Management of Inland Open Water Fisheries

Bulletin No. 83

May 1998

Central Inland Capture Fisheries Research Institute
(Indian Council of Agricultural Research)
Barrackpore 743 101 West Bengal India

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Foreword

Fish production in open waters is a complex natural process which needs to be understood in consonance with the intricate changes that take place continuously in terms of habitat variables and biotic communities . In large water bodies, the production is based on wild untended populations which, in turn, is dependent on a complex community metabolism. The efforts to optimise yield are closely linked with the conservation of habitats and their biotic communities. Thus, there is a need to continue with open water fisheries research *vis-a-vis* environmental management.

To enrich the knowledge and skill of the developmental officials of Sri Lanka, a 1-month International training course on " Management of Inland Open Water Fisheries" was organised at the Institute during May,1998. This booklet is the compendium of lectures delivered by the experts in the respective field during the training course. It is hoped that this booklet will be beneficial to all.

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Director

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Inland Fisheries resources of India and their utilization

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1. INTRODUCTION

Inland fish production in the country has registered a phenomenal increase during last about four decades. As against 0.2 million t produced in 1951, the production of inland fish in the country during 1995-96 is estimated at 2.2 million t. The projected domestic requirement in the country by 2002 AD is 12 million t, a half of which has to come from the inland sector. To achieve this national goal, proper development/conservation of inland open waters is a must for which a scientific understanding of all types of inland fisheries resources is imperative to back up their optimum exploitation. In addition to its capability of achieving the goal of required fish production, the inland open water fisheries being a labour intensive activity its development has the potential to improve the quality of life of some of the most vulnerable sections of the society. Out of the estimated 0.71 million fishers in the country, 0.49 million are inland fishers who live in abject poverty. Number of fishers per km of river stretch has been estimated to be 3.2 in Narmada to 7.8 in Ganga, the average being 6.5. However, there exists as many opportunities to augment the yield from inland fisheries resources as there are constraints which operate against them.

Inland fishery resources of India, comprising vast expanse of rivers, canals, estuaries, lagoons, reservoirs and floodplain wetlands (lakes) are noted for their variety as well as their rich production potential. (Table 1). The enormity and diversity of these systems demand separate, sector-wise approach in their development as they portray different pictures of environmental parameters and production dynamics. Dotted with floodplains, oxbow lakes, quiescent backwaters and interspersed deep pools, the rivers possess a mosaic of varying biotopes ranging from lotic to lentic habitats. A large number of river valley projects have been built and commissioned since independence, as a part of our developmental activities, resulting in a chain of new aquatic resources like irrigation canals and reservoirs. Extensive areas under floodplain wetlands in the form of *mauns, beels, chaurs, jheels* are available in eastern U.P., northern Bihar, West Bengal, Assam, Tripura, Manipur, Arunachal Pradesh and Meghalaya. These are shallow nutrient rich water bodies formed mainly due to change in river courses (or tectonic actions) and offer ample scope for culture-cum-capture fisheries. The end saline areas of the river systems, known as estuaries, and lagoons also form an important component of fishery resources of the country.

Table 1. Inland Fishery Resources of India (compiled)

Rivers	45,000 km
Reservoirs	3.15 million ha
Estuaries	2.7 million ha
Lagoons	0.19 million ha
Floodplain wetlands	0.24 million ha

2. RIVERINE FISHERIES

The extensive network of Indian rivers alongwith their tributaries, with a total length of over 45,000 km constitute one of the major inland fisheries resource of the country. Indian rivers carry a surface run off of 167.23 million ha metres which is 5.6% of the total run off flowing in all the rivers of the world. The river systems of the country comprise 14 major rivers, each draining a catchment of more than 20,000 km^2, 44 medium rivers, having catchment between 2000 and 20,000 km^2 and innumerable small rivers and streams that have a drainage of less than 2,000 km^2.

The Ganga river system, with its main tributaries like Yamuna, Ramganga, Ghagra, Gomti, Kosi, Gandak, Chambal, Sone etc., is the original habitat of the three major carp species of the sub-continent *viz.*, catla, rohu, and mrigal, better known as Indian major carps, and continues to be the source of its original germ plasm. The Gangetic system alone harbours not less than 265 species of fishes. Similarly 126 species belonging to 26 families have been recorded from the Brahmaputra system. The peninsular rivers have been reported to bear at least 76 fish species.

The riverine scene, however, is a complex mix of artisanal, subsistence and traditional fisheries with a highly dispersed and unorganised marketting system which frustrates all attempts to collect regular data on fish yield. A firm database being elusive, for production trends, one has to depend on the information collected by CIFRI from selected stretches of rivers Ganga, Brahmaputra, Narmada, Tapti, Godavari and Krishna. Based on the studies made by CIFRI the fish yield in these rivers vary from 0.64 to 1.6 t per km. The catch statistics over the years indicate some disturbing trends in the riverine sector, especially the Ganga. The biologically and economically desirable species have started giving way to the low value species, exhibiting an alarming swing in the population structure of Gangetic carps. The average yield of major carps has declined from 26.62 kg/ha/yr during 1958-61 to 2.55 kg/ha/yr during 1989-95. (Table 2).

Table 2. Estimated yield of Indian major carps in the river Ganga (in kg/ha/yr)
(Jhingran, 1992 + Personal communication)

Centres	1958-61	1961-69	1980-86	1989-95
Kanpur	83.5	24.3	-	-
Allahabad	15.6	21.5	9.29	1.72
Buxar	17.1	3.8	7.00	-
Patna	13.3	13.3	5.08	3.04
Bhagalpur	3.6	7.5	2.90	2.90
Mean	***26.62***	***14.08***	***6.07***	***2.55***

A survey of river Brahmaputra in the state of Assam brought to light a decline in the fishery of the middle and lower stretches of the river since 1972. The survey also revealed large-scale destruction of brood fishes and juveniles. A detailed survey conducted earlier in the Godavari also indicated a depletion in fish yield. The production potential in lower Ganga was estimated at 198.28 kg/ha/yr, whereas the actual fish yield was 30.03 kg/ha/yr and thus, only 15.15% of the potential is harvested. In the middle stretch the utilisation of the potential is marginally better than the lower stretch. However, in general, the potential is not fully utilised and there is enough scope for further improvement.

Unfortunately, the anadromous hilsa fishery has almost disappeared from the stretch of river Ganga above the Farakka barrage where it used to contribute a lucrative fishery upto 1,500 km up the sea mouth (up to Kanpur). Collapse of hilsa fisheries (Table 3) due to this river course modification has affected the lives of thousands of fishers along the riparian stretches in Uttar Pradesh and Bihar. Catadromous migrants like eels, freshwater prawn and *Pangasius* also seem to have been affected by such river course modifications.

Table 3. Average landings (in tons) of hilsa in middle stretch of river Ganga during pre-Farakka and post-Farakka periods. *(Jhingran, 1992)*

Centres	Pre-Farakka	Post-Farakka
Allahabad	19.30	1.04 (94.61)
Buxar	31.97	0.60 (98.12)
Bhagalpur	3.95	0.68 (83.05)

Figures in parentheses denote % decline

A significant development with regard to hilsa fisheries has been the attempts to practice its aquaranching for its revitalization. CIFRI has been successful in developing a hatchery management practice for hilsa to stock the depleted stretches of the river with the produced seed. Attempts in this direction have borne fruits and a sample consignment of hilsa seed has been stocked in the Ganga above Farakka barrage as well as in Ukai reservoir (Gujarat). This is the beginning of an ambitious plan to set up a hilsa hatchery at Farakka and to take up a regular stocking programme. But the practicability and success of this ranching programme is still a subject of controversy.

Recent tagging studies of hilsa by CIFRI have conclusively proved that the fish is able to negotiate the barrage during monsoons when the level of water on both sides is equal. Evidence of its breeding upstream have also been found. But its usefulness in rejuvenating the hilsa fishery is a matter of debate because of the required both way migration of fish in different stages of its life cycle.

2.1 *Factors influencing fish yield*

A recent study (1995-96) by CIFRI covering 43 centres on river Ganga from its origin to the sea mouth has revealed few starting facts of this aquatic environment. Environmental aberrations like sandification of river bed upto Patna (over 90% sand), blanketing the river bed productivity, and marked reduction in water volume due to increased sedimentation (caused due to deforestation in the catchment areas) and increased water abstraction, accompanied with river course modifications and irrational fishing practices appear to be key factors responsible for decline in fishery. Taking the river water as a whole, following the method of composite sampling across the river, pollution levels have been observed to be well within tolerance limits of fish and fish food organisms. This is quite in contrast to earlier observations of polluted stretches based on point sampling in and around effluxion points. The present ecological condition of Ganga water may also be a direct result of Ganga Action Plan (Phase I) launched in the year 1985.

Flood control measures, sedimentation and increased water abstraction also effect the flood regime and inundation of grounds needed for feeding and breeding. In the Ganga basin, 33.5 billion m^3 of water is presently held in storage reservoirs behind the weir and barrages apart from 18 major canal networks diverting the water to irrigate 7 m ha of agricultural land.

3. FISHERIES OF ESTUARIES AND LAGOONS

The various estuaries and lagoons in the country (Table 4) form an important component of fisheries resources of the country. The fisheries of estuaries of 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. The Hooghly-Matlah estuarine system, Chilka lagoon, Adyar and Mankanam estuaries, Pulicat lagoon, coastal belt of East Godavari, Vembanad lagoon and Mandovi estuary have also been identified to be excellent sources of naturally ocurring fish and prawn seed for exploitation for aquaculture purposes.

