a must to quantify biological diversity in a discrete unit of aquatic system. Addressing the scientific quest is no doubt necessary, but relating the current environmental and social imperatives of sustainable development is a must too. Sustainable development confers maintenance of ecological systems, natural resource bases, in tune with the social systems. The question is whether quantifying biodiversity is some esoteric quest or whether it relates to fundamental of sustainable development?

Quantifying biodiversity directly relates to the societal imperative of sustainable development and it includes straightforward "Biological House-keeping" i.e. the inventory, survey and monitoring of basic biological resources. For most people biological survey and monitoring are unnecessary scientific jugglery, but in fact they are ignorant of the extent we depend on or benefit from biodiversity. The majority of the society feels that a handful of plants and animals directly associated with man as foods got to be conserved. The point of argument is that awareness campaign with vengeance is the need of the hour to educate people about the role of biodiversity in our day-to-day life. No country can afford to lose her biodiversity beyond a point and this is more relevant in thickly populated developing countries, owing to ever increasing demands on the food front. Conservation of biodiversity can't be done in isolation, rather each of us have to be cautious not to over exploit the biological resources, being the custodian of natural wealth.

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ROLE OF INFORMATION TECHNOLOGY IN THE ASSESSMENT AND CONSERVATION OF BIODIVERSITY

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Introduction

Assessment of aquatic wealth and its conservation is of fundamental importance to successful development process. Rational and sustainable use of these resources and an understanding of the ecosystem require continuous assessment of the resource base through appropriate methodologies and judicious identification of the required parameters. With the fast increase in population and shrinking resource base, an effective and appropriate approach is required to evolve eco-friendly techniques and technologies to improve production at a faster rate on sustainable basis without affecting biodiversity of the ecosystem. High input and high output approach, with least concern to sustainability, however, appears no longer relevant in the long run as its negative side effects are alarmingly evident. In this context, informatics and its application have great potential and this area needs to be fully exploited in different facets of fisheries research.

Information Needs

Appropriate information based on existing data and rapid appraisals are needed in time in order to take policy decisions through ecosystem and fisher farm community analysis. Due to advancement in information technology in the recent times, scientists now have access to a strong knowledge base world over which can be a boon in developing strategies and technologies for integrating the concerns of productivity increases, the environment and the quality resource base in fisheries. This requires development of management information system for fisheries comprising methodology and guidelines for data collection.

In this age of information technology the transfer of information is considered as a basic requisite for determining future activities of economic and social development of a country. Fisheries data is collected, compiled and processed by various agencies and there is still an enormous volume of data related to fisheries lying scattered all over the country with a lot of duplicacy and there are no information centers to store, compile, process and disseminate this data in a systematic way. As a result potential users starve for systematic information and the policy framework and programmes to formulate the strategies of future growth and evaluation of fisheries progress suffer from large inadequacies and unreliability.

Information technology has an important role in the diffusal of relevant experties and technology to farmers through the use of tools such as databases, expert systems and mathematical models. However, these tools are often efficient when used in isolation, their full potential can only be realized through integration. The integration of tool is not, in itself, sufficient to ensure the effective and efficient use of information. The specific information needs of different decisions makers will vary, and we cannot afford the luxury of creating distinct systems for each type of users, however, these differences may be more apparent than real, representing different rules through the same information structure. The concept of information integration describes an attempt to organize data and knowledge in a single cohesive unit. The resented complexity necessitates the provision of tools which provide appropriate access to and navigation within the information structure. It is anticipated that this system will enhance the diagnosis, treatment and management of fish disease, increase understanding of fish nutrition and allow health and productivity record to be more effectively maintained.

The immediate needs are to establish a network of information centers, efficient document delivery system, bibliographical center for effective retrieval of information, deposit libraries for preserving information for posterity, rural information centers, facilities for information data analysis, condensation and repackaging of fisheries information to meet variety of farmers and rural demands. The creation of information highways have now made it possible to synergise the combined capabilities of cyberspace technologies along with optimizing informatics on the use of land and water resources for taking a quantum leap in agricultural research and production.

Considering the dynamic trend, free flow of information is of crucial importance for fisheries development, sustenance and rational programme planning. Dearth of information database and absence of technological strategy have resulted in fisheries not getting the priority that it deserves in the mainstream of national agricultural policies. Information availability on fisheries has lagged far behind than of other discipline and evaluation indicate that fisheries scientific literature output is less than 10% of the agricultural literature output. Inadequate infrastructure facilities, poor communications, lack of trained manpower are further limiting the access and dissemination of fisheries information to the users.

The advancement in communication technology in this decade has helped to satisfy the information needs of the mankind covering even those who are remotely located , through network of computers; locally or widely located, or even through the network of networks popularly known as INTERNET. The communication revolution has led to the development of pagers, mobile cellular phones, satellite communication, electronic mail so much so that a stage has reached where the data signals, voice signals, video graphic image signals and animated drawings can be combined over the same communication channel and transferred through the same peripherals. Thus, computer networking and information processing go hand in hand so that a term "information technology" has been coined to cover all aspects of computer systems and communications.

The development of information technology in India has taken a boost due to launching of various computer and communication based programmes for gathering information on almost all the aspects of human activity. The following services in the field of information technology in India are now available in the field of agricultural research and education in the country.

"NICNET" programme of National Informatics Centre

NICNET programme for information dissemination launched by National Informatics Centre has proved very effective in the field of communication network. This nationwide satellite based network plays a key role in providing the researchers in agriculture with online access to many of the databanks available at different universities and institutions. NICNET has access to all the district headquarters in the country numbering over 500. The agricultural universities and research centers located in the neighbourhood of these district headquarters have easy access to the information highway through an inexpensive dialogue modem and telephone line. Where the existing telephone network is unable to provide this connectivity, a micro-earth station with a very small aperture (VSAT) enables the users to access the network. An executive information system (EIS) is under development by NIC to strengthen the existing management information system. EIS covers production prospects, project programme reports, transfer of technology, guidelines, information on various schemes etc. This may assist the government in further improving the information availability. Hence, NICNET having its nodes in almost all districts all over the country would play an important role in providing computer communication facilities for the management of information on fisheries and for better planning, monitoring and implementation of such programmes.

Information systems in Agricultural Research & Education

To cater to the needs of Agricultural Research & Education, Indian National Agricultural Research System (NARS) through its vast network of 30,000 scientists working at 49 Central Institutes, 10 Project Directorates, 30 NRCs, 86 AICRPs and 261 KVKs of ICAR, 28 SAUs and their 120 ZRSs, one CAU, numerous regional stations and other research centers have been generating knowledge since 30's and have developed technologies in various fields of agriculture. The scientific achievements in the field of agriculture by attaining green, white, yellow and blue revolutions have made

India a leading agricultural nation on both regional and international levels. With the currently witnessed revolution in information technology, access to desired information by working scientists and research managers has assumed paramount importance. India is rapidly becoming a world leader in this field also, known for its expertise in computer software development. Therefore, application of information management in agricultural research will prove to be a success for its growth in India.

With this in view, ICAR through its project ARIS "Agricultural Research Information System" is trying to develop infrastructure at majority of sites of National Agricultural Research System (NARS) institutions for development of database and access of information. It is expected that ARIS will improve research, planning, dissemination of research findings, information sharing mechanism, feedback mechanism and will provide electronic interface between development agencies and research organizations. This will also help in bringing an element of transparency in flow of information, which will be a great gain for the system. some of the systems developed by ICAR are geven below:

i) Agricultural Research Personnel Information System (ARPIS)

The ***Personal Information System*** has been developed with the objective of keeping the information on the ICAR Scientists, Technical and Administrative Personnel at a central place so as to provide easy access to different types of information like cadre strength, number of scientists in position, type of trained manpower available, distribution of scientists according to sex, caste, state, institute, discipline etc. The information on training, received in India and abroad as well as visits to foreign countries is also included. This will help the management in planning recruitment, identification of subject matter specialists in various fields, research work being undertaken on different commodities with respect to agro-climatic zones and resources used etc. Recruitment being part of personnel management a personal recruitment system for the ***Agricultural Scientists Recruitment Board*** (ASRB) has also been developed.

ii) Agricultural Research Financial Information System (ARFIS)

Agricultural Research Financial Information System (ARFIS) maintains the databases on finances namely monthly accounts etc. from voucher level. With the help of this service it has been possible to access the information on various aspects of finances of ICAR institutes. There is a strong need to develop such service at the national level at least for governement sector so that people may get up to date information at their own sites.

iii) Agricultural Research Library Information System (ARLIS)

The ARLIS envisages the on-line access by Indian agricultural scientists to the (a) international databases and scientific literature; (b) new database on Indian agricultural and socio-economic research and development to be created under ARLIS; and (c) external database accessible through the worldwide web. Efforts are being made to create more and more CD-ROM libraries at centralized place accessible to all concerned. Training to develop manpower has been organized and support for modernisation of the library systems and procedures in being provided. The IARI Library is being developed as a National Library.

iv) Agricultural Research Management Information System (ARMIS)

The basic purpose of the ARMIS is to provide the research managers the relevant information which help them in decision-making related to effective planning, priority-setting, monitoring and evaluation of scientific research; management of physical, personnel and financial resources; organizational restructuring and policy initiative. A software package is being developed to fulfill above objectives and provide easy access to the information related to various institutes and projects under different divisions of ICAR which are relevant from the management point of view. A database can be created, using data entry option of the above package at divisional level for the institutes and projects related to the divisions. Finally, the data from different divisions can be merged to provide a comprehensive management information system.

Few important information systems developed by different organizations with specific purpose of providing information on specialised fields are also presented below:

The Asian Biotechnology and biodiversity Sub-programme (ABB) provides information on new biotechnologies and assess these to determine their potential to contribute to the natural resource management in Asia. The proposed Bioinfomatics Network is one of the principal components of this Sub-programming. It aims to establish a link amongst selected research institutions, NGOs and potential end-users of new biotechnologies, with particular relevance to the needs of the resource poor farmers in rainfed areas. The network will be an enabling mechanism for all member countries to have access to information relevant technologies and would also serve to process the information in a form suitable for various participating countries.

The ARPU Information Management System (AIMS) has always remained in the focus all through out the evolution of the ACRP approach because of its diverse capabilities to respond to the dynamic nature of planning process and the innovative needs from time to time. The original objective of AIMS was to serve as a durable knowledge base providing area specific information on a variety of subjects representing entire set of economic activities specific to agriculture economy, at all disaggregated level. However, the subsequent evolution of AIMS included various analytical systems such as socio-economic indicators, decision support models and prototype export system, in addition to the land-use mapping by satellite imageries on 1: 250,000 scale for each.

Perceiving the implications of the future trends, AIMS is planned to include information on market arrivals and prices of important commodities at all possible levels of disaggregated for India and for other nations as well. The process of planned integration of agriculture economy with Global Village will require information on credit, infrastructure, fertilizer consumption etc. al all levels. AIMS may be expanded to include sociological factors for qualitative evaluation of economic developments within given geographical boundaries. Historically, communications with masses, especially at grass-root levels, have been more effective through vernacular languages, and hence, documentation and dissemination of ACRP knowledge base with the help of recent innovations in IT including the multimedia technology offering integrated presentation capabilities, innovations in networking and possibilities of transcription in various regional languages would be the areas on future expansion for AIMS.

The Aquatic Sciences and Fisheries Information System (ASFIS) supplied by the FAO fisheries programme is a computerized modular system for collection and dissemination of information regarding the aquatic research and the exploitation of the resources. The ASFSI modular system brings out a Worldlist of Aquatic Sciences and Fisheries Serial Titles as well as carries of the issuing body, the language and frequency of publication. It also brings out a Meeting Register giving advance current information about meetings dealing with fisheries.

National Atlas & Thematic Mapping Organisation (NATMO) has been preparing maps and atlases which directly or indirectly provide information on the status of the Indian agriculture, its likely changes and other parameters related to sustainability of agricultural practices. The National Atlas of India itself has several plates on the different aspects of agriculture of India. The examples of such maps are plates on agricultural labour, working force, land holdings and the like. Further, in addition to the National Atlas there are following three most important publications which are brought out :

a) Atlas of the Agricultural Resources of India,
b) Irrigation Atlas of India 1st and 2nd editions,
c) Water resources Atlas of India

NATMO has also taken up a mega project on the District Planning Map Series (DPMS). This Institution has been preparing maps for about 50% of the districts of India, which provide a lot of information on agriculture and associated factors. The information sources vary considerably from the latest remote sensing data to conventional statistics and also like air photographs, agricultural censuses, population and housing censuses, livestock censuses printed maps on soils and field data. The maps have been prepared on 1: 1M, 1: 2M or 1: 6M scales and they can be superimposed and used for GIS applications as well.

Role of ICAR in developing databases under ARIS

The ICAR would take the responsibility of developing the following database both in centralized and decentralized pattern depending upon its flow of data.

1. Scientific and Technical information
2. Crop wise databases
3. Technological databases (Package of practices, post harvest technology)
4. Animal Husbandry and fisheries databases
5. Projects databases
6. Financial databases
7. Personnel databases
8. Resource databases like soils, genetic, material etc.
9. CD-ROM of AGRIS, AGRICOLA and database on abstracts of Indian Journals.

The above databases will be in decentralized pattern (distributive database) and maintained by different ICAR research institutes in their respective places. In order to develop the databases, standard input and output formats for each of the above databases will be designed to capture and update the same periodically. In addition, each ICAR research Institute will maintain database on the following:

- Research results databases (includes experimental designs, data and the results).

- Database on abstracts of journals relevant to their mandate.

- Databases on financial, personnel and physical resources.

Role of SAUs in developing databases under ARIS

The development of different databases will be similar to that of ICAR and its research institutes concentrating on geographic area under their jurisdiction. Recently, NAARM has developed an AGRIUNIS package envisaging personnel, research, academic, R&D and budget for all SAUs. While developing a proposed model, the experience gained from this project will be made use of.

Role of State Departments

The development activities and rural development are done by different agencies like Department of Agriculture, Horticulture, Animal Husbandry, Fishery etc. in collaboration with NARS and banking sector. The feedback from the farmers channeled through these agencies will help ICAR and SAUs in refining the technology and information system. Presently the transfer of technology of ICAR and SAUs is being carried out through the extension services like KVKs, ZRSs and others. Usage of information technology in order to disseminate the information is as follows:

- Access to different databases as discussed above and also other databases maintained by National Informatics Centre (NIC) like village information,
  market information etc.

- Access to INTERNET through the ARIS network.

- Multimedia computers to train the farmers.

- Expert system cells in order to access the expertise on different technologies.

- Feedback form the farmers to different databases and vice-versa which will facilitate the scientists to know the acceptability of their technology in terms of its economic viability and adaptability.

Creation of Web Site and Home Page

For the organizations with rapidly growing IT, internet culture and its own mandate having a Web Site and Home Page has become essential and foremost needs to expand its horizon on global dimensions. It provides a quick and less costly interaction between research institutions and among scientists.

Suggestions and future needs

There is an urgent need to attempt for convergence of different approaches made by different agencies and develop databases at agro-climatic zonal level by screening useful primary data generated under different projects of the ICAR and the planning commission. This will immensely help in formulating agricultural developmental plans at zonal levels. Further, there is a strong need for development and implementation of a central fisheries information system with a definite national fisheries policy, establishment of network with effective regional centers, strengthening with equipment, adequate financial and manpower support to manage this type of system.

Summer School on ***Environment Impact Assessment of Inland Waters for Sustainable Fisheries Management and Conservation of Biodiversity***
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FISH STOCK ASSESSMENT OF OPEN WATERS FOR SUSTAINABLE FISHERIES MANAGEMENT

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A fishery resource is a self-renewable living natural resource in a dynamic habitat. This resource is affected by man's activities, which must be controlled to derive maximum social benefit. Since it is a living resource, it always balances itself by adjustment of its inherent biological characteristics like growth, recruitment and mortality. When fishing exploits a resource, it can still recover by growth and new recruitment and retain the original level, but it changes mortality and may alter all the biological characteristics and its behaviour pattern. As fishing activities have been intensified during the past few decades, it has become essential to predict catches and particularly the effects on catches due to change in the fishing activity with a view to proposing steps to ensure that increasing fishing intensity (effort) will continue to give sufficiently increasing returns. Before advising any measures it is necessary to assess the fish stock in the system. We describe the fish stock assessment as the search for exploitation level, which in the long run gives the maximum yield in weight from the fishery. For a given fishery resource there is, however, a largest average catch or yield that can be continuously taken from a stock under existing environmental conditions so that the stock remains uneffected. Therefore, ultimate objective of management programme of a given fishery resource is to assess this maximum yield or what is termed as maximum sustainable yield .

Fig.1 illustrates the basic objectives of fish stock assessment. On the horizontal axis is the fishing effort and on the vertical axis is the yield i.e., the landing in weight. It shows that upto a certain level we gain by increasing the fishing effort, but after that level renewal of resource cannot keep pace with the removal caused by fishing and a further increase in exploitation level leads to a reduction in yield.

Objectives of the fish population/stock assessment

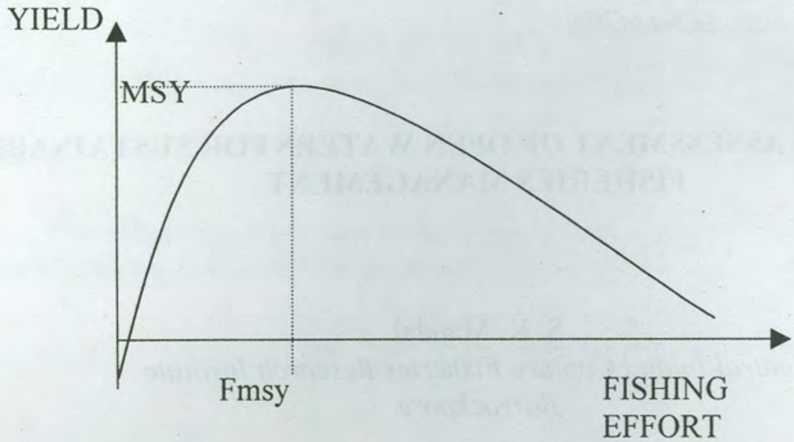

Fig 1 : The basic objective of fish stock assessment

The fishing effort level which in the long run gives the highest yield is indicated by F_{msy} and the corresponding yield is " MSY " , which stands for maximum sustainable yield. The phrase "in the long term " is used because one may achieve a high yield in one year by sudden increase in fishing effort, but then meagre years will follow, because the resource have been fished down. Normally we are not aiming at such single year with maximum yield, but at a fishing strategy, which gives highest steady yield year after year.

In studying the state of the fish stocks and the effect of fishing on them, the fishery biologist should carry out his analysis in quantitative terms. To do this he must use mathematics, and to use mathematics the complexities of the real situation must be replaced by more or less simplified and abstract mathematical models.

MODELS :

A description of fishery consisting of three basic elements :

1) the input (the fishing effort)

2) the output (the fish landed)

3) the process which link input and output (the biological processes and the fishing operations).

Fish stock assessment aims at those processes, the link between input and output and the tools used for that are called " models ". A model is a simplified description of the links between input data and output data. It consists of a series of instructions on how to perform calculations and it is of what we can observed or measure, such as for example fishing effort and landing.

There are two groups of fish stock models - 'holistic models ' and 'analytical models '. The analytical models are based on a more detailed description of the stock and they are more demanding in terms of quality and quantity of the input data. These models are age-structured models, working with concepts such as mortality rates and individual body growth rates etc.

The simple holistic models also called " surplus production models " use fewer population parameters than the analytical models and do not take into account, for example, the length or age structure of the stock. In this model stock is considered as one big unit of biomass. The model uses catch per unit effort as input. The data usually represent a time series of years. The models are based on assumption that the biomass of fish in the water body is proportional to the catch per unit effort. The surplus production models deal with entire stock, the entire fishing effort and total yield obtained from the stock. The main objectives of the application of surplus production model is to determine optimum level of effort, that is the effort that produces maximum yield that can be sustained without effecting the long term productivity of the stock. The production models can be applied when reasonable estimates are available of the total yield (by species) and / or the CPUE by species and the related fishing effort over a number of years. The fishing effort must have undergone substantial changes over the period covered.

Basic concepts on simple linear regression

If X and Y denote the two variables under study, the scatter diagram is obtained by plotting(Fig.2) the pairs of values of X and Y along the X-axis and Y-axis in graph paper. This diagram gives an indication of whether the variables are related, if so, the possible type of line or estimating equation, which can describe the relationship. If the scatter of points indicate that a line can better fit the data, then the relationship between the variables is said to be linear. If X tends to increase as Y increases, the relationship between the variables is said to be positive and linear. If X decreases as Y increases, the relationship between the variables is said to be negative and linear.