Table 4. Important Resources of Estuarine & Lagoon fisheries in India
(Updated from Jhingran, 1992)

Estuarine system	Estimated area (ha)	Production level (t)	Major fisheries
Hooghly-Matlah	802,900	20,000-40,000	Hilsa, *Harpodon, Trichiurus, Lates, prawns* etc.
Godavary estuary	18,000	c.5,000	Mullets, prawns
Mahanadi estuary	3,000	c.550	Mullets, bhetki, sciaenids, prawns
Narmada estuary	30,000	11148-13954	Prawn, Hilsa
Peninsular estuarine systems (Vasista, Vinatheyam, Adyar, Karuvoli, Ponniar, Vellar, Killai & Coleroon)	-	c.2,000	Mullets, prawns, clupieds, crabs
Chilka lagoon	62,000	c.4,000	Prawns, mullets, catfishes clupeids, perches, threadfins, sciaenids
Pulicat lake	36,900	760-1,370 (20.6-37.2 kg/ha)	Prawns, mullets, bhetki, pearlspot, chanos
Vembanad lake and Kerala backwaters	50,000	14,000-17,000 (fishes) 88,000 (live clams) 1,70,000 (dead shells)	Prawns, mullets, tilapia, bhetki
Wetlands of West Bengal a. Freshwater bheries b. Saline bheries	9,600 33,000	-	No data available on catch
Mangroves	1,36,200	-	No data available on catch

Mangroves are biologically sensitive ecosystems which play a vital role in breeding and nursery phases of many riverine and marine organisms of commercial value besides contributing through its own fishery. Nearly 85% of the Indian mangroves are restricted to Sunderbans in West Bengal and Bay Islands. The Indian share of Sunderbans covers an area of 4,264 km^2 of which 3,106 km^2 has already been lost due to reclamation, leaving only 1158 km^2. Several of its creeks are ideal sites for fish and prawn seed collection which sustains the aquaculture in the region, providing livelihood to thousands of fishers. The Sunderbans fishery comprises 18 species of prawn, 34 species of crabs and 120 species of fish besides 4 species of turtles.

River course modifications have played their part in estuarine fisheries also. A glaring example of the same is the over all decline in the salinity of Hooghly-Matlah estuary after commissioning of Farakka barrage (Sinha *et al.*, 1996) with gradient and marine zones being pushed down towards sea. This has brought about distinct change in the species composition of fishes caught, with freshwater species making their appearance in tidal zone and few neritic species disappearing. However, the stock of hilsa continues to be the prime fish of this estuary contributing 10-15% of the catch.

The likely impact of taming of river Narmada on its estuarine fishery is another such example. In a desk review (Anon, 1994) of likely impact of Narmada Sagar and Sardar Sarovar on the fisheries downstream, carried out by CIFRI for Narmada control Authority, it has been pointed out that as per report of the Narmada Water Dispute Tribunal (Anon, 1978) there would be 72.71% reduction in water availability downstream at 30 years of commencement of construction. It may not change the salinity regime during non-monsoon months but the annual event of dilution during monsoon months shall not be maintained. This shall effect the migratory fauna, particularly *Tenualosa ilisha* and *Macrobrachium rosenbergii*, and accordingly the fish yield of the downstream will decline. Stage attained at 45 years from the commencement of construction, when freshwater release from Sardar Sarovar shall cease, will be very critical as it shall be associated with steep hike in salinity and in absence of compromising factor (freshwater flow), the tidal ingress shall be more towards river side. It is most likely that the whole estuary shall undergo a transformation into a biotope characterised by hypersaline condition with salinity tongue further invading inland. Fishery shall drastically change. There shall be a total collapse of prevailing floodplains providing congenial breeding and feeding sites to fishes. Mangroves shall also be affected and the rich fishery harboured by them shall undergo a drastic change.

With the present height of 80.3 m attained by Sardar Sarovar dam, impact of impoundment are already discernible in the water downstream. They are in form of increased transparency, significant increase in dissolved oxygen, decline in the nutrient status and localized spurts in planktonic biomass. Presently, there seems to be no adverse impact due to present level of freshwater crunch in the downstream, but with further increase in dam height it is likely that consequences may be felt more prominently.

Recently conducted survey of Chilka lagoon in 1995-96 by CIFRI has indicated that regulated discharge in coming rivers, siltation and anthropogenic pressure have made marked negative impact on 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.

4. RESERVOIR FISHERIES

Large number of river valley projects have been built and commissioned in our country since independence as part of developmental activities. More such projects are on the arvil. Though created basically for irrigation or power, it forms the most important fishery resource in the country, at present, simply because of its magnitude. (Table 1).

Indian reservoirs are classified into large, medium and small (Table 5) based on their area. The fish yield from reservoirs in India is frustratingly low. At the present level of management, they yield, on an average about 30 kg/ha whereas, a production of 50-100 kg/ha can easily be realised from large and medium reservoirs. The small reservoirs have the potential to yield even more (100-300 kg/ha).

Table 5. Reservoir fishery resources of India *(After Sugunan, 1995 a)*

Category	Number	Area (ha)
Smal (< 1000 ha)	19,134	14,85,557
Medium (1000-5000 ha)	180	5,27,541
Large (> 5000 ha)	56	11,40,268
Total	**19,370**	**31,53,366**

The biological potential of reservoirs was not evaluated to any reliable level till 1970 when CIFRI took up an All India Coordinated Research Project on Ecology and Fisheries of Reservoirs and gave a new dimension to the sporadic work carried out until then. These studies brought about an improvement in technical capabilities and provided guidelines for managing the reservoir fisheries. The three pronged strategy comprising enlargement of mesh size, increase in fishing effort and stocking support has paid rich dividends (Table 6, Table 7). In large and medium reservoir 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.

Table 6. Increase in fish yield obtained in medium and large reservoirs as a result of scientific management technique *(Anon, 1997)*

Reservoirs	Yield (kg/ha)	
	Before	*After*
Yeldari (Maharashtra)	3	37
Girna (Maharashtra)	15	45
Gandhisagar (Madhya Pradesh)	1	44
Ukai (Gujarat)	30	110
Gobindsagar (Himachal Pradesh)	20	100
Pong (Himachal Pradesh)	8	64
Bhavanisagar (Tamil Nadu)	30	94
Sathanur (Tamil Nadu)	26	108

In contrast to the large multi-purpose reservoirs, the small irrigation reservoirs, created on small intermittent water courses, serve to trap the surface run off for its abstraction during seasonal irrigation demands. Experience has revealed that these water bodies offer immense potential for fish husbandry through extensive aquaculture. Considering the urgent need to enhance inland fish production in the country, emphasis need be laid on a management approach of such water bodies based on optimum stocking of suitable species and effective recapture (culture based capture fisheries). A good response to this management option is discernible in many of the small Indian reservoirs raising their yield to 70-275 kg/ha/yr (Table 7).

Table 7. Increase in fish yield obtained in small reservoirs after adopting scientific management technique *(Anon, 1997)*

Reservoirs	Yield (kg/ha) Before	After
Chulliar (Kerala)	35	275
Meenkara (Kerala)	10	105
Markonhalli (Karnataka)	5	70
Gulariya (U.P.)	33	170
Bachhra (U.P.)	NA	150
Baghla (U.P.)	NA	110
Thirumoorthy (Tamil Nadu)	70	200
Aliyar (Tamil Nadu)	27	215

Reservoir fisheries development is a must for a quantum jump in inland fish production in future as well as improving the socio-economic condition of 0.49 million fishers of the country. Sugunan (1995a) has compiled the present level of fish production and potential of different categories of reservoirs in the country (Table 8). It is evident therefrom that this resource alone has the potential to yield 0.24 million ton of fish, with modest targets of average production, if managed on scientific lines.

Table 8. Present yield and potential of production from different categories of reservoirs in India *(After Sugunan, 1995 a)*

Category	Total available area (ha)	Present		Potential	
		Avg. Production (kg/ha)	*Fish production (t)*	*Avg. Production (kg/ha)*	*Fish production (t)*
Small	1485557	49.90	74129	100	148556
Medium	527541	12.30	6488	75	39565
Large	1140268	11.43	13033	50	57013
Total	3153366	29.7	93650	77.7	245134

5. FISHERIES OF FLOODPLAIN WETLANDS

India has extensive riverine wetlands in the form of oxbow lakes (locally called *mauns, chaurs, beels, jheels)* especially in the states of Assam, Bihar, eastern U.P. and West Bengal. State-wise areas of wetlands associated with the floodplains of the riverine systems of Ganga and Brahmaputra are depicted in Table 9.

Table 9. Distribution of floodplain wetland in India *(Sugunan, 1995 b)*

State	River basins	Local names	Area (ha)
Arunachal Pradesh	Kameng, Subansiri, Dibang, Lohit, Dihing & Tira	*beel*	2,500
Assam	Brahmaputra & Barak	*beel*	1,00,000
Bihar	Gandak & Kosi	*mauns, chaurs*	40,000
Manipur	Iral, Imphal, Thoubal	*pat*	16,500
Meghalaya	Someshwari & Jinjiram	*beel*	213
Tripura	Gumti	*beel*	500
West Bengal	Ganga & Ichamati, Hooghly & Matlah	*beel, bheries*	42,500 40,000
Total			**2,42,213**

Floodplain wetlands can be broadly divided into two categories. Those which have retained their connection with the parent river through narrow channels atleast during monsoon are called open *beels*, while the ones which are cut off permanently from the parent rivers are called closed *beels*. Besides occuppying a prominent position among the culture based capture fisheries of India, by way of their magnitude as well as production potential, the open type of floodplain wetlands have vital bearing on the recruitment of population in the riverine ecosystem and provide excellent nursery grounds for several fish species and a host of other fauna and flora.

Nutrient-wise these bodies are extremely rich as reflected by rich organic carbon and high levels of available nitrogen and phosphorous in their soil. But these nutrients are usually locked up in the form of large aquatic plants, especially water hyacinth, and thus unable to contribute to fish productivity. The ecologically degraded condition of floodplain wetlands and lack of proper management measures have resulted in their swampification and rather paltry fish yield (100-300 kg/ha/yr), against a production potential of 1000-1800 kg/ha/yr through scientific management, leaving a significantly wide gap between the actual yield and their harvest potential.

In most of the *beels*, marginal areas are utilised for agricultural purposes. These water bodies are subjected to a variety of environmental stresses especially from pesticides and other agricultural run off, municipal wastes and siltation. The siltation adversely effects the reproduction of fish by accumulation of sediments in the marginal areas of the beels which form the breeding grounds for the fish. Adverse breeding conditions in open beels also adverselyeffects the concerned river's fishery as they are the ideal breeding grounds for riverine fish populations.

The floodplain wetlands, by virtue of their productive potential as well as magnitude, constitute one of the frontline areas, capable of contributing substantially to country's fish production. The management strategy for this vital sector should be based on a category-wise approach. Optimum exploitation of floodplains with riverine connection should revolve round the concept of keeping the deeper central portion exclusively for capture fisheries and utilization of margins and pockets for culture fisheries. Capture fisheries would entail monitoring of recruitment and subsequent growth of natural population. In closed wetlands stocking is the mainstay of management, whereas in weed choked lakes, clearance of weeds and a detritivore-oriented stocking schedule would enhance the yield rate considerably (Yadava, 1987).These lakes also provide ideal conditions for pen culture operations. CIFRI has evolved and demonstrated technologies for production of 3-4 t/ha/6 months of major carps and 1,000-1,300 kg/ha/3 months of freshwater prawn through pen culture in such water bodies.