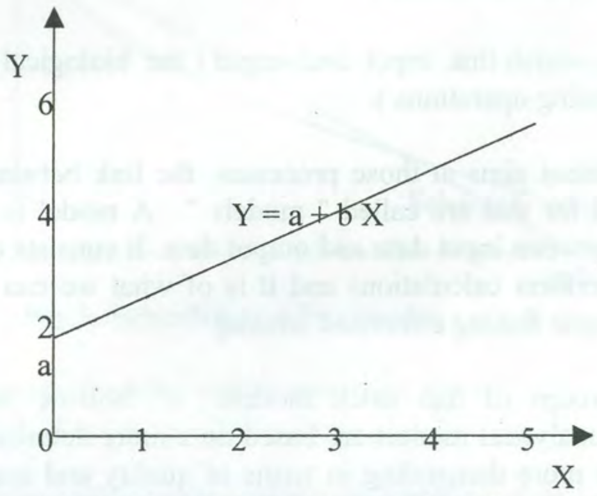

Fig 2: Linear regression of Y on X

If two variables are found to be highly correlated, then a more useful approach would be to study the nature of their relationship. Regression analysis achieves this by formulating statistical model, which can best describe these relationships. This model enables prediction of the value of one variable, called dependent variable from the known values of the other variable. It differs from correlation in that regression estimates the nature of relationship whereas the correlation coefficient estimates the degree of intensity of relationship. If scatter diagram indicates that the relationship is linear in nature, next step would be to develop a statistical model and proceed to estimate the underlying relationship. It is assume that linear relationship of the form, $Y = a + b X$ exits between the variables X and Y. Where a and b are constants. 'a' is called as the intercept and 'b' is called as the slope. The intercept is the distance from the point (0,0) in the (X,Y) diagram to the point where the regression line intersects with the Y-axis. The slope b indicates how steep the line is. The values of constants a and b may be estimated from the observed data. The best method that is used for estimating a and b is the method of least square. Estimates of the parameter a and b are obtained by the following formulae:

$$b = \frac{\Sigma xy - \frac{(\Sigma x \, \Sigma y)}{n}}{\Sigma x^2 - \frac{(\Sigma x)^2}{n}}$$

$$a = \bar{Y} - b \, . \, \bar{X}$$

Estimated values of these constants are substituted in the equation Y = a + b X to get the regression equation.

The Schaefer and Fox models:

The maximum sustainable yield (MSY) can be estimated from the following input data

f(i) = effort in year i, i = 1,2,.......n
Y/f = yield (catch in weight) per unit effort in year i.

The simplest way of expressing yield per unit of effort, Y/f, as a function of the effort f, in the linear model suggested by Schaefer.

$$Y(i) / f(i) = a + b\, f(i)$$

An alternative model was introduced by Fox. It gives a curved line where Y/f are plotted on effort.

$$\log \{Y(i)/f(i)\} = c + d\, f(i)$$

which can also be written as

$$Y(i)/ f(i) = e^{c + d\, f(i)}$$

Both models conform to the assumption that Y/f declines as effort increases, but they differ in the sense that the Schaefer model implies one effort level for which Y/f equals zero, namely when f = -a/b whereas in the Fox model , Y/f is greater than zero for all values of f.

This can easily be seen in Fig.3 where the plot of Y/f on f gives a straight line in case of the Schaefer model and a curved line, which approaches zero only at very high levels of effort, without ever reaching it in the case of the Fox model.

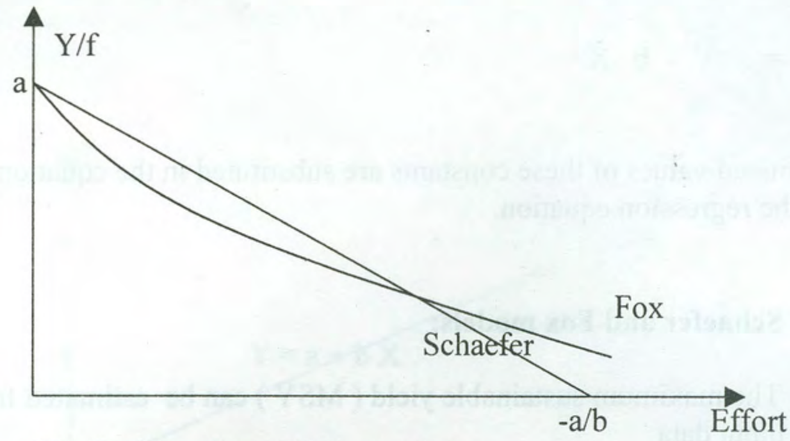

Fig 3: Schaefer and Fox model

The Schaefer's model can be written as

$$Y(i) = a\ f(i) + b\ f^2(i)$$

It has its maximum value of Y(i),the MSY level, at an effort level

$$f_{msy} = -\ 0.5\ a/b$$

and the corresponding yield

$$MSY = -\ 0.25\ a^2 / b$$

The Fox model can be written as

$$Y(i) = f(i)\ e^{c + d\ f(i)}$$
$$f_{msy} = -\ 1/d$$
$$MSY = -\ (1/d)\ e^{(c - 1)}$$

Year	Yield Y(i)	Effort f(i) X	Schaefer Y(i)/f(i) Y	Fox log{Y(i)/f(i)} Y
1969	50	623	0.080	-2.523
1970	49	628	0.078	-2.551
1971	47.5	520	0.091	-2.393
1972	45	513	0.088	-2.434
1973	51	661	0.077	-2.562
1974	56	919	0.061	-2.798
1975	66	1158	0.057	-2.865
1976	58	1970	0.029	-3.525
1977	52	1317	0.039	-3.232

Mean 923.22 0.0667 -2.7648

$a = 0.1065$ $c = -2.0403$
$b = -0.00004312$ $d = -0.0007848$

MSY Schaefer $-0.25\, a^2 / b = 65.8$

Fox $-(1/d)\, e^{(c-1)} = 60.9$

f_{msy}
Schaefer $-.5a/b = 1235$
Fox $-1/d = 1274$

Relative response-model of Alagaraja (1984)

This model depends on successive catches to provide the maximum catch that the fishery can sustain. There are three assumptions for success of this model. These are (1) Stocks existing in a particular area are exploited by various types of gear that are not species specific. This implies that the effect of fishing a mixture of stocks by these gears is proportional to the relative abundance of stocks in the mixture. (2) The fishing is increased over a time till the optimum level is achieved. (3) When the effort is increased the catches also increases till a maximum level is reached, but the rate of increase increases first and then decreases and finally reaches to nil. In the progressive fisheries where multispecies are exploited by multigears and when evaluation of effective effort poses problems particularly in tropical fisheries, this model is useful. The model in its simplified form is

$C_{t+1} = a + b\,C_t$

C_t is the catch of the t-th period, a and b are constants.

$C_{max} = a/(1-b)$

In the progressive fishery the level of maximum catch can be predicted and suitable management measures may be suggested.

Example

The following data relate to the catch record from the Hooghly estuary for five years. Estimate the catchable potential yield from the data.

Year	Catch (t)
1	30578
2	37981
3	44628
4	48608
5	50713

Solution

C_t x	C_{t+1} y
30578	37981
37981	44628
44628	48608
48608	50713

$C_{t+1} = 17038.8 + 0.703\,C_t$

$C_{max} = 17038.8/(1-0.703) = 17038.8/0.297 = 57369.7$ t

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Summer School on ***Environment Impact Assessment of Inland Waters for Sustainable Fisheries Management and Conservation of Biodiversity***
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ENDANGERED FISHES OF INLAND WATERS OF INDIA

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ABSTRACT

India has a very rich aquatic biodiversity with 2118 fin fishes distributed in different ecosystems. Of these, 520 are found exclusively in cold and warm freshwater ecosystems. About140 fin fishes are found at some stage of their live cycle in freshwaters. In 1993, based on secondary information collected,63 freshwater fishes were listed under the threatened species list. However,due to lack of data on abundance and distribution, the exact threatened status of many fishes cannot be ascertained with certainty. Some fishes in the threatened list may be abundant in one part of their historic distribution range while in another part, they might have undergone local extinction. One of the priorities for conserving the fish biodiversity is to have accurate data on the abundance and distribution of each species. Another difficulty that is being faced is the taxonomic confusion with regard to certain genera. The freshwater fishes are under many threats like water abstraction, habitat destruction, pollution, introduction of exotics, as well as over-exploitation and destructive fishing. These impact of these threats have become more pronounced in the river system. There is a need for developing mitigative measures which can be implemented taking into consideration the priorities given for development in general as well as the requirement for clean water from many other sources. To develop a conservation plan under this scenario, it is very important that we have a better understanding of the habitat requirements of different live stages. Unfortunately in India this aspect has received the least attention especially with reference to the earlier live stages. It might not be feasible to implement habitat restoration as well as fish conservation measures in all waterbodies. Based on priorities, it might be possible to implement in *situ* conservation measures in selected water bodies. These aquatic sanctuaries if developed on scientific lines and managed through community participation may help to sustain our fin-fish biodiversity as well as help to sustain some fisheries.

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ECONOMICS OF ENVIRONMENTAL DEGRADATION - AN INDIAN PERSPECTIVE

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In economics, environment is viewed as a special asset, since it provides the life support systems, which sustain our very existence. But the agony is that mostly, it is a common resource in open access, limiting any one's exclusion from its irrational use, resulting in degradation. To measure the magnitude of this environmental degradation, it is necessary to quantify the extractions from nature and the residuals or wastes disposed into it. This exercise of measurement or quantification is in physical terms, but to evaluate or assign them some monetary value is the subject matter of environmental economics including economics of environmental degradation. In India, studies related to environmental economics are very few particularly on aquatic environment. Since, aqua-resources form the habitat of fishes, the study primarily deals with environmental degradation in context of water pollution. The complete knowledge of degradation of aquatic environment including i) availability of quality water; ii) major sources of water pollution; iii) environment management system (EMS); and iv) major steps taken to combat such degradation (Ganga action plan) is the pre-requisite for such a study. Therefore, these aspects are briefly addressed in Indian perspective alongwith summary of the concepts, methods and techniques used in environmental economics.

Availability of Quality Potable Water

In India, utilizable water availability per capita per year is estimated at 1250 m^3 (Central Water Commission, 1999), but due to uneven distribution of water resources over time and space many regions face severe shortage of water. In 1993, 78% of rural and 85% of urban Indians had access to safe potable water; it left about 200 million persons without safe drinking water (Central Statistical Organisation (CSO), 1997). In recent times the water quality has deteriorated further, especially, in case of major rivers, the water quality is below Central Pollution Control Board (CPCB) prescribed best use water category (Parikh *et al.*, 2000). An estimated 80% people in our country use groundwater for their domestic needs. India's total replenishable groundwater resources are estimated at 431.8 km^3 (CSO, 1997). The overexploitation of ground water in some of the states (Punjab, Haryana, Tamil Nadu, etc.), particularly for irrigation purpose, is also a cause of concern for sustainable use of this scarce resource.

Major Sources of Pollution

Natural and human activities have direct impact on quality of freshwater. Major sources of aquatic environmental degradation are domestic and industrial waste, and agricultural run-off.

a) Domestic waste

The water pollution from domestic activities is most problematic. Pathogenic water pollution due to domestic waste is the cause of many water borne diseases. The domestic and municipal effluents are estimated to constitute 75% of India's wastewater by volume (Ministry of Environment & Forests, 1992). In 1988, Mumbai and Delhi individually generated 1714 mld (million liters per day) and 1480 mld, respectively. On an average it was more than wastewater discharge of 241 medium towns, if put together. In terms of urban municipal solid waste generation in India, it has been estimated to increase from 48 to 3000 million tonnes per annum during 1997 to 2047 (Uberoi, 1999). It means over 62 times increase in waste generation. As per estimates, if present methods of waste disposal continue, the area under landfill sites would increase seven times. To recover and recycle such huge volumes of domestic wastes there is urgent need to plan strategies and to implement them the earliest.

b) Industrial waste

Indian industry has registered substantial growth during last decades. The ever increasing volume of industrial wastes are becoming important source of aquatic environment degradation. Indian industrial sector represents a wide cross-section of industries in terms of size, manufacturing processes and product range. Over 3 million small-scale industrial units (SSIUs) are the special features of our economy. From a survey of CPCB, it is ascertained that about 25 to 30% of SSIUs are of polluting nature. In case of large water polluting industrial units discharging effluents into rivers and lakes, only 29% have adequate effluent treatment plants (Ministry of Environment & Forests, 1997).

Table 1 Status of installation of pollution control systems (PCS) in large and medium industries in India

Category	Total units		Number of units closed		Having pollution Control system		Not having pollution control system			
							Pre 1981		Post 1981	
	Number	% of total	Number	% of total	Number	% of total	Number	% of total	Number	% of total
Aluminum smelter	7	0.45	1	14.29	4	57.14	2	28.57		
Caustic soda	25	1.61			23	92.00	2	8.00		
Cement	116	7.48	3	2.59	96	82.76	12	10.34	5	4.31
Copper smelter	2	0.13					2	100.00		
Distillery	177	11.41	18	10.17	101	57.06	40	22.60	18	10.17
Dye & dye intermediate	64	4.13	5	7.81	51	79.69	6	9.38	2	3.13
Fertilizer	110	7.09	8	7.27	94	85.45	8	7.27		
Integrated Iron and steel	8	0.52			2	25.00	6	75.00		
Leather	70	4.51	7	10.00	41	58.57	17	24.29	5	7.14
Pesticide	71	4.58	7	9.86	62	87.32	2	2.82		
Petrochemical	49	3.16			49	100.00				
Basic drug & pharmaceutical	252	16.25	24	9.52	215	85.32	10	3.97	3	1.19
Pulp & paper	96	6.19	15	15.63	59	61.46	14	14.58	8	8.33
Oil refinery	12	0.77			9	75.00	3	25.00		
Sugar	391	25.21	17	4.35	256	65.47	103	26.34	15	3.84
Thermal Power plant	97	6.25	2	2.06	60	61.86	30	30.93	5	5.15
Zinc smelter	4	0.26			3	75.00	1	25.00		
Total	1551	100.00	107	6.90	1125	72.53	258	16.63	61	3.93

As a follow up policy, CPCB has identified 17 categories of industry as highly polluting industries for priority action. These industries alongwith their total number, and number of units having pollution control systems are enlisted in Table 1, Sugar sector has the maximum number of units followed by pharmaceutical, distillery, cement and fertilizer. Out of these 77 and 15% of the industries are predominantly water and air polluting, respectively, while 8% are polluting both water and air. It is evident from the table that 72.5% of these industries have the pollution controlling systems. The highest compliance of pollution control norms was for petrochemical industrial units (100%) followed by caustic soda, fertilizer and pharmaceutical units. On the contrary both the copper smelter were non-complying units, followed by integrated iron and steel (75%), distilleries and Aluminum smelters (57%). From these observations, it can be concluded that most of the non-complying industries, were pre 1981. It may be due to use of obsolete manufacturing technology and post-facto pollution control technology for the units established prior to 1991.

The appraisal of status of installation of pollution control systems over different states for these industries revealed that in Himachal Pradesh and Goa all the units are complying with pollution control norms. Among the states with broader industrial base for selected categories of industries, Tamil Nadu, Gujrat, Maharastra, Rajasthan, Uttar Pradesh, Andhra Pradesh and Karnataka seem to be more concerned about environment, and for all these states more than 80% of the units have pollution control systems. In other states the scenario is not so good, particularly for Jammu & Kashmir, West Bengal, Punjab, Orissa, Bihar, Delhi and union territories of Pondicherry. Depending upon the type of ownership, it has been estimated that about 43% of the non-complying units belong to private sector, 9% to Central Public Sector and the remaining 48% to State Government owned Public Sector and Co-operative units (Uberoi, 1999). In other words Central Public Sector Undertaking units seemed to be more environment friendly.

c) Agricultural runoff

Agricultural activities are one of the primary causes of environmental degradation through water pollution. The problem became more pronounced in developing countries like India, where agriculture is the major enterprise. Excessive use of fertilizer resulted in eutrophication in many aquatic habitats. In addition groundwater may also become contaminated with fertilizers and pesticides. The runoff from animal feedlots also carries nutrients, organic matter and bacteria. Irrigation water leaving the fields and entering the water bodies typically carries heavy load of salt that degrades the water body. The use of agricultural chemicals results in contamination of sediments and aquatic organisms. The problem of water pollution becomes more severe and unmanageable, as the magnitude of source of agricultural runoff is very vast, the large expanse of open fields.

Green revolution in India has increased the use of high yielding varieties and thereby agricultural chemicals in the form of fertilizers, insecticides, pesticides, weedicides, etc. Although, it has increased our food grain production manifolds, but their negative effects are often indiscriminate, particularly on water environment. Fertilizer ($N+P_2O_5+k_2O$) consumption has increased from 7.7 million tonnes in 1984 to 13.9 million tonnes of nutrients in 1995-96. Use of technical grade pesticides has also increased from 24305 tonnes in 1971 to 85030 tonnes in 1994-95 (Central Statistical Organisation, 1997). This rise in consumption and their increasing concentration in food chain (bio-magnification) have affected various species including man.

<u>Environment Management System</u>

In seventies the environmental degradation received greater emphasis and the aspects of environment protection and sustainable use of resources were discussed at length in various meetings of Government of India (GOI) and Planning Commission of India. As a result in 1980, a separate Department of Environment was created to promote and coordinate the environment and related issues. In 1985, a separate Ministry of Environment and Forests (MEF) was formed. Primarily, it is responsible for environmental protection, conservation and development. It works in close co-ordination with other ministries of centre and state, CPCB, State Pollution Control Boards (SPCBs) and number of scientific and technical institutions, including Central and state institutes, universities and non-governmental organisations. This combinedly form the environment management system of India.

The key functions of MEF are: environment policy planning, ensuring effective implementation of legislation, monitoring and control of pollution, eco-development, environmental clearance for industrial and development projects, environmental research, promotion of environment education, training and awareness, co-ordination with concerned agencies of national and international level, Forest conservation, protection and development of wildlife, and biosphere reserve programme. The key functions of CPCB included: advise to central government on environmental concerns, co-ordination and providing technical and research assistance to SPCBs, information dissemination, training and environment awareness, lay down and modify the standards for stream, well and air quality, planning and execution of nation wide programmes for prevention, control and abatement of water and air pollution, ensure compliance and execution of provisions of various environmental protection acts and regulations. The SPCBs are responsible for similar functions at state level. Although, key functions for MEF, CPCB and SPCBs are specified, but there exists ambiguity in their functions.

Ganga Action Plan

One of the most important examples of water pollution in India is river Ganga. Considered as the life line of millions of people, it was subjected to tremendous pressures due to i) diversion of its water into canals; ii) dumping of untreated municipal, industrial effluents and residues of agricultural chemicals in it; and iii) manmade modifications, in terms of construction of barrages, changing the river course, etc. The situation was further aggravated by deforestation resulting in silting and floods. To combat this water pollution hazard, GOI asked CPCB to study the pollution in river Ganga. The CPCB report revealed that 75% of the pollution of river Ganga was from untreated municipal sewage and 25% from industrial effluents. In 1985, GOI set up Central Ganga Authority for planning and execution of a time bound programme to prevent river Ganga from pollution. It is better known as GANGA ACTION PLAN. Based on the report submitted by CPCB in 1984, 261 schemes were sanctioned. The categories and distribution of these schemes in gangetic states are given in Table 2, while Table 3 indicated the towns, where these schemes were implemented. In total 254 schemes have been completed including 105 in Uttar Pradesh, 45 in Bihar and 108 in West Bengal. Maximum number of schemes was devoted towards handling sewage, which was the major source of pollution of the river. It was evident that the work on sewage treatment plants was slow, particularly in the state of Bihar. The schemes under other categories conceived well. The total budget of the plan was Rs 259.27 crores.

More than 79% of the budget was directed towards interception, diversion and treatment of the sewage followed by about 8% for low cost sanitation.

Table 2 State and type-wise distribution of schemes completed under Ganga Action Plan

Type of scheme	Uttar Pradesh	Bihar	West Bengal	Total	Total cost)	
					(Rs in crores)	% in total
Sewage interception and diversion	40 (40)	17 (17)	30 (31)	87 (88)	99.5	38.38
Sewage treatment plant	12 (13)	3 (7)	14 (15)	29 (35)	105.08	40.52
Low cost sanitation	14 (14)	7 (7)	22 (22)	43 (43)	20.4	7.87
Electric crematoria	3 (3)	8 (8)	17 (17)	28 (28)	10.44	4.03
River front development	8 (8)	3 (3)	24 (24)	35 (35)	13.47	5.20
Other schemes for biological regeneration of river	28 (28)	3 (3)	1 (1)	32 (32)	10.37	4.00
Total	105 (106)	41 (45)	108 (110)	254 (261)	259.27	100.00

Figures in parentheses represent the number of sanctioned schemes

Table 3 Towns covered under Ganga Action Plan

Uttar Pradesh	Bihar	West Bengal
Haridwar	Patna	Behrampore
Rishikesh	Chhapra	Nabadwip
Farukhabad	Munger	Calcutta
Fatehgarh	Bhagalpur	
Kanpur		
Allahabad		
Mirzapur		
Varanasi		

Second phase of the plan was launched in 1993 incorporating pollution abatement of rivers Yamuna and Gomti. The water of Yamuna river is unfit for drinking and bathing between Delhi and Agra. The scheme was implemented in fifteen towns of Yamuna basin. This phase envisaged i) use of appropriate sewage treatment technologies; ii) using treated sewage water for irrigation and aquaculture; and iii) use of biogas for power generation. In addition to continuing the schemes of phase I, the problems of riverbank erosion, and pollution from agricultural run off are also undertaken. Although, the plan is a success and much headway has been achieved to combat pollution of river Ganga, but immense scope still exists for improvement through i) better co-ordination between concerned state and central agencies; ii) monitoring of inflow of untreated waste into the river; and iii) emphasis on local public awareness and participation.