6. MAJOR CONSTRAINTS IN DEVELOPMENT OF INLAND FISHERIES

A number of diverse and complex problems confront the inland fishery managers. The constraints can be broadly grouped under four major heads *viz.,* biological, environmental, socio-economic and legal.

6.1. Biological constraints

The extraction of fish riches from the rivers, based on the principle of maximum sustained yield, has not been possible in the Indian context. Fishing has been guided by the principles of economic profit rather than biological principles. The intensity of fishing, nature of exploitation and species orientation in the characteristic artisanal fisheries of Indian rivers are governed by *(1) seasonality of riverine fishing activity; (2) unstable catch composition; (3) conflicting multiple use of river water; (4) cultural stresses leading to nutrient loading; (5) lack of understanding of the fluvial system and infirm data base; (6) fragmentary and outmoded conservation measures lacking enforcement machinery; (7) inadequacyy of infrastructure and supporting services; (8) defective marketing and distribution systems ; (9) demand directed by availability; affordability, and palatability, and (10) socio-economic and socio-cultural determinants* (Jhingran, 1984).

Infirm database of inland fisheries resources has been another serious constraint plaguing the development process. Even market intelligence statistics suffered from various drawbacks due to disposal of appreciable quantity of fish that passed directly from the primary producers to consumers. Through a Central Sector Scheme on Inland Fisheries Statistics, launched during Seventh Plan by Union Ministry of Agriculture, CIFRI has been able to evolve a methodology for data collection on inland fisheries. It is expected that in years to come the database in this field would also be firm.

Absence of suitable fish yield models for the multi-species fisheries of our open waters is a major biological constraint for formulating a successful management strategy. Developing such a model, keeping an eye on hydrology and fish stocks, accompanied with observance of closed season and setting up of fish sanctuaries will definitely prove its efficacy in fostering recovery of impaired open water fishery of our country.

6.2 *Environmental constraints*

Notwithstanding the rather discouraging picture the riverine sector portrays, conservation and management of the biological resources of the rivers assume greater significance in the Indian context. Some definite steps have been taken in this direction during the last few years, among which the Ganga Action Plan (GAP) is worth mentioning. GAP is a massive national project launched in the year 1985 with a view to halting and reversing the process of environmental degradation in India's prime river, the Ganga. The main objectives were to improve the water quality of the river Ganga and its tributaries to acceptable standards and to oversee the implementation of a long-term programme for undertaking suitable measures for restoring the water quality of the river Ganga. Till 1991, 368 mld of domestic sewage has been diverted through the efforts of GAP. Water quality of river Ganga has shown definite improvement at the stations that completed pollution abatement schemes (Table 10).

But the problem of sedimentation and water abstraction, two main factors adversely effecting fisheries of rivers and floodplain wetlands have not been given due attention so far in the fishery perspective.

Table 10 : Ecological changes in the river Ganga at Kanpur due to diversion of sewage effluents *(After Jhingran 1992)*

Zone	Before diversion				After diversion			
	1	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Energy fixed by producers (cal/m^2/day)	4152	2968	3913	222	4352	3212	5309	5256
Photosynthetic efficiency (%)	0.355	0.254	0.330	0.019	0.372	0.272	0.454	4.50
Fish production potential (kg/ha/yr)	144	103	136	8	151	111	184	182

6.3 *Socio-economic constraints*

The riverine fishers constitute a section of economically weak, tradition-bound society. Most of them live at subsistence level or below poverty line. The environmental degradations and the resultant decline in fish populations have deprived them of a steady catch. The problems are further compounded by the competition among fishers due to increase in their population.

Socio-economic milieu under which the inland fishermen operate is not conducive enough to attract credit and infrastructure support for required modern crafts and gear from traditional banking and financial Institutions. A sector's ability to attract finance and specially loanable funds depends largely on evaluation of risk elements by prospective funding agencies. The migratory character, seasonality of fishing activity and unstable catch composition of capture fishery does adversely effect investment appraisal and assessment of funding possibilities because of various reasons. There is an inescapable need to evolve some distinct criteria for financing the capture and culture based capture fisheries of inland open waters where the input-output relations are relatively less precise. This would need evolving a new set of criteria for the creditworthiness and repaying capacity of such fishers.

6.4 Legal constraints

Fisheries legislation in the country is, by and large, guided by the Indian Fisheries Act 1897, which stipulates the closed season, defines the irrational fishing practices to be prohibited and limits the minimum size of fishes and the mesh sizes to be employed. Prepared basically on empirical knowledge available at that time, this act can be termed, at best, as a reference material for law makers. In India, fisheries being a state subject, it is the prerogative of the state governments to frame rules on conservation and management of riverine fisheries resources. Many states in India like West Bengal (till recently) and the states in North East have no fisheries legislation. Rajasthan enacted fisheries legislation in 1984. Some states like Uttar Pradesh, Andhra Pradesh, Madhya Pradesh and Kerala have some rules for regulation of fisheries but they have played a subordinate role owing to enforcement problems. More efforts and emphasis are needed for strict enforcement of the legal provisions.

The complexity of factors involved in regulation of fisheries in India stems largely from the common property nature of resources, difficulties in enforcing a limited access concept, divergent auctioning and leasing policies followed by different states and the multiplicity of agencies that control the water resources and regulate the environmental parameters. Considering the urgent need for a comprehensive legislation, a legal sub committee has been constituted under the Ganga Action Plan and a draft legislation prepared.

7. CONCLUSION

The development of inland fisheries in India is a must to obtain the required quantity of fish but it is at a critical point in its development. Degradation and loss of fisheries habitats are increasing and a national perspective is essential for the sustainable development and exploitation of our inland fisheries resources. Ecosystems are threatened by fast changing coastal configurations, wetlands loss, environmental perturbations and destructive fishing practices. These resources in developing countries are specially vulnerable because the national priorities for their development are often in conflict with the norms of conservation. Development strategies need to have a holistic approach suiting to all aspects of the resource. In the integrated development of multipurpose use systems, it should be mandatory to develop all living resources together.

Thus, a system which links the management of fisheries, forestry and agriculture to agro-industrial and hydro-electric units will facilitate optimization of production from the river basin. Sound environmental protection norms, keeping fisheries in perspective, accompanied with due priority for proper utilisation of available inland fisheries resources is a must for sustainable development. CIFRI would continue to provide the required research back up to combine the environmental norms and sustainable development of inland fisheries resources in order to meet the requirement of the country. It is essential that all concerned (scientists, planners and development agencies) work together for utilisation of this most important resource bestowed to us by nature.

8. REFERENCES

Anon., 1978. Report of Narmada Water Dispute Tribunal, *Vol. IV. Government of India.*

Anon., 1994. Studies on Fish Conservation in Narmada Sagar, Sardar Sarovar and its Downstream. A Desk Review sponsored by Narmada Control Authority. *Central Inland Capture Fisheries Research Institute, Barrackpore.*

Anon., 1997. Vision 2020. Perspective Plan of CIFRI (1995-2020). *Central Inland Capture Fisheries Research Institute, Barrackpore.*

Jhingran, A.G., 1984. Development of riverine fisheries resources - some policy issues. **In** Strategy for development of inland fishery resources in India - Key issues in production and marketting (*Eds.* U.K. Srivastava and S. Vathsala), *Concept Publishing Company, New Delhi.*

Jhingran, A.G., 1992. Inland fisheries management in India - Development potential and constraints. **In** FAO Fisheries Report No. 458 suppl. (*Ed.* E.A. Balayut), FAO, Rome.

Sinha, M., M.K. Mukhopadhyay, P.M. Mitra, M.M. Bagchi, H.C. Karmakar, 1996. Impact of Farakka barrage on the hydrology and fishery of Hooghly estuary. *Estuaries,* **19**(3).

Sugunan, V.V., 1995 a. Reservoir Fisheries of India. *FAO Fisheries Technical Paper No. 345,* FAO, Rome.

Sugunan, V.V., 1995 b. Floodplain wetlands - a fisheries perspective. **In** Conservation and sustainable use of Floodplain wetlands (*Ed.* J.R. Howes), Asian Wetland Bureau, Kuala Lumpur, *AWB Publication, No. 113.*

Yadava, Y.S., 1987. Studies on the limnology and productivity of an oxbow lake in Dhubri District of Assam (India). *Unpublished Ph.D. Thesis, Gauhati University, Assam.*

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Estimation of Inland Fisheries Resources base by conventional and Remote sensing Techniques.

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Introduction

Inland fisheries resources are vast and diverse in nature and normally located throughout the cross section of the land surface. These resources mainly comprise ponds, lakes, reservoirs, rivers, estuaries and lagoons, etc. Classification of these resources can broadly be done under two major heads namely capture and culture fisheries. Inventorying and monitoring of these resources are essential as information on their area coverage, spread and fish production is needed for planning and development. The planning process has not yielded desired results particularly in third world countries due to lack of information on this front. Unless resources are extensively surveyed, it is difficult to formulate appropriate policy for their optimum utilization. Any prioritization along with targeted levels of achievements can be suitably and precisely formulated if reliability, timely availability and comparability of data base is ensured. Moreover, reliability and comparability of data are also essential as they are the basis for measuring the success of various development projects and programmes being implemented in various states for the benefit of the fishing communities.

Methods of Assessment :-

Inland capture and culture fisheries is a widely dispersed activity in most of the countries. Hence monitoring and enumeration of these resources need large human and financial resources in order to collect reliable data. Hence, the total enumeration/census is a very costly and complicated operation. The sample surveys based on sound statistical methods with larger coverage through point-source measurements may be the way out of this impass in order to develop comprehensive and reliable database useful for planners to formulate appropriate strategy for development of inland fisheries. Other methods which may be employed on a large scale to estimate the surface water spread, their shape and distribution may be remote sensing techniques. In the succeeding text we will discuss these two methods in details for employing those for assessment of these resources.

Convention Methods based on Point Source Measurement : -

As discussed earlier, sample survey techniques are mostly used to gather information on inland fisheries resources and productivity. For accurate and reliable assessment of production, it is essential that some sample survey methods are designed with high degree of precision. But before we discuss these methods which are based on the exploitation and marketing intelligence information, we would look into all the typical resource categories and suggest appropriate classification so that suitable sampling procedure may be formulated for each class.

Classification of water bodies : -

Inland fisheries resources cover diverse nature of water bodies which can be stated below:

Fresh water resources.

1. Aquaculture ponds and tanks
2. Large irrigation tanks
3. Ox-bow lakes/ cut off meanders
4. Reservoirs
5. Swamps
6. Playas
7. Waterlogged
8. Quarries
9. Ash ponds
10. Excavations
11. Rivers and canals

Saline water

1. Lagoons
2. Estuaries
3. Creek
4. Mangrove
5. salt pans
6. Marsh
7. Other Impoundments (such as berries of West Bengal)

So many of the above water bodies do not contribute significantly and, therefore, be left out from the perview of the classification for the purpose of fish production assessment.

Selection of sample

For assessment purposes, the resources may, thus, be classified into the following broad categories.

Group - I (Water bodies up to 10 ha. of water spread area)

1. Aquaculture ponds and tanks
2. Brackishwater impoundments
3. Waterlogged areas

Group - II

1. Large irrigation tanks
2. Reservoirs and check dams.
3. Lakes

Group - III

1. Rivers
2. Canals
3. Estuaries
4. Lagoons

5. Back waters

Sampling Design :

The whole state is divided into three nearly homogeneous groupscalled strata (each stratum comprising a number of districts) on the basis of certain characteristics such as climate, rainfall, soil quality etc. Strata should be formed in such a way that geographical contiguity of districts within the stratum is maintained. From each stratum a sample of 30% districts may be selected at random for the sample survey. Further sampling within each selected district is discussed for each group separately in the succeeding paragraphs.

Sampling procedure for Group I water bodies:

Sampling frame should be prepared for each selected district by making a list of villages. This can be achieved by using the census records. Villages having waterbodies of this group may be highlighted and clusters of five nearby villages may be formed from among the pond bearing villages. From these clusters a sample of nine clusters be selected by random sampling for assessment of water spread area. A further sampling of five ponds in each cluster is recommended for estimation of fish production.

The whole selection procedure may be encompassed under stratified three stage sampling where districts, clusters and ponds are first, second and third stage units of selection respectively.

Sampling procedure for Group II water bodies:

As far as area statistics is concerned, a total inventory of resource under each stratum for group-II should be prepared and a sub group of small, medium and large units as defined elsewhere in the text be made. 25 to 30% sample water bodies at random from each subgroup of each stratum should be selected for collection of data on fish catch. Catch data from selected waterbodies is recorded in the following manner.

Investigations have shown that two types of exploitation pattern is adopted in these waterbodies. They are:

(1) Waterbodies which are harvested for a short interval extending from a fortnight to about a month during the year. These waterbodies are mostly small reserviors and lakes which fall under the perview of state departments and exploitation is affected either by auctioning them to private contractors under certain terms and conditions or exploited departmentally by engaging contract labour. Hence, the bulk of harvest is a one time operation which continues for a fortnight to about a month. Data for such waterbodies may be collected on total enumeration basis.

(2) Water bodies which are exploited round the year by fishermen cooperatives or individual fisherman on the basis of licenses, free fishing, royalty or any other such mode. In such situations 4 to 6 days may be selected for on the spot observation of catch and production may be assessed as per the formula given under estimation procedure.

In brief this procedure can be described as stratified two stage sampling where selection of waterbody is the first stage and sample days is second stage of selection.

Sampling Procedure for Group III water bodies:

Sampling frame for this group is prepared by enlisting district-wise all the fishing villages/landing centres in each of the strata. 25 to 30% of these units are selected by random sampling from amongst the selected districts of each stratum at the second stage. For each selected unit 4 to 6 sampling days within a month are further selected at the third stage for collection of catch data.

Hence, the above procedure may be termed as stratified three stage sampling where districts, villages and days of sampling form the first, second and the third stage of sampling respectively. The observation of catch is made by the following procedure.

Each selected centre/fishing village is physically observed on two consecutive days in each of the first and second fortnight during the month. On a selected day of sampling at a centre, data is collected during 1200 to 1800 hrs. and on second day from 0600 to 1200 hrs. Data on night landings, if any, in between the consecutive days are collected by inquiry on the second day. On the selected day of observation the investigator should collect information on the total number of fishing units operated on that day, and the total catch landed from the observed units and species composition. He should also ascertain the number of fishing holidays observed during the last month. However, the sampling days in a month may be increased depending on the available resources and the units potential in fish landings.

(The diagrammatic representation of each stage of sampling for the above three groups is given in figure 1.)

Limitations of conventional method

The conventional method tend to be slow, arduous and suffers from the hazards of subjectivity. Moreover, in the conventional approach, there is no satisfactory solution for resource mapping in inaccessible or poorly accessible areas. Further, these methods are inaccurate, expensive and time consuming.

Remote Sensing Method

These methods offer the advantage of reliability, speed and cost effectiveness over the conventional procedure. As a consequence, remote sensing methods are advancing very rapidly and the technology is increasingly used as an operational modern procedure rather than an alternative experimental tool. The advantage of RS is providing synoptic view and repetitive coverage of large areas to enable better understanding of the interrelationships among the different ... and their land uses, physiographic units and environmental functions.

Basic concepts

Remote sensing literally means perception from a distance-teledetection. Broadly, it is an acquisition of data about specific objects or phenomena by an information gathering device not in intimate contact with the subject under investigation. In a stricter sense, remote sensing connotes a technology of acquisition and interpretation of data about the terrestrial and atmospheric objects and processes in the form of photographs, imagery, video tapes or other forms of recordings in a beyond the range of human vision and photographic sensitivity from a vantage point in air or space to derive information which can be quantified.

Aerial photography is the earliest form of remote sensing but remote sensing commonly implies satellite remote sensing for detection of energy emitted or reflected by the objects on earth's surface.

It invloves data reception, data transformation, processing, analysis, interpretation and generation of information in the form of text, tabular statement, and/or map. The components of the system are (1) radiation source (2) transmitting medium ,(3) target , and (4) a sensor

The reflectance and emittance of an object in different wave length bands followed a pattern, called as spectral signature. The logic of RS, which is founded in inference draws from the spectral signature. Inference is used to know 'what' ,'where' and 'how much'.

Resolution, which is a measure of the ability of an optical system to distinguish between signals that are spatially near or spectrally similar controls soil differentiation for mapping of soil at different categoric levels and monitoring of degradations, land uses and other dynamic aspects. Four types of resolutions namely, spectral, spatial, radiometric and temporal are considered in order to interprets remote sensing data.

Spectral resolution : - It refers to the locations of the spectral bands in the electro magnetic spectrum. Normally, the bands are selected to maximise the contrast between the objects of interest and to minimise the atmosphere effect. Spectral resolution is the ability of sensors to measure the spectral properties of the smallest targets. The special resolutions of commonly available RS data are: LISS-I-72.5 m , LISS-I1-36.2 m, SPRT-10 m.

Radiometre resolution refers to number of digital levels used to express the data collected by the sensors. Temporal resolution of a sensor system refers to periodicity with which a given sensor collects the data of a specific area. Multidate data helps in extracting the information about the temporal variations of the object which is changing with time. Temporal resolution of IRS and land set TM are 22 and 16 days respectively.

RS Data Interpretation :- RS Data Interpretation for surface waterbodies can be defined as detecting , delineating and identifying water bodies at the chosen categoric levels (controlled by the scale of mapping as well as by spatial and spectral resolutions of RS data) based on their spectral signatures gained as a result of ground truth. Two set of temporal data namely pre-monsoon and post-monsoon may be preferred for analysis to detect the changes in the surface water area over an year.

Ground Data Collection :- Ground truth is an integral part of the RS. These observations should be distinguished throughout the survey area, covering all types of waterbodies. Success of ground truth collection in the context of image interpretation of necessity depends on the accurate location of the observation site. One method to achieve this accuracy is to pin-prick the imagery at the site location using detectable ground reference points. The pin-prick is circled on the back of the imagery and numbered corresponding to the number on the field form. Period of ground truth collection should preferebly match the period of satellite pass within reasonable variations.

Visual Interpretation :- The availability of remotely sensed data from new sensors with better resolution in different wavelength regions and a variety of data products have improved their uses for the purpose of surface water and catchment area mapping by manual methods. Single band black and white imagery, standard false colour composites or enhanced colour composites in the form of paper prints or transparencies are used in visual interpretation. Visual image interpretation involves an understanding of spectral nature of the objects (water bodies, vegetation) and the basic large characteristic namely greytone/colour, texture, pattern, shape, size, shadow, location and association. Other factors influencing image interpretability are spatial resolution, scale and the date of imagery.

The basic principles of Visual interpretation are :-

1. The RS imagery is a pictorial representation of the pattern of landscapes.
2. The pattern is composed of elements which reflect physical, biological and cultural components of the landscapes.
3. Similar conditions in similar environments reflect similar pattern and unlike conditions reflect unlike patterns.
4. The type and amount of information which can be extracted is proportional to the knowledge (refrence level), experience, skill, interest and local knowledge of the interpreter, the methods used and the awareness of the limitations.

Visual interpretation allows human logic and intuition in translating the image into meaningful information. Techniques, such as stratification based on variations in geology, landform and elevation, and natural vegetation corresponding to the parent material, topography and biotic factors of pedogenesis, improve the interpretability to a great extent. Normally visual interpretation is performed either with single band black and white imagery or false colour composite. Interpretation of enhanced image provides better information than is possible from raw data image.

The visual interpretation generally proceeds from general considerations to specific details and from known to unknown classes. Major land forms are first delineated using detectable patterns on the imagery. It may not be always possible to correlate the pattern per se with landform but by reference to corresponding topographical map and by employing the principle of conjugate evidence it would be possible to identify the patterns as ' probably, possibly or certainly' a specific landform.

Further details in each of the patterns/landforms are abstracted using the image elements collectively. In practice, the patterns and specific features are usually considered together. The understanding of cause-effect relationship in regard to size, shape, colour tone, texture, shadow, site, association and resolution is fundamental to the success of interpretation.