Economics of Environmental Degradation

The major problem in environmental economics is (e)valuation i.e. how to value or measure the degradation or exploitation of environmental asset(s) in monetary terms. The emergence of sustainable development as fundamental imperative of any economy has made this valuation process a pivotal point. India is in no way an exception. A nation is said to have sustainable development, if it enables to satisfy its requirements (social, economic and others) without jeopardizing or compromising with the interests of future generations. The relation between an economic system and environment is depicted in Figure 1. It indicated the extraction of natural resources from environment and adding the residual or waste material into it. Therefore, the valuation of environmental degradation should be from viewpoint of benefits extracted from environment and losses due to residuals or waste disposal into it.

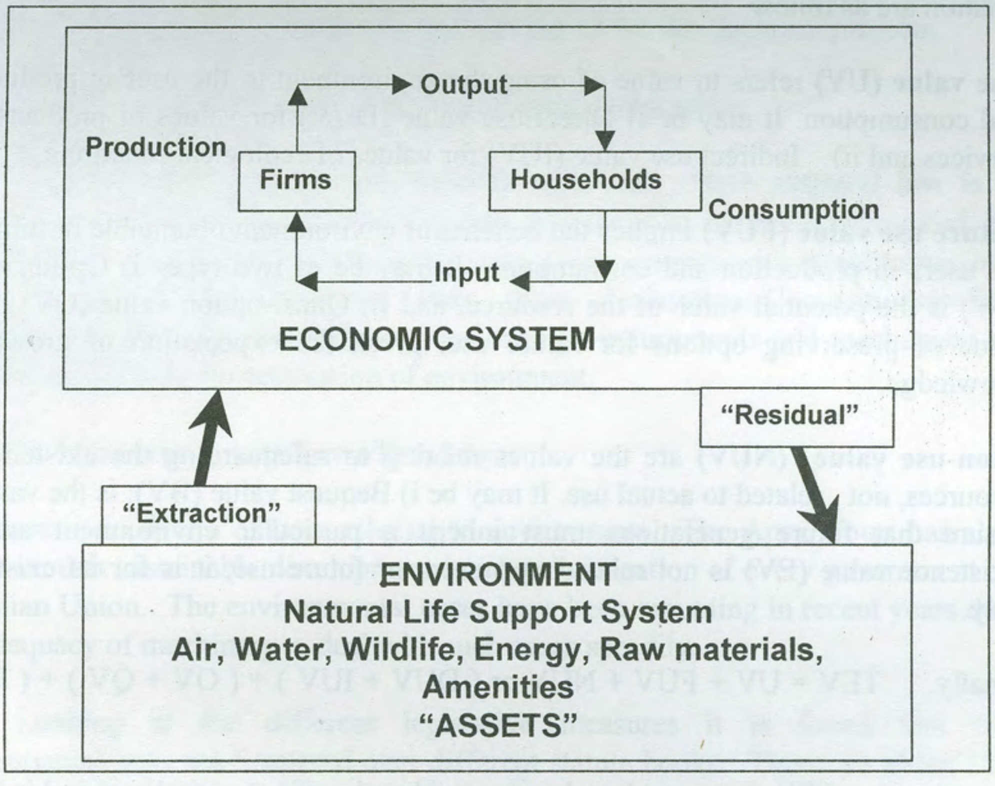

Figure 1 Interaction of Economic System and Environment

Prior to working out economics of environmental degradation, one must be clear about the objectives. Accordingly, the process of observation starts with identifying the concerned degraded resources, extent of their degradation; the reasons for degradation, sources of pollution, the clientele affected, the existing EMS including measures taken to combat the degradation, technologies available for treatment of concerned polluting residuals alongwith the cost of technology, number or percentage of users with pollution control systems, concerned environment protection legislation, etc. It is necessary because as such there is no fixed market or assigned price/cost for most of the i) factors causing environment pollution or degradation; ii) magnitude of environmental damage; iii) impact of the damage; iv) preventive measures towards reducing or averting environmental damage or degradation, etc, Therefore, all the environmental costs, prices, and returns are based either on direct valuation or indirect hypothetical valuations derived from the information collected from the people related to different aforementioned aspects of environmental degradation and protection.

Valuation of environmental degradation

To valuate the benefits from and losses to environmental assets, the term total economic value (TEV) of environment is used. Briefly, the components of TEV and their explanation are as follow

a) **Use value (UV)** refers to value of using the environment to the user in production and consumption. It may be i) Direct use value (DUV) for values of products and services and ii) Indirect use value (IUV) for values of ecological functions.

a) **Future use value (FUV)** implies the benefits of environment obtainable in future to the users in production and consumption. It may be of two types i) Option value (OV) is the potential value of the resource, and ii) Quasi-option value (QV) is the value of preserving options for future use, given the expectation of growth of knowledge.

b) **Non-use value (NUV)** are the values relating to safeguarding the existence of resources, not related to actual use. It may be i) Bequest value (BV): is the value to ensure that future generations must inherit a particular environment and ii) Existence value (EV) is not related to present or future use, it is for its existence only.

Finally, TEV = UV + FUV + NUV or (DUV + IUV) + (OV + QV) + (BV + EV)

While, estimating TEV care must be taken to avoid trade off between direct and indirect use values and double counting.

Method of valuation

In valuation, the prime concern is measuring benefits from improvement of environment and costs from deterioration in environmental quality. A benefit is a gain in human welfare while cost is loss to welfare. For valuation, we give a money measure to economic benefit/cost. It is related to both preference and intensity of preference of the user(s). The preferences of user(s) or concerned clientele are weighed in terms of money, which reveals their "Willingness to Pay" (WTP) and "Willingness to Accept" (WTA). WTP is the maximum amount an individual is ready to pay for an increment or improvement in any environmental good or service. On the other hand, WTA is the minimum amount an individual is ready to accept for a decrement or degradation in any environmental good or service.

Techniques of valuation

The techniques of valuation of environment may either directly place some value for environmental benefit/cost or indirectly assign a value for this benefit/cost. Therefore, these techniques are categorised under two approaches, namely, direct and indirect.

a) **Direct Approach**: involves the techniques, which attempt to elicit preferences directly through experiment or survey. The direct techniques are of four types namely, experiments, contingent methods, contingent valuation, and contingent ranking.

b) **Indirect approach**: evaluates the preferences indirectly based on the inferences from actual individual behaviour in relation to environmental goods and services. These are of two type i) Surrogate and ii) Conventional market type. The surrogate market techniques included Household production function (Travel cost and Averting behaviour) and Hedonic pricing (Property and labour market), while Conventional market techniques are of three types: Dose-response, Replacement cost and Opportunity cost.

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Summer School on ***Environment Impact Assessment of Inland Waters for Sustainable Fisheries Management and Conservation of Biodiversity***
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THE EFFICACY OF LEGISLATIVE INSTRUMENTS FOR CONSERVATION OF AQUATIC ENVIRONMENT

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With its geographic, climatic and biological diversity, India has a unique environmental heritage. The country represents almost all types of habitats of the world and the land mass of country and its water bodies sustain rich variety of plants and animals. However, development based on intense utilization of natural resources and polluting and energy intensive industrial technology along with pressures of population and poverty have taken a heavy toll of these environmental assets over the years. Economic development without environmental considerations can cause a serious damage, in turn impairing the quality of life of present and future generations. Sustainable development attempts to strike a balance between the demands of the economic development and need for protection of the environment. Sustainable development was well defined by **1987 Brundtland commission** as the meeting of "the needs of present without compromising the ability of future generations to meet their own needs."

Aquatic Environment :- Vis-a-vis Scarcity of Water

The probe into scenario of water use arouses mixed feelings. Our efforts mainly centred around developing the resource and very little attention was paid to ensuring its efficient, equitable and sustainable use. Though earth is known as waterplanet, yet water is becoming most scarce one for human use. Of the total water resource, 97.4 percent is salt water 1 .8 percent in frozen form and only 0. 8 percent is the fresh water which sustains life, development and environment. A note of caution was sounded by **International Conference on Water & Environment held** in **Dublin, Ireland** in **January, 1992.** It stated, "scarcity and misuse of fresh water pose a serious and growing threat to sustainable development and protection of environment. Human health and welfare, food security, industrial development and the ecosystem on which they depend, are all at risk, unless water and land resources are managed more effectively in the present decade and beyond that they have been in the past." The observations made in this statment are perhaps more applicable to India than many other countries. The **national water policy,** adopted way back in **1987** recommended, "economic development and activities including agricultural, industrial and urban development, should be planned with due regard to constraints imposed by configuration of water availability. There should be water zoning of the country so as to secure eco-friendly economic development."

Evolution of Environmental Jurisprudence

Jurisprudence both civil and criminal has a long history of its development but focus on environmental laws has been relatively of recent origin. It is still in a nascent stage. Most of laws on environment have been in response to changes registered in 20th century due to pressure of population in relation to availability of natural resources. There have been mainly two sources of environmental laws and regulations. (i) International Conferences and Policy declarations and (ii) Judicial Pronouncements of Apex court and various judicial bodies. The succeeding paras deal at length with international and domestic measures aiming at protection of the environment in general and aquatic environment in particular.

International Measures

Pollution of environment is a world-wide phenomenon. To combat it the United Nations has also expressed its deep concern. It organized Conference on **Human Environ**ment **at Stockholm in June, 1972** which laid down the principles and action plans for regulating and controlling human environment. This conference declared : (1) Man has the fundamental right to freedom, equality and adequate conditions of life, in an environment of quality that permits a life of dignity and well being; and (ii) man bears solemn responsibility to protect and improve the environment for present and future generations. The declaration also warned against pollution of sea and emphasised the need to support the struggle against all types of pollution. Stockholm Declaration is considered as the **Magna Carta** for international environment movement. The recommendations of the Stockholm Conference were finally enacted into the Act entitled **Security and Co-opration** in **Europe on lst August, 1975.** Accordingly, each state must ensure that its activities may not cause environmental degradation. The balance of ecosystem must be preserved **by** controlling air, water and soil pollution, in protecting the marine atmosphere, and in improving the environmental conditions of human settlements. The one hundred and thirteen participating states in Stockholm Conference resolved and affirmed that, preservation and improvement of human environment was their moral duty. Further, the charter of **Economic Rights and Duties of state, 1974** as a sequel to Stockholm Conference is a historic document.