Image interpretation is an integrated process and therefore ground truth and ancillary data in the form of available maps, reports and other records are important for successful surface water mapping. Guided by such data and the relationship between the water category classes and image manifestations, established in the field, the different image interpretation units are translated into waterbody classes. The reference level knowledge about the area and skill of the interpreter play a crucial role in achieving reliable and consistent results.

Summarising the discussion on manual methods of image interpretation, the reliability and accuracy of water cover mapping are governed by the following factors :

- Quality of imagery
- Season of the imagery
- Pedologic and edaphologic reference level of the interpreter
- Knowledge about the resource conditions of the project area
- Distribution and number of ground observation sites
- Availability and reliability of collateral data
- Methods and techniques used for interpretation
- Quality of interpretation aids

Image Enhancement : - Image enhancement and shadow suppression are particularly important for mapping in hilly and rolling landscapes using visual interpretation techniques. Among the various enhancement techniques, band ratioing, principal component analysis, greenness index and hue-saturation intensity transformation are generally found useful. Hybrid colour composites of band ratios have been widely used to remove the topographic effects of shadowing. Principles components (PC) transformation helps to negate the data redundancy of compressing information content of the original multi-band data into fewer new channels.

Digital Classification :- Digital image classification involves grouping of a number of individual pixels (picture elements) into specified soil classes. The classification is based on the assignment of an unknown pixel to the category of the known pixel of similar spectral characteristics. The underlying priciple is that the various WB calsses/ categories exhibit different spectral patterns which can be expressed in a quantative-multivariate fashion. It therefore follows : (1) identification of spectral pattern for each WB class at the chosen categoric abstraction level, and (2) assignment of the pixels to the WB classes on the basis of their spectral characteristics with reference to the known spectral pattern developed in the first step by employing appropriate classification decision rules. The following are the major decision rules used in digital classification.

1. Minimum distance to the means - The unknown pixel with a feature vector f is assigned to that class whose mean vector is close to f. Computationally this is a relatively simple classifier with limited accuracy, especially when the variance of features are large.

2. Paralleipiped - It is based on calculating minimum and maximum brightness values in each spectral band. A paralleipiped is thus a multidimensional rectangle defined by the upper and lower spectral limits of known pixels. The unknown pixel is assigned to the class whose paralleipiped corresponds with the unknown pixel. Although fast, this decision rule does not employ rigorous statistical decision criteria.

3. Maximum Likelyhood - It is most commonly used algorithm in supervised classification. With this approach, each WB is evaluated statistically for its multivariate probability density function. The probabilities are calculated from the mean, variance and covariance between data channels for each class and the brightness value of each pixel in question. the pixel is assigned to the WB class for which it shows highest probability. The pixel is left unclassified if the probability values are below the threshold. This classifier is more rigorous and requires more processing time, but generally yields more accurate results.

Methodology:

The digital data from satellite of a selected area is collected for pre-monsoon and post-monsoon periods on 1:50,000 scale. The shape and size of water bodies are estimated through computer aided packages. The survey of India (SOI) topographical maps on 1:50,000 scale are used as base maps. Ground truthing of 5% of the waterbodies is taken up and final maps are prepared to map all the water cover categories of that area. Classification and other aspects of the survey remains the same as in conventional method described above.

Assessment of openwater fishery dynamics through modelling approach for sustainable yield

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The aim of open water fisheries management is to adopt measures which will best serve long term social and economic interest. The planning of the activities should take into account the condition of the fish stocks and the effects on these stocks of the action being contemplated. In this regard the decision makers need scientific advice about the state of fish stock.

In studying the state of the fish stocks and the effect of fishery on them, the fishery biologists should carry out analysis in quantitative terms. To do this we 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. Such models may be used to represent both quantities of interest (abundance of population, size of individual fish), and the relation between these quantities.

Two groups of fish stock assessment models are used for description of fish stock : holistic models and analytical models. The simple holistic models use fewer population parameters than the analytical models. They consider a fish stock as homogenous biomass and do not take into account , for example, length or age structure of the stock. 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 input data. On the other hand, as a compensation, they are believed to give more reliable predictions.

The type of model to be used depends on the quality and quantity of input data. If data are available for advanced analytical model then such a model should be used, while the simple models should be reserved for situation where complete set of input data for analytical approach is not available, but where the available data exceed the demand of the simple models. As an alternative to using simple models in this case, the lacking input data can be replaced by assumptions or qualified guesswork. Often, the lacking parameter for a particular stock can be replaced by known parameters from another similar stock.

Analytical models

A basic feature of analytical models is that they require the age composition of catches to be known. For example, the number of one year old fish caught, the number of two year old fish caught, etc. may form the input data.

The basic ideas behind the analytical models may be expressed as follows:

(i) If there are "too few old fish" the stock is overfished and the fishing pressure should be reduced.

(ii) If there are "very many old fish" the stock is underfished and more fish should be caught in order to maximise the yield.

The analytical models are "age-structured models" working with concepts such as mortality rates and individual body growth rate.

The data are collected on length frequency of the species. The von Bertalanffy growth equation is fitted. Different steps involved in fitting analytical models are

(a) Collection of length-frequency data or age structured data.
(b) Estimation of growth parameters
(c) Estimation of mortality parameters
(d) Estimation of maximum sustainable yield

(a) Collection of length-frequency data or age structured data

Data are collected from landing centres/fishing villages on gearwise, sexwise and specieswise catch and length-frequency. The sampling procedure adopted should be random and it is preferable to collect data on commercially important fishes.

(b) Estimation of growth parameters

The study of growth means basically the determination of the body size as a function of age. Therefore all stock assessment methods work essentially on age composition data. In temperate waters such data can usually be obtained through the counting of year rings on hard parts such as scales and otoliths. Such rings are formed due to strong fluctuations in environmental conditions from summer to winter and vice versa.

In the tropical areas such drastic changes do not occur and it is therefore very difficult, if not impossible to use this kind of seasonal rings for age determination.

However, several numerical methods have been developed which allow the conversion of length frequency data into age composition. Although these methods do not require the reading of rings on hard parts, the final interpretation of the results become much more reliable if at least some direct readings are available. The best compromise for stock assessment of tropical species is therefore an analysis of large number of age readings on the basis of rings.

The widely used von Betalanffy growth equation is described as

$$L(t) = L_{\infty} (1-\exp(-k(t-t_0))),$$

where $L(t)$ is the length at age t,

L_{∞} is asymptotic length (mean length of very oldfish),

k is the curvature parameter and t_0 is the initial condition parameter.

The parameter of the equation is estimated from length-frequency data. The mean lengths of age groups are determined by Bhattacharya's method. The mean length are used to estimate the parameters of growth equation by Gulland & Holt plot.

(c) Estimation of mortality parameters

The growth is the positive aspect in the dynamics of a fish stock, where as mortality /death is the negative counterpart. The growth is described by a model and a number of parameters. Similarly the death process is also described. The key parameters used when describing death are called mortality rates.

As it is difficult to get age composition data, the mortality coefficients are estimated by linearised catch curve based on length composition data. Here we use past data and estimate parameter values under certain assumptions.

For predicting the development of fishery on future under different conditions such as fishing pressure and mesh size of the nets the fishery scientist may use length based Thompson and Bell biomass and yield prediction model. The analysis takes the fishing mortalities by length groups as input and calculates the number caught as well as the stock numbers.

(d) Estimation of maximum sustainable yield

There are two basic models for estimating maximum sustainable yield(MSY)s from fish stocks, namely the "yield per recruit " model of Beverton and Holt and its variant .

Holistic model

These models are used when data are limited. One of these models is surplus production model. The surplus production methods use catch per unit effort as input. The data usually represent a time series of years and usually stem from sampling of commercial fishery.The models are based on the assumption that the biomass is proportional to the catch per unit effort as shown if Fig.1.

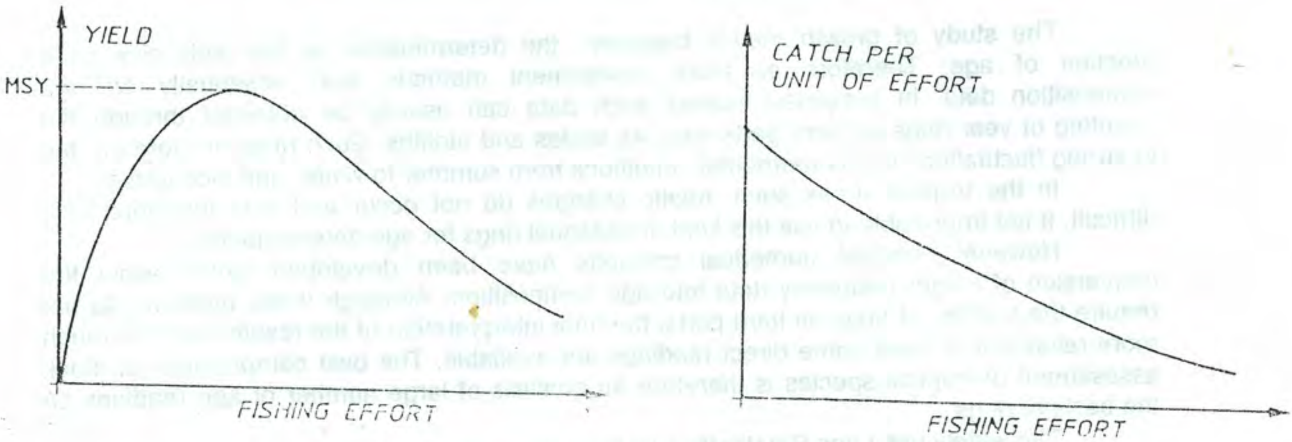

Fig.1 :- Surplus production model

Estimation of maximum sustainable is done by the "surplus production" model of Schaefer and its variants.

The Schaefer model - in its simplest version at least - is quite easy to handle. The step for estimating MSY by means of this model are:-

(i) Catch (Y) and effort (f) data are tabulated and catch per unit effort is computed.

(ii) Catch-per -unit effort values against this corresponding values of effort are plotted. A linear regression line is fitted to the data and intercept (a) and the regression coefficient (b) are determined.

$Y/f = a + bf$

(iii) MSY is estimated as $a^2 /(-4b)$,

optimum effort f(msy) as $a/(-2b)$ and

yield (Y) for a given effort (f) as $af - bf^2$

An alternative model was introduced by Fox. It gives a straight line when the logarithm of (Y/f) are plotted on effort.

Here , the model is expressed as

$Ln(Y(i)/f(i)) = c + d\, f(i)$

optimum effort is estimated as $f(msy) = -1/d$ and

MSY is estimated as $MSY= -(1/d)exp(c-1)$

Suggested Readings

1. Sparre,P., Urkin, E. and Venema,S.C.,1989.Introduction to tropical fish stock assessment - Part I-Manual. FAO Fisheries Technical Paper 306/1.
2. Pauly,D., 1983.Some simple methods for the assessment of tropical fish stocks. FAO Fisheries Technical Paper No.234.
3. Gulland,J.A.,1977.Fish Stock Assessment-A Manual of Basic Methods,Vol-I.John Wiley and Sons, New York.

Concepts and Methodologies for Fishery Management in Reservoir Ecosystems

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Introduction :

Though the vast water resources of the reservoirs offer immense scope for achieving high fish production, their potentiality is not being harnessed properly. As these reservoirs are mainly meant for hydel power generation, flood control, irrigation, supply of drinking water, etc., there is not much scope for altering the existing ecological conditions due to the sharp fluctuation in the water level brought about by the constant inflow and outflow of the water. However, their natural biogenic production potentiality can be profitably exploited for enhancing the fish yield through the adoption of scientific management techniques of judicious stocking and harvesting. However, a vast majority of them remain either undeveloped or underdeveloped due to the inadequate understanding of their production dynamics and consequent low level of adoption of the scientific management strategies. Hence, the Reservoir Division of the Central Inland Capture Fisheries Research Institute undertook detailed investigations to evaluate the production potentiality of some of the small reservoirs. The studies have brought to light the reasons for the low fish yield being obtained as against the great production potentiality in these small reservoirs in Peninsular India. The ecology-based investigations carried out in Aliyar reservoir (av. area : 324 ha) and Thirumoorthy reservoir (av. area : 234 ha) in Tamil Nadu have helped to formulate certain valuable guidelines that would go a long way in bridging the wide gap between the great production potentiality and the actual yield being obtained from these reservoirs. The studies on the ecology-based scientific management in these reservoirs will help in embarking on fishery development in similar reservoirs.

I. Importance of ecological investigations :

The detailed investigations on various ecological parameters are the most important pre-requisites before undertaking any massive fishery development in the reservoirs. The formation of the reservoirs across the rivers bring about very conspicuous changes in the ecological conditions in the newly formed lotic environment which is influenced by the morphological, edaphic and climatological features. The production potentiality of the reservoir is determined by the inherent quality of water and soil, inflow of allochthonous nutrients, the quantity of the constant inflow and outflow of water, etc. Hence, it of paramount importance to have a thorough understanding of all the ecological conditions including the physico-chemical parameters of water and soil, the biotic communities like plankton, periphyton, bottom macrofauna, primary productivity, etc. before planning the course of actions for enhancing the fish yield from the reservoirs (Selvaraj *et al.*, 1997).

II. Importance of stocking :

Existing fish fauna : Detailed investigations have to be undertaken to assess the existing fish fauna in the reservoir. The studies would help to find out the existence of the unwanted as well as the commercially important species of fishes and the extent of their contribution to the yield of the reservoir. Then, it can be decided about the introduction of the fast growing carps for enhancing the fish yield. It is also important to investigate the maturation and breeding behaviour of the different fast growing carps which are introduced into the reservoir. There were instances where the carps introduced failed to attain proper maturation in their establishing in the reservoir (Joseph *et al.*, 1990 ; Selvaraj *et al.*, 1990 a). Hence the fishery has to be sustained through regular stocking of advanced fingerlings of the fast growing major carps (Selvaraj *et al.*, 1990 b).

Size of the fingerlings to be stocked : It is often noticed that enough care is not taken to decide the size of the fingerlings to be stocked. The fish seed produced in the government fish farms are disposed off to private fish farmers as early fry in order to avoid heavy mortality due to over-crowding in the farm ponds. In their anxiety to achieve the target of seed production in the farm as well as achieving the target of stocking in the reservoir, the early fry are stocked in the reservoir, resulting in heavy mortality during the transport and also in the reservoir due to predation by piscivorous fishes already existing in the ecosystem. Hence, it is desirable to rear the fry in the farm ponds till they attain the size of advanced fingerlings of more than 100 mm in length. This ensures better survival of the seed stock in the reservoir (Table).

Density of stocking : The reservoirs are invariably stocked at high stocking density without any relevance to the carrying capacity of the reservoir, resulting in heavy mortality and poor fish yield. The studies have indicated that the stocking density can be drastically reduced when the reservoirs are stocked with advanced fingerlings of over 100 mm in length. It is found that it is sufficeint to stock the small reservoirs at a low stocking density of 200-300 advanced fingerlings of major carps (Fig. 1).

Ratio of differnt species stocked : Since detailed studies have already been undertaken, the quantum and quality of various biotic organisms available in the ecosystem are known. Hence, with the background knowledge of the food and feeding habits of different species of fish and also the different feeding niches available in the reservoir, it becomes easy to decide about the ratio of the species to be stocked.

The ratio of the different species also depends on their different growth rate in a particular ecosystem with different feeding niches. Hence, it is highly essential to assess the growth rate of different species. This can be carried out through various marking techniques. The experiments on tagging of fishes have not yielded satisfactory results. However, the method of group marking through clipping of the pelvic fin has been proved to be more successful means to evaluate the growth rate of different fishes in the open water ecosystem (Selvaraj *et al.*, 1987; Murugesan *et al.*, 1990; Murugesan and Selvaraj, 1990).

Experiments carried out at Thirumoorthy reservoir have established that the manual removal of the pelvic fin from advanced fingerlings of carps with fingers has proved to be very effective means of marking the carps. The process is easy to perform and saves a lot of time in marking a large quantity of fingerlings at a time. The wound caused by clipping of the fin is treated with hydrogen peroxide, followed by an application of furacin cream to avoid any possible infection. The rate of recovery of the clipped specimen was ranging from 5.8 % (rohu) to 43.2 % (catla). Thus the method of clipping for group marking helps not only for assessing the growth rate and survival of different species of fishes but also for formulating the stocking and exploitation strategies so as to achieve a sustained optimum yield from the reservoirs (Murugesan, *et al.*, 1998).

Period of stocking : The reservoirs are often stocked within a short period between August and October every year, resulting in heavy competition for food among the seed of the same age group and also there is a great stress on the population density at a given time of the year. This resuts in stunted growth and subsequent heavy mortality, leading to poor fish yield. The studies have indicated the need for stocking the seed through all the months of the year (Fig.2) to ensure better survival and growth of the stocked varieties of fishes (Selvaraj and Murugesan, 1990).

III. Importance of judicious harvesting :

It is advisable to operate gillnets with 50 mm meshbar so as to ensure the harvesting of fishes of more than 1 kg in size. As it is well known, the financial return through the sale of major carps of more than 1 kg in size is much more than the sale of undersized fishes due to the difference in the selling price. Besides, the fishes must be provided with enough opportunity to attain the harvestable size within the shortest time possible because of their great growth potentiality during the early part of their free-life period in the reservoir.

IV. Conclusion :

Thus, the adoption of the scientific management techniques resulted in a record fish yield of 193.58 kg/ha/year from Aliyar reservoir with an average of 132.67 kg/ha/year during the period of 7 years. Simultaneously, the contribution to the total yield by the major carps also improved substantially (87.0 - 99.1%) with an average of 95.0% (Fig. 3). Interestingly, the medium and minor carps and also other miscellaneous uneconomic species of fish have almost disappeared (Selvaraj and Murugesan, 1990). Besides, the catch per unit effort also increased conspicuously (16.91 kg) as against the poor catch per unit effort of 4.95 kg obtained before the adoption of the scientific management techniques. As a result of the better management strategy, the revenue also increased substantially (669%).

The investigations have revealed that the fish yield depends more on the quality of the seed stocked rather than their quantity (Fig. 4). The studies have established that the small reservoirs can contribute substantially to the freshwater fish production. Even at a modest yield of 100 kg/ha/year, a significant improvement in the revenue can be achieved through the adoption of the scientific management techniques.

The scientific management techniques developed at Aliyar reservoir were put to test in a similar reservoir - Thirumoorthy reservoir (av. area : 234 ha) located under similar geoclimatic conditions, resulting in a record production of 213.4 kg/ha/year during 1996-97, with an average yield of 149.35 kg/ha/year (Selvaraj *et al.*, 1994; Selvaraj *et al.*, 1997; Murugesan, 1997).

Thus the results obtained in Aliyar and Thirumoorthy reservoirs have established that there is trmendous scope for achieving several-fold increase in fish production from all such reservoirs, irrespective of the area of the reservoir or the existing fisheries in the reservoir through the adaption on these techniques to suit to the local needs of any such reservoir in the region.

References:

Joseph, K.O., C. Selvaraj, V.K. Murugesan and P.K. Aravindakshan, 1990. Observations on the effect of low electrolyte reservoir water on carp eggs hatching and survival rate. **In:** *(Eds.)* Jhingran, Arun, G., V.K. Unnithan and Amitabha Ghosh. *Contribution to the fisheries of inland open water systems in India*, Part I, 141-146.

Murugesan, V.K., 1997. Yield optimization in small reservoirs - a case study in Thirumoorthy reservoir. **In:** Summer School on *Fisheries Enhancement in Small Reservoirs and Floodplain Lakes*, *CIFRI, Bulletin No.* 75, pp 133-139.

Murugesan, V.K. and C. Selvaraj, 1990. Observation on fin-clipping of carps cultivated in reservoirs. **In:** *The Second Indian Fisheries Forum Proceedings*, Mangalore, India, pp 153-155.

Murugesan, V.K., C. Selvaraj and P.K. Aravindakshan, 1990. Growth of major carps in Aliyar reservoir based on the recovery of marked fish. **In:** *(Eds.)* Jhingran, Arun, G., V.K. Unnithan and Amitabha Ghosh. *Contribution to the fisheries of inland open water systems in India*, Part I, 115-121.

Murugesan, V.K., C. Selvaraj and S. Manoharan, 1998. Role of fin-clipping in fishery development in reservoirs. **In:** *Fourth National Seminar on Fish and their environment*, Bangalore, 21-23 January, 1998 *(Abstracts)*.

Selvaraj, C., 1997. Yield optimization in small reservoirs - a case study in Aliyar reservoir. **In:** Summer School on *Fisheries Enhancement in Small Reservoirs and Floodplain Lakes*, *CIFRI, Bulletin* No. 75, pp 127-131.

Selvaraj, C., Mathew Abraham and K. Gopinathan, 1987. Validity of fin-clipping to study the growth rate of Gangetic carps in Aliyar reservoir, Tamil Nadu. *J. Inland Fish. Soc. India*, **19** (1): 74-77.

Selvaraj, C., M. Kaliyamurthy and K.O. Joseph, 1990 a. Gonadal maturation in major carps with particular reference to hydrological features of Aliyar reservoir. *J. Nat. Acad. Sci. India*, **59**: (B) (II): 147-154.

Selvaraj, C. and V.K. Murugesan, 1990. Effect of intensive stocking of advanced major carps fingerlings on the fishery of Aliyar reservoir. **In:** *The Second Indian Fisheries Forum Proceedings*, Mangalore, India, 157-159.

Selvaraj, C. and V.K. Murugesan, 1990. Management techniques adopted for achieving a record fish yield from Aliyar reservoir. **In:** *(Eds.)* Jhingran, Arun, G., V.K. Unnithan and Amitabha Ghosh. *Contribution to the fisheries of inland open water systems in India*, Part I, 86-98.

Selvaraj, C., V.K. Murugesan and P.K. Aravindakshan, 1990 b. Impact of stocking of advanced fingerlings on the fish yield from Aliyar reservoir. **In:** *(Eds.)* Jhingran, Arun, G., V.K. Unnithan and Amitabha Ghosh. *Contribution to the fisheries of inland open water systems in India*, Part I, 109-114.

Selvaraj, C., V.K. Murugesan, V.K. Unnithan and S. Manoharan, 1994. Fish production potentiality in small reservoirs in Tamil Nadu. *J. Inland Fish. Soc. India*, **26**(2): 9-16.

Selvaraj, C., V.K. Murugesan and S. Manoharan, 1997. Record fish yield from Thirumoorthy reservoir under scientific management. **In:** *National Seminar on changing perspectives on inland fisheries*, Barrackpore, March 1997. *(Abstracts).*

Selvaraj, C., V.K. Murugesan and V.K. Unnithan, 1997. Ecology-based fishery management in Aliyar reservoir. *CIFRI Bulletin No.* 72

	C.catla	*L.rohita*	*C.mrigala*	*C.carpio*	*H.molitrix*	*C.idellus*	Total
Total no. of fingerlings stocked	2,80,808	1,36,277	1,38,446	1,45,065	14,712	1,956	7,17,264
Composition (%)	39.1	19.0	19.3	20.2	2.1	0.3	100
No. of fish harvested	39,715	34,252	43,246	32,264	1,643	4	1,51,124
Average recovery (%)	14.1	25.1	31.2	22.2	11.2	0.2	21.1

Table 1. **Total quantity of fingerlings stocked and harvested from Aliyar Reservoir during 1985-92.**

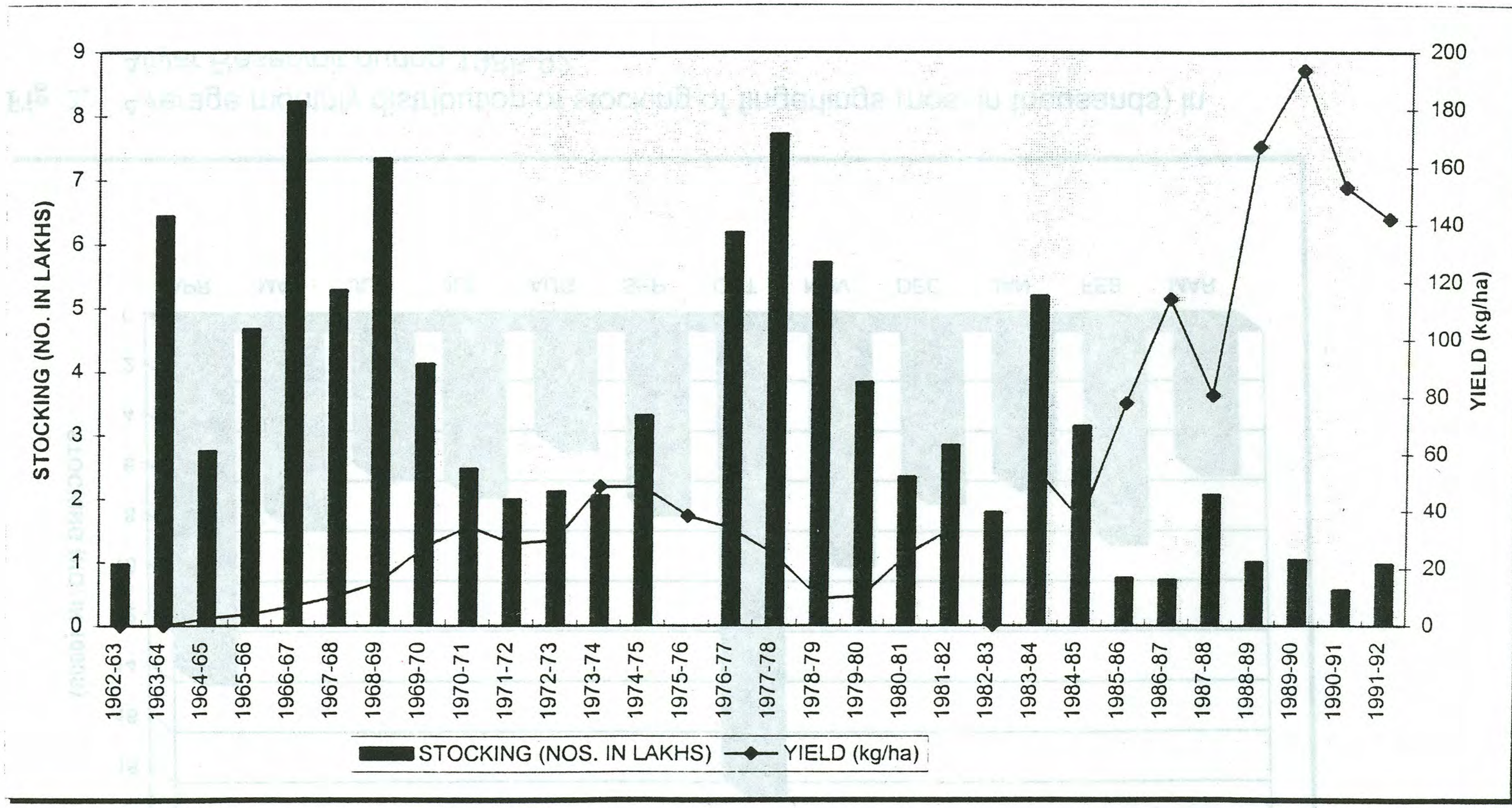

Fig. 1. Stocking rate and yield in Aliyar Reservoir during 1964-92.

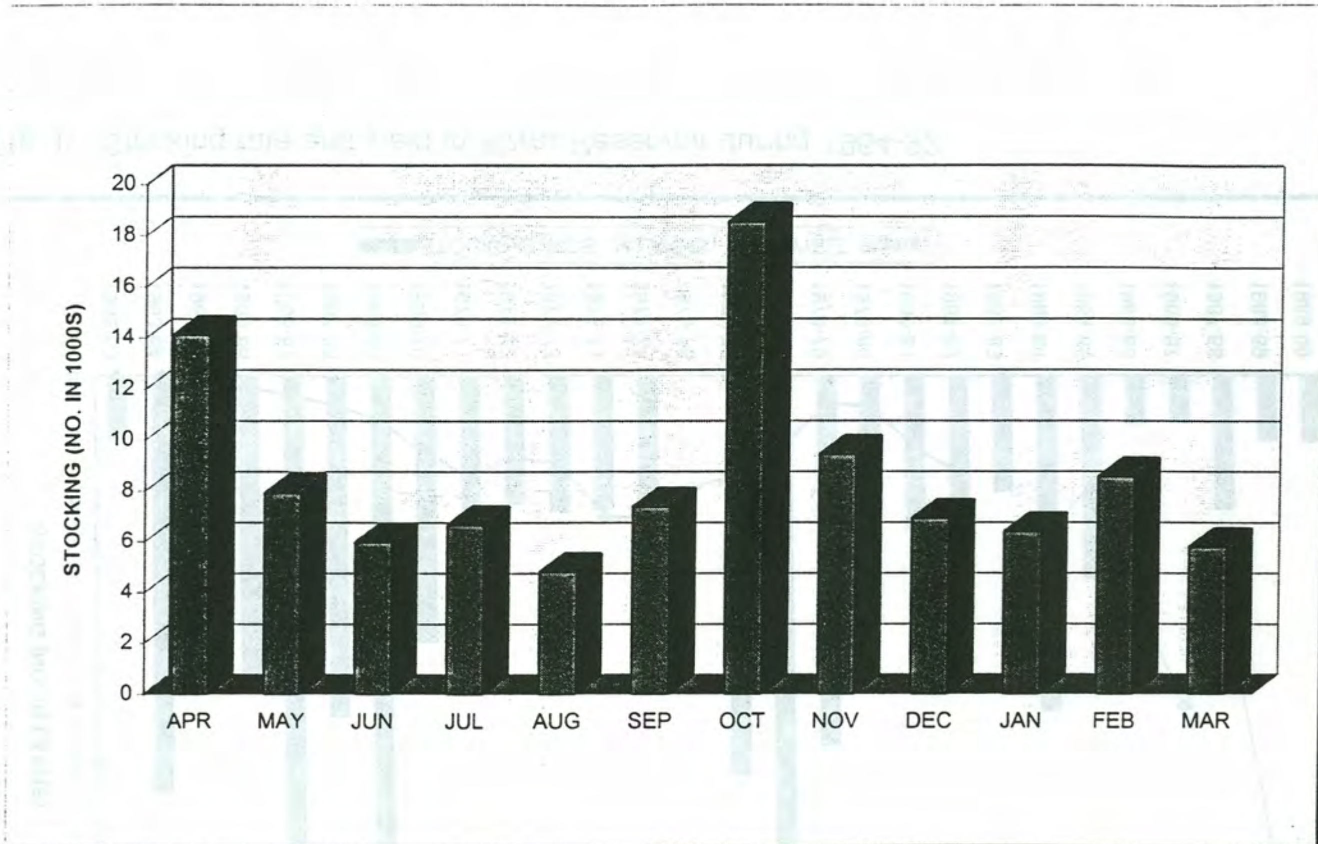

Fig. 2. Average monthly distribution of stocking of fingerlings (nos. in thousands) in Aliyar Reservoir during 1985-92.