World Charter on nature adopted by U.N. General Assembly on 28th Oct., 1982 declared that nature shall be respected and its essential shall not be impaired. Conservation of nature should be a part of total planning.

Earth Summit in Rio de Janerio - 1992

The Earth Summit held in Rio de Janerio in 1992 came up with a comprehensive programme of action to promote environmentally sound and sustainable development in the world. Five major agreements were signed by participating governments. These were : **(a) The Rio Declaration on Environment and development in the form of 27 principles; (b) Agenda 21, a bluė print for sustainable development into 21st century; (c) the declaration of forest principles recommending multiple use of the world forests; (d) The climate change conventions signed by 163 governments and (e) the convention on biological diversity signed by 160 governments.** After this conference, EIA has emerged as a potent tool of feasibility study in any of the development projects.

Limitations of International Laws/Conventions/Declarations

Long back Roman jurist Hugo Grotius said, that, **"International law is a vanishing point of jurisprudence"** Unless International measures advocated by various bodies are reflected in municipal laws of the country with penal provisions for violations of environmental laws these declarations/Conventions/policy documents remain only guiding principles through inducements and mechanism of international funding for restoration of environment.

Domestic Measures :- Acts/Laws/Provisions

There is no dearth of laws relating to environment. The Apex Court has also laid down that sustainable development is a legal obligation of every government of the Indian Union.. The environmental cases have been mounting in recent years due to inadequacy of machinery to deal with such cases speedily.

Looking at the different legislative measures it is found that the environmental laws are Scattered over different statute books. There are about 200 central and state enactment, which have Direct or indirect relation with environmental protection. For instance, under Indian Penal Code, spreading of infection of any disease dangerous to life, fouling of water of public spring or reservoirs, and rendering it unfit for human consumption, making atmosphere noxious to health, creating public Nuisance and mischief, are acts of offence. There are newly enacted laws relating to environmental pollution and protection. These comprise, **Wildlife (Protection) Act, 1972, Air (Prevention and Control of Pollution) Act, 1981, the Forest (Conservation) Act, 1980.** Under the **Environmental Protection Act, 1986,** the Central Government can exercise comprehensive powers for the purpose of protecting and improving the quality of environment and preventing, controlling and abating pollution. Article 48A of the Indian Constitution pertaining to Directive Principles of State Policy enshrines, "The state shall endeavour to protect and improve the environment and safeguard the forests and wild life of the country". Article 51 A(g) of the constitution makes it a fundamental duty for every citizen to protect and improve natural environment including forests, lakes, rivers and wild life and to have compassion for living creatures.

Water (Prevention and Control of Pollution) Act, 1974

In 1974, the Indian Parliament enacted this law. The first case under this Act by **way** of public interest litigation was decided in 1991 by Supreme Court. *Subhash Kumar* vs *State of Bihar,* concerned with the discharge of coal slurry into Bokaro river. The Apex Court put environment on the highest possible legal pedestal by declaring it to be a fundamental right to life in Article 21 of the Constitution. A petition under Article 32 for prevention of pollution is maintainable at the instance of affected person or even group of social workers or journalists. By 1993, the Supreme Court gave a teeth to this new fundamental right by declaring *in Nilabati Behera vs State of Orissa,* that there is a fundamental right to monetary compensation for the violation of this right. This right to compensation is distinct and separate from other legal remedies of prolonged civil suit for damages. In recent years a historic judgement relating to aquafarming in long coastal belt of India by Supreme Court has been stayed and the matter is to be heard again.

Citizen And The Law

How far legislative support in the form of various laws and enactments has achieved the desired objectives ? To have a body of legislation is one aspect and to implement them is another. It is not the question of having more and more stringent laws but by solving environmental problems by implementing existing laws. In fact, multiplicity of laws has destroyed the respect for law. Laws can be respected only if they are implemented without fear or favour. The element of deterrence is too tenuous a basis to secure obedience. It is said that hardened incorrigibles are not detered by law and good people don't require law as there is habitual obedience on their part as an enlightened citizen. In case of violation more than severity of punishment, it is certainty of punishment that proves more effective. Besides this, sincerity of purpose is required on the part of political leadership at centre and state levels and implementing authorities at local levels. Municipal commitees and corporations continue to throw their untreated sewage in rivers, canals and open fields. Laws were made and laws are being framed, but they seem to be devoid of teeth. Further, judicial process being rickety and time consuming often goes in favour of defendants. **Judicial pronouncements in their obiter dicta have more snarl than bite.**

Outlook - The environmental scene of the country today is both of concern and hope. The concern arises from the various environmental problems/issues which require immediate attention. The hope arises from to fact that country is still one of the world's richest in terms of biological diversity and other natural resources. The hope for the future is based on the many positive factors that are emerging and increasing number of peoples movements focussing on environment, greater public and media concern for these issues and spread of environmental awareness among children and youth.

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ROLE OF EXTENSION IN CONSERVATION OF AQUATIC ENVIRONMENT – A NECESSITY FOR SUSTAINABLE PRODUCTION

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Introduction

The environment, in an aquatic ecosystems embodies total physical and chemical factors that exert effect upon the biotic communities. Our interest in the envirornnent, from fisheries point of view, stems from the premise of harvesting maximum sustainable yield from water bodies. Fisheries development in inland water is becoming increasingly difficult due to the environmental constraints posed by the anthropogenic stresses. Some of these stresses have been recognised as over-abstraction of water, construction of dams and barrages, siltation of rivers and reservoirs and pollution due to urban industrial and agricultural run off. The resultant stresses exerted by these developmental processes culminate in mortality of fish and fish food organisms, destruction of breeding grounds and impediments in migration, instances are well documented. Pollution has been considered as one of the important factors that has limited the country's inland fish production. Thus, the targeted fish production of the last century could not be achieved.

Pollution in aquatic ecosystems

Water is essential for all forms of fish farming. The disposal of human wastes has been always constituted a serious problem. With the development of urban areas, it become necessary, from public health and aesthetic considerations, to provide drainage or sewer systems to carry such wastes away from the area. The normal repository usually are the nearest waterbodies.

Historically, the major concern with regard to pollution of surface waters was with their oxygen resource. However, in the past two decades, an increasing concern is the pollution of surface waters and ground waters with pollutants of primarily industrial or agricultural in origin. During past three decades, a large number of chemicals are in use for agricultural practices. There has been dramatic increase in the application of nitrogen fertilizers. Residues of these materials are often carried to water courses during periods of rainfall and have serious effect upon the biota of water bodies. Thus, the vast water resources *vis-a-vis* fish production of the country are affected.

Table-I:- Water resources of India

River (km)	29,000
Irrigation canals **(km)**	1,20,000
Flood plain lakes (ha)	2,03,213
Upland lakes (ha)	72,000
Fresh water Ponds (ha)	7,53,000
Reservoirs (ha)	37,57,908
Estuarine wetlands(ha)	50,000
Brackishwater impoundments(ha)	9,02,00
Estuaries, backwater, lagoon etc. (ha)	60,00,000

Need for conservation

It is the time that conservation and rational use of water is considered as prime national need. The approach of planning, development and management rests on established interdependence of water, land and the people. Emphasis is required to be laid for basin improvement, building and storage reservoirs, developing indrustries, planning crops, programmes on health where change- agent system has to take lead role to educate the clientele and motivate people's participation. The success of aqutic ecosystem protection venture ultimately depend on the reaction of mass awareness and participation of local people.

Role of Extension system towards protection of aquatic ecosystem.

Change-agent system is used as an instrument to bring about a desirable change,be it sociological or technological . It is a multidimentional system with interrelationship, linkage and transactions between and among internal and external domains. It aims at causing planned change or progress in the target field as per the greater sociological and economic changes designed by the political will of the people. In view of its crucial role, the aquatic ecosystem conservation programme planning towards fisheries development also has to include the extension component as an integral part.

The role of change-agent system is much beyond mere dissemination of information. It has a central role to play in the process of transfer of ideas in relation to its research, clients and support. The role becomes even more important when it becomes the question of influencing the behavioural change of people towards adopting conservation measures. The research system should be engaged in the development of management policy *vis-a-vis* conservation plan in close association of the change-agent system as well as client's system. The aquatic ecosystem conservation programme, thus generated will be tailor made to the conditions of the clientele. The change-agent system has to translate various aquatic ecosystem protection measures into the form of messages understandable to the target group and organise a strategy, so that they are disseminated through the utilization of appropriate media. The success of the system on aquatic ecosystem development not only depends upon its capability in safeguarding fishery resources through adoption of conservation measures but also its abilities to provide relevant technological and management base to various categories population operating under divergent resource endowments and aqua-ecological characteristics.

Strategy for effective communication for mass awareness.

The present strategy towards conservation of aquatic ecosystems in the country calls for rapid dissemination of information to the clientele in mass scale direction and bringing the gap between research system and target groups in the field. The strategy for communication of information on conservation measure to the target group is to be treated henceforth as one of the essential inputs to overall activity in the intended fishery development programmes.

Type of information.

Ideally information system for protection of aquatic ecosystems should cover;

a) Information on local natural resources and biodiversity
b) Information on direct abstraction to potable supply.
c) Information on food for human consumptions derived from inland water.
d) Information on indrustrial abstraction.
e) Information on crop irrigational abstraction
I) Information on livestock watering.
g) Information on local indrustries and nature of its effluents.
h) Information on domestic sweage discharge.
i) Information on chemicals in use in aquaculture.
j) Information on chemicals in use in agriculture.
k) Information on status of local deforestation.
1) Information on status of soil erosion.
m) Information on fish mortality.
n) Information on public health hazards.
0) Information on conservation measures.
p) Information on socio- economic status of the population.
q) Information pertaining to existing facilities and infrastructure.

It has been felt that negligible efforts so far, have been made in the country to provide such information to te target groups towards development of inland fisheries. Thus, a large gap has been created between awareness and adoption of measures towards protection of aquatic ecosystems.

Communication planning for mass awareness

The prime objectives of the programmes towards development of inland fisheries by protecting aquatic ecosystems could not be achieved unless communication is taken as an important component and ingredient of development efforts. The constructive application of communication for developmental process calls for proper planning that takes equal note of the national priorities and needs, preference of individual and of social priorities. An essential ingredient of such communication planning is an understanding of the specific assets and limitation of each of different media. It may be appropriate to have an idea of the impact of each of these on the society.

Face to face oral strategy

Extension personnel through personal contacts will establish rapport with the receiver and will communicate well tested messages to improve their skills, attitudes and knowledge.

Case studies

The case studies may come from all the areas of extension activities of the inland fisheries development *vis-a-vis* protection measures of the aquatic ecosystems. The case studies may be on achievement/activities of individual worker and experience of fishermen. The information can be compiled to give upto-date data.