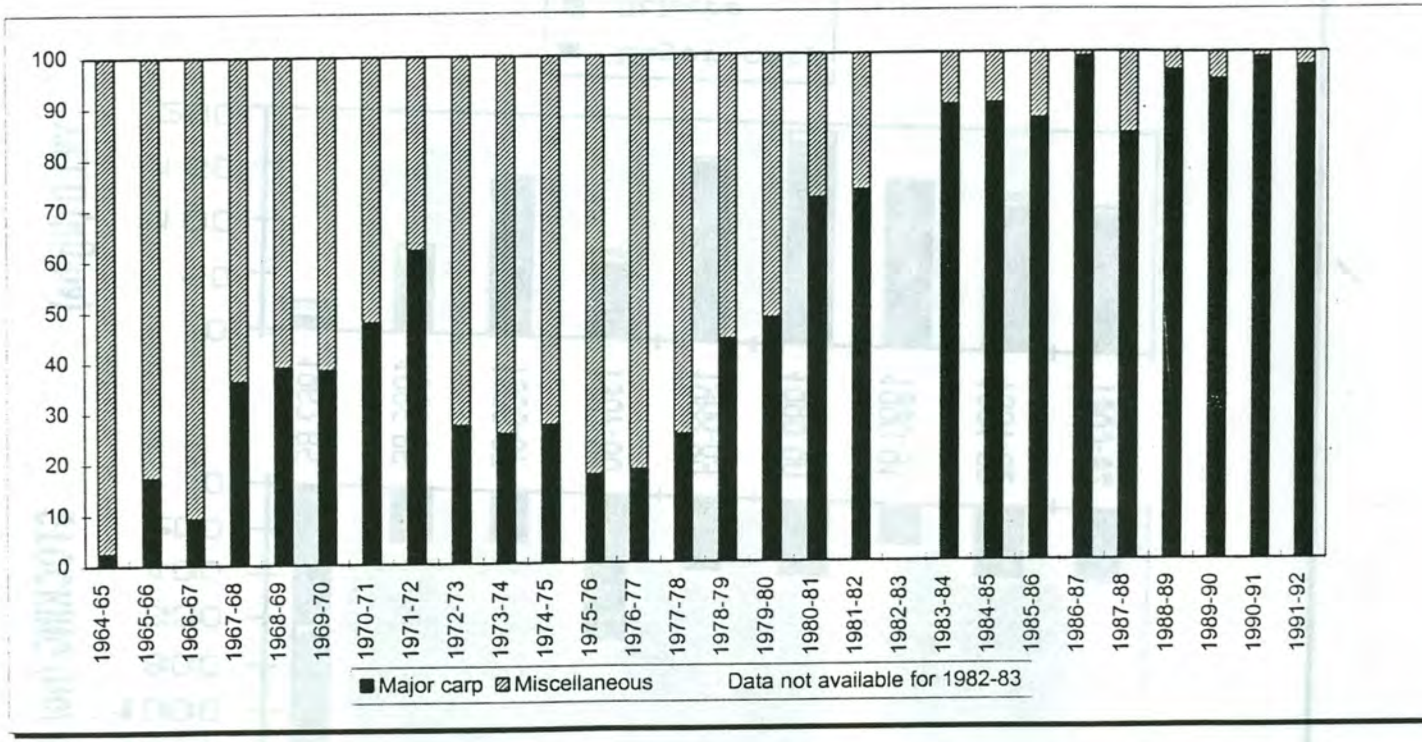

Fig. 3. Percentage composition of commercial fish catch in Aliyar Reservoir before (1964-85) and after (1985-92) CICFRI management.

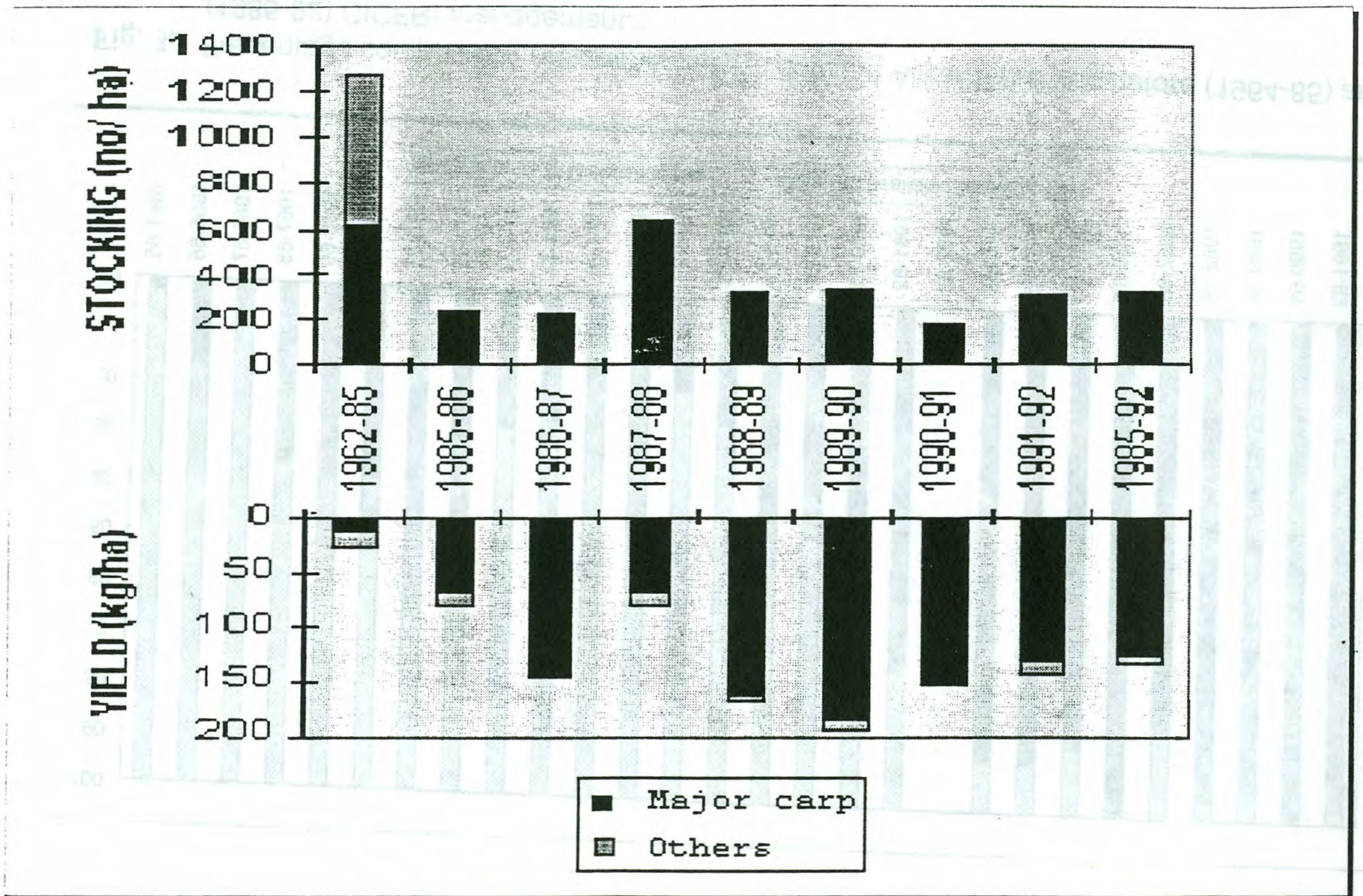

Fig. 4. Impact of stocking of advanced fingerlings on the yield from Aliyar Reservoir.

Classification, morphometry and basic limnological features for evaluating fish yield potential of reservoirs

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Introduction

Reservoirs are man-made ecosystems constructed with a view to harnessing the immense potential of river systems for irrigation, power generation and to meet water supply demands of industries, cities and townships. According to UNESCO report (1978) the total surface area of world's reservoirs is about 60 million hectares. The erstwhile USSR has an area of over 5 million ha followed by USA with 4 million ha and in Southeast Asia it is expected to reach 15 million ha by the end of the century (Lapitzsky 1965, Bhukaswan, 1980). Some of the largest man-made lakes are in Africa and Russia. The reservoirs of India are not comparable in area to those of Africa and Russia. In India the reservoir resource is estimated at over 3 million ha which is expected to double in the near future. In P.R. China the cultivable area under reservoirs is over 2 million ha constituting 40% of total freshwater area.

Fisheries development is reservoirs on scientific lines is of recent origin. In USA the emphasis is for sport and in other countries it is mainly for production of commercial fisheries. In recent years China has made rapid strides in the development of reservoir fisheries. India is on the threshold of a break through in this field.

Classification of reservoirs

The need to evolve a classification for reservoirs from fisheries management point of view is well recognised. However, there are no set norms or criteria to classify reservoirs according to the size. Every country and state has its own norms. The Indian Institute of Management, Ahmedabad (Srivatsava et al 1984) classified reservoirs into small (< 1000 ha), medium (1000 - 5000 ha) and large (> 5000 ha) ones. In China they have been categorized as huge (> 6670 ha), large (670- 6670 ha) , medium (70-760 ha), small (70-70 ha) and mini (6-7 ha) reservoirs.

In general reservoirs could be categorised as small and large and the distinguishing features may be summarised as follows.

Small reservoirs	Large reservoirs
Dams built of earth, stone or masonry on small tributaries and streams.	Dams built with precise engineering skill, elaborate with cement concrete or stone on long rivers.
Provided with concrete or stone spill way.	Provided with more complex engineering devises.
Single purpose reservoirs.	Multipurpose.
May dry up in summer.	Always maintain a conservative pool.
Shore line not very irregular, sheltered areas absent.	Shore line irregular, sheltered areas by way of bays and coves present.
Maintains connection with the river above only during flood season.	Maintains connection with parent river for prolonged periods.
Shallow and biologically more productive	Deep and less productive
Can be subjected to experimental manipulation for testing ecosystem response to environmental modifications.	Cannot be subjected to experimental manipulations
Breeding of major carps do not takes place, if occurs, it is invariably observed above spill way.	Breeding mostly observed in the head waters.
Fisheries development envisages annual stocking and cropping