Circulation

Information on protection measures on aquatic ecosystems could be widely circulated in the form of circular letter, hand-out, leaflet, pamphlet, mimeograph etc.

Joint field visit

Joint field visits of researcher and extension worker will enable them to understand about success of the conservation programmes of aquatic ecosystem and to identify the constraints.

Group approach

Instead of the individual approach in communication, the group approach should be emphasised to get the desired results in the field.

Use of Audio-Visual aids for mass awareness of the target group

Audio-Visual aids play important role in effective communication of information on management measures towards protection and resource conservation. The extension functionaries working in fisheries development programme must be equipped with audio-visual equipment. Radio and Television have a great potential as a medium of mass communication. The authorities concerned with Radio and TV may be co-opted to ensure that they plan their programme to broadcast /telecast information on the above regularly for mass awareness of the target group to strengthen aquatic ecosystems conservation movement.

Extension system and holistic participatory approach

At every step of the management of aquatic ecosystem to control pollution people's participated in all the four extension systems viz., Research System, Extension System, Client System and Support System, is of much more importance that the product or process put to use.

Local participation is not the only new criteria by which the management of any such programme need to be judged. It is equaly important that the problems be approached holistically taking into account of the full range of human and community potentials.

Aquatic pollution control projects necessarily involves both individual and group action. The need for participatory approaches is probably maximum in such developmental projects. In fact, participatory approaches are indispensable for successful management of such projects.

The very purpose of delelopment activity seen in its broadest sociopolitical sense is

- to enable people to critically understand their situations and problems:
- to identify their needs and to prioritize then;
- to evolve methods of resolving these needs and problems;
- to mobilize local resources;
- to implement activity in an organised manner; and
- to monitor, evaluate and learn from the effort.

Naturally, the participation of the people is necessary for such an effort. Since, development efforts can not stipulate people's participation as in initial condition, such participation should be actively promoted as an integral part of each practice of protecting aquatic ecosystems and should work, within a time frame, towards an ideal (even if it may not be wholly achievable) condition.

People's participation -a desired phenomenon.

Encouraging people's participation in the management of aquatic pollution control projects is not a new concept. But whatever this widely talked of concept's name, the concept of people's participation itself seems to mean many things to many people and there has been much confusion and misapplication in its implementation. Therefore, there is need to clearly understand the level of people's participation, that is necessary to achieve the goals of a specific programme on fisheries. To arrive at such and understanding, people's participation should be looked at in terms of:

i) the quality of participation
ii) the types of participation possible
iii) the phases of participation
iv) the proportion of those potentially effected who really participate in such schemes
v) the representativeness and accountability of the leader and the local organisations of the potentialy-effected community.
vi) The degree of people's participation in terms of labour and money inputs.

Participation with its peculiar dual nature of being a tool and end to be achieved by the tool,suggests ,that,no matter how little the participation to begin with, it is a possitive step towards not merely efficient socially feasible action but towards development itself Development, welfare and problem-solving were, in the past, activities that families, kinfolk and communities talked. But with development and welfare increasingly and unfortunately, often exclusively becoming government responsibilities, or at best agency functions,the question of who participate in whose activity becomes very relevant.

Generally speaking, it is the Government /Development agencies who, now a days, do some things for the beneficiaries, whether this involves transferring technology of building infrastrucure, or whatever other tasks the effort is that of the agency.

Participatory management

Participatory management activity by its very nature means working in management process with groups and communities. The research agency and change-agents will have to make the management of the fisheries in open water bodies possible by the people themselves rather than do it to or for them. This shift in thinking will have dramatic implications to not only management process but to the agency's culture as well. That will emerge or needs to emerge, is a shift from the developer-developee hierarchy to a situation of partnership where both the research/extension agency and the people see themselves as co-workers in the management process. This shift approach might even require in the research/extension agency to hold back on what it believes to be true, scientific and modern and begining a dialogue that,in time, will enable the beneficiary to, on his or her own, come to the same learning-perhaps to a learning which blends the research/extension agencies learning with indigenous leanings and realities.

There are two essential aspects to the organizational approach - one facilitates day-to-day activity with the community choosing representatives to speak on its behalf or undertake specific talks, the other one is more political aspects which involves empowering the community to make its sure it gets its rights and to hold external agencies responsible Research /extension agencies by their very nature, work with communities only for short periods of time. If the development activity has to be selfsustaining and self-perpetuating, then the participating people's organisation has to have be permanence and the ability to sustain the involvement of the community.

Conclusion:

The people's participation in the aquatic ecosystem conservation programmes have demonstrated that participation in the said programme is possible when the members of the target group are able to pool their efforts and resources in pursuit of objectives and goals, they set for themselves. It is suggested to bring change-agents, scientists, and local bodies under one umbrella to motivate the clientele towards success of the programme.

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ENVIRONMENTAL BIOTECHNOLOGY – APPROACHES FOR 21st CENTURY

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Introduction

The use of biotechnology in human society has a long history, as testified by the knowledge existed in making Bread, Beer or Wines from very ancient time. Products like Yogurt, Cheese and Penicillin were also made using the traditional biotechnologies known from very ancient time. The Whole concept of 'Ayurveda' revolves round the concept of biotechnology only. *Modern biotechnology, however, is a combination of biochemistry, molecular biology, microbiology and biological engineering.* Therefore it can precisely be defined as " *techniques, where organisms or their parts are being used for creating or modifying microorganisms, plants, animals or some specific products*". In recent time the methods like recombinant DNA technology or hybrid-DNA-techniques or gene technology, cell fusion and bioprocessing technologies are the important tools of modern biotechnology.

The science of Biotechnology, therefore, is a practical means of using gene technology. The methods are based on the concept of changing the genetic code in living cells in order to create new cells with improved characteristics such as organisms that can produce pharmaceuticals or industrial enzymes or can degrade waste materials. Biotechnological methods are also useful in isolation and use of selected parts in the diagnosis of specific disease, optimizing agriculture including fisheries and forestry operations, enhancing food productions, developing medicines, synthesizing new chemicals and above all environmental protection.

Biotechnology and Management of Environment

Biotechnology has assumed a centre stage of late and perhaps the only hope for the future in solving the problems likely to arise in energy sector as well as in the abatement of environmental pollution. The emerging issues like beneficial use of biological wastes as an energy resource and the need to combat excessive emission of carbon dioxide in the environment have attracted the attention of Planners, Developmental authorities and Scientists alike and hopefully these are being taken care-of through effective research and rational application of biotechnology. The emission of other hazardous gases can also be minimized through the application of biotechnology such as microbial de-sulphurization of oil and coals, prior to their combustion. The expectation is that many contemporary environmental problems related to Air, Soil and water, are being solved using biotechnological tools.

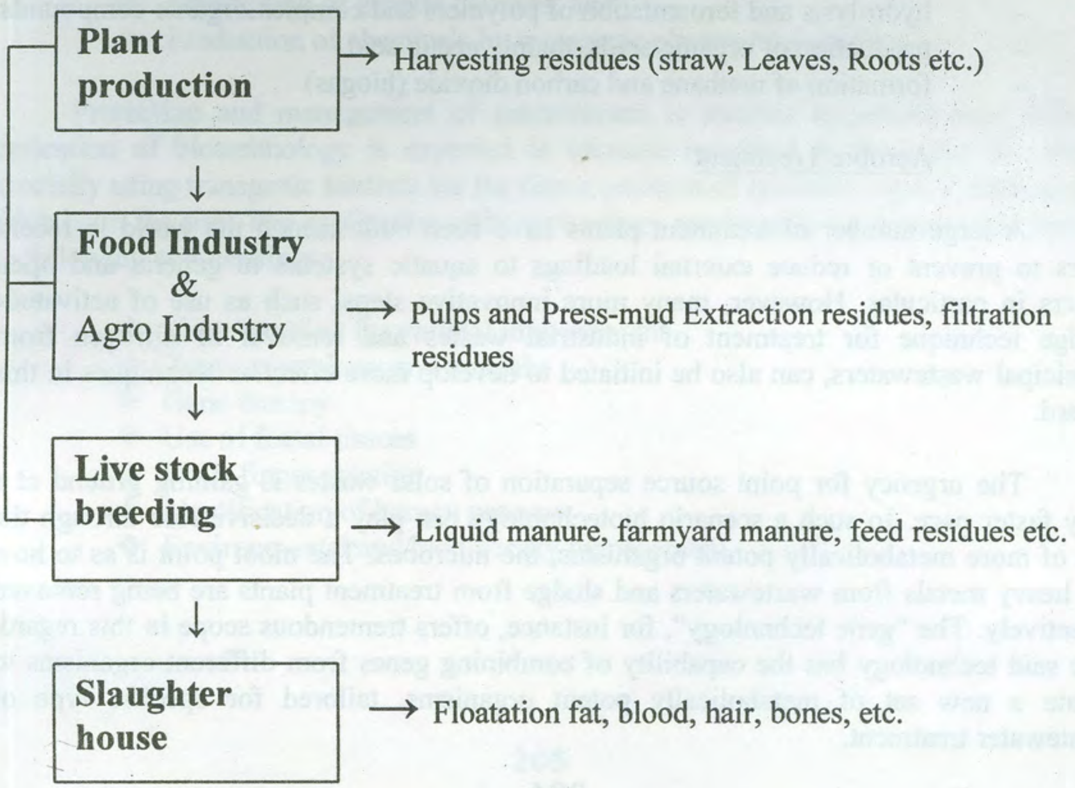
Waste management and waste utilization

The generation of wastes of various types and from various sources has taken a serious dimension in recent past owing to increased human population and subsequent rise in living standard.

Agricultural wastes and wastewater:

The anthropogenic activities are on the rise in various sectors of development. For instance, the wastes and residues generated from the growth and processing of agricultural products has assumed a menacing proportion, especially in third world countries where the entire economy of a nation is nothing but biomass economy. There can't be any doubt that more the wastes more the aberrations on natural resources. The environmental problems arising out from the storing, handling and disposing of agricultural wastes is another important area of serious concern. The problems of such natures are small and localized at the level of individuals, but they may pose serious environmental problems when transform into a large-scale enterprise as these can generate regional surplus of wastes.

The wastes generated through agricultural activities are generally organic in nature and can be in solid, slurry or liquid form (Flow chart 1).



Origin of Agricultural and agro-industrial wastes

Management of Solid wastes is, however, an area agitating the minds of one and all in view of its magnitude and in all probability it is going to assume serious dimension in the very near future. It is in this backdrop that immediate and effective steps are needed in this direction to keep the environment relatively clean. No space may be sufficient enough to dump the ever-increasing solid wastes. Accordingly, conversion of such materials into beneficial by-products like composting through microbial activities or generation of energy appears to be the best option to tackle this problem on priority basis. Necessary microbes can be isolated or biotechnologically improved and are used for specific functions, while handling the waste and waste disposals. Evidently, microbial treatment of degraded soils is an emerging field in the management and protection of environment.

Anaerobic Treatment

Anaerobic digestion processes are used widely to treat waste-water and wastes from agricultural source, keeping in view that through these processes besides solving the pollution problems valuable products such as biogas or compost can be obtained (Weiland, 1997b). Nevertheless, such process reduces the load of pathogenic germs, degrades malodorous compounds, increase the fertilizing effect of waste due to conversion of organic nitrogen into ammonia nitrogen and improves the handling properties of manure and other sludges. The microbial process has three independent steps and at least three types of micro-organisms are being involved in the entire process:

- hydrolysis and fermentation of polymers and complex organic compounds
- production of organic acids, mainly acetic acid
- formation of methane and carbon dioxide (biogas)

Aerobic Treatment

A large number of treatment plants have been built around the world in recent years to prevent or reduce external loadings to aquatic systems in general and open waters in particular. However, many more innovative steps, such as use of activated-sludge technique for treatment of industrial wastes and removal of nitrogen from municipal wastewaters, can also be initiated to develop more effective techniques in this regard.

The urgency for point source separation of solid wastes is gaining ground at a very faster pace. In such a scenario biotechnology can play a decisive role through the use of more metabolically potent organisms, the microbes. The moot point is as to how the heavy metals from wastewaters and sludge from treatment plants are being removed effectively. The "gene technology", for instance, offers tremendous scope in this regard. The said technology has the capability of combining genes from different organisms to create a new set of metabolically potent organisms, tailored for specific type of wastewater treatment.

Another important area, where biotechnology can make a significant dent is, the protection of environment through the use of "biosensors" to monitor levels of emission of various kinds and thus becomes an effective tool in EIA studies. The application of biotechnology has a greater relevance, as it can solve many immediate problems, in third world thickly populated developing countries, where people live in abject poverty and the generation of wastes is much more unorganized.

Present status and future implication of biotechnology application

During the last one decade, the application of biotechnology has increased manifold, especially in industrial sector. The development of gene technology in 70s has opened up a new chapter in biological science, as in USA alone more than 1000 companies are working seriously on various aspects of biotechnology use.

The contemporary R & D in biotechnology comprises Research, Development and Application of available knowledge on biochemistry, molecular biology and gene technology in agriculture including fisheries, forestry, food production, medicine, environmental protection and so on. It has ushered a better and enhanced understanding of the mechanism of living organisms, which are of vital importance to design new products. During the current century following areas would attract larger attention of scientific community, planners, industrialist and many others in:

- Identification of genetic heritage
- Interpretation of structure of protein molecules
- Elucidation of tumour–suppressing proteins
- Description of genetic diseases; and
- Production of chemicals by transgenic plants and animals

Protection and management of environment is another important area, where application of biotechnology is expected to increase manifold in the years to come, especially using transgenic bacteria for the decomposition of synthetic organic chemicals, which is on the rise. The application of biotechnology can broadly be summarized under the following sub-headings:

- Plant breeding for varietal improvement
- Transgenic plants and animals
- Gene therapy
- Use of foetal tissues
- DNA finger printing
- Identification of human genome
- Environmental and biodiversity management

Biotechnology and fisheries

In recent years the role of biotechnology has been recognized as an important tool for increasing the productivity status in culture systems. Fish and fisheries are the important components of aquatic environment and accordingly better the conservation and healthier the fish stock, more the production of fish biomass, which is an indicator of a normal ecosystem with better functioning and as such may be considered as relatively pristine aquatic environment. The areas where biotechnology has already left its imprint or about to make significant dents are:

<u>Genetic Engineering</u>

GENETIC ENGINEERING

- Gynogeneses
- Androgeneses
- Polyploidy
- Production of transgenic fish species

<u>Harmonal Production</u>

CONTROLLED BREEDING & INCREASE IN YIELD

- Humus cryonic
- Gonadotropin
- 17α, hydroxyl positron
- Deoxycoticostran
- LHR H-analog
- Dopamine antagonistic like pymozide, Domaridan, 17- α methyl testosterone, 17- β steroidal
- Cry preservation of sperm and ovum
- Bio-nitrogen stabilization
- Bio-fertilizers (*Azolla* sp. Cyanobacteria)
- Bio-purification of waste waters for reuse in fish culture
- Environmental management of fishery waters
- Determination of intra specific population
- Disease resistance and development of vaccines, etc.

<u>GENETIC ENGINEERING</u>

GYNOGENESES:
Through this mechanism the female
Gene gets activated to produce females only-------------Female Offspring (F)
ANDROGENESIS:
Through this mechanism male
Gene becomes active producing male offspring only--------Male Offspring (M)

(F X M = New species, which can produce 30-40% more than the original)

POLYPLOIDY:

Through this process 'Triploidy' (3 N) and 'Tetraploidy' (4 N) fish species are produced. The sterile Grass carp produced through this mechanism has shown much higher growth than the original stock. This technique is also helpful in case of Tilapia and common carp.

VARIETAL IMPROVEMENT BY SELECTED BREEDING:

Aiming at to obtain sustainable production efforts have been made for varietal improvement through selective breeding of fish species. In order to accomplish this Gene profile of test fish species is a must, which can be done through cytogenetics and biochemical genetics methods. Established fast growing species are being selected for this purpose and two different such species are crossed to obtain a new species. Production of *Jayanti RI 1* at CIFA is a species of that kind. Normally such fishes indicate much higher rate of production.

TRANSGENIC FISH:

Transgenic fish species are produced through Gene therapy mainly to develop disease resistant properties.

PRODUCTION OF CROSS BREEDS:

This kind of fishes can be produced by selecting two different fish species from natural conditions and are being crossed. This kind of Cross-Breeds, acquire the characteristics of both the parents and generally and have been found more productive than the original stock.

CHANGE IN SEX / UNISEX:

Change of sex as per the requirements of culture system has been found effective in aquaculture. In such cases the young ones are fed with steroids, for getting desired results.

CRYO-PRESERVATION OF SPERM AND EGGS:

The success of biotechnological development of Cryo-preservation of sperm and eggs of fishes is a landmark achievement facilitating assured supply of fish seeds to farmers at different seasons and agro-climatic conditions.

In addition to the aforesaid biotechnologies available for fishery sector a number of Hormones such as breeding-regulating hormone, growth-promoting hormone etc. are also in use to improve the production and productivity of aquaculture.

Tissue culture, Gene Therapy, Gene Mapping etc, are some of the biotechnological tools used for assessment and control of fish disease.

Biotechnology vis-à-vis Biodiversity

Prioritization of Research and Developmental issues is essential to provide necessary technical or information support in developing a scientific management strategy for conserving the biodiversity. Accordingly, nine priority areas, as under, have been accepted throughout the world.

1. Survey,
2. Composition, structure & function of ecosystems,
3. Monitoring
4. Sustainable use
5. Valuation
6. Integration of traditional knowledge & skills
7. Social, economic
   & Cultural factors
8. Development of restoration technologies
9. Technology application (biotechnology)

In the face of increasing threat perceptions the above priorities can never achieve the level of successes necessary for human welfare or to full-fill the esoteric scientific quest, unless adequately supported by low-cost and low-input biotechnologies. Application of biotechnological techniques is all the more essential for the restoration and multiplication of economically important species, especially in areas where appreciable decline in the population of any species has taken place. Besides this, high-input biotechnologies may also be essential for both *in situ* and *ex situ* conservation of keystone, rare, threatened and endangered species.

Principles of Monitoring Biosensors

A variety of biological reactions can be used for the detection of pollutants in an aquatic ecosystem (Table 1). In environmental monitoring two different approaches are employed: first, registering specific substances or at least groups of pollutant and second, monitoring of sum parameters. Immobilized enzymes or many other biomolecules with high specificity such as antibodies, nucleic acids or lectins are used as biological recognition elements in case of high selectivity requirements.

Increasing complexity of biological compound often results in lower selectivity allowing the measurement of sum parameters, as performed by sensors containing mutants of *salmonella typhimurium* to determine Mutagens or Biosensors for BOD measurement and toxicity control. To determine the bio-available organic carbon or biological oxygen demand (BOD) bacterium like *Bacillus cerus* or yeast (*Trichosporon cutaneum*) and *Rhodotorula mucilaginosa* are invariably been used.

Table 1: Approaches to detect Environmental Pollutants

Mode of detection	Pollutants detected	References
Enzymatic reactions or microbial metabolism	Pesticide, Nitrate/nitrite, phenols, halogenated hydrocarbons	Riedel,1992; Peter et al, 1996, Konig et al, 1996
Enzyme inhibition	Pesticides, metals	Marty et al, 1993
Respiration inhibition	Toxic materials	Ikebukero et al 1996
Bacterial luminescence	Metals, organic compounds	Hyun et al, 1993
Photosynthetic activity	Herbicides	Van Hoof et al 1992
Molecularly imprinted membranes	Pesticides	Scheller et al, 1997
Immuno-chemistry	Herbicide, polychlorinated biphenyls	Chemnitius et al, 1996

Environmental risk factors with the application of biotechnology

The adoption of biotechnological tools at various levels of environmental management is an emerging area and it offers tremendous new possibilities for environmental management and conservation. Environmental degradation of soil and water caused by oil spills, production and discharge of bio-accumuable chemicals, inappropriate handling of wastes, leaching of metals from mining and industrial wastes etc. can be minimized or even abated with the adequate technical support developed through biotechnological tools. There might, however be potential negative impact on environment also through production processes and products of biotechnology, which could multiply quickly if appropriate precautions are not taken in time. A holistic approach, therefore, needed for protecting the environment with due consideration to the possible risk factors arising out of genetically engineered products. Over-dose of biotechnological materials into any natural system may prove detrimental, as it may develop aberrations in its normal functioning. It is imperative, therefore, that the application of biotechnological tools and products and the relevant environmental issues need careful monitoring and thorough debate.

CONCLUSION

The application of biotechnology in *Environmental Management* and holistic *Development of Fishery* sector needs greater attention, especially in the face of diminishing resources, both physical and biotic owing to ever increasing growth in human population. The freshwater resource in 21st century is going to become very critical as the per capita demand of water is bound to increase with the increase in population and modernization of society. The developments, which have taken place in biotechnologies around the world, on various facets of fish and fisheries, environment and biodiversity conservation etc. need to be applied in Indian waters, wherever possible. However, the risk factors in relation to biotechnology application should also not be ignored as irresponsible application may lead to total disintegration of ecological functions.

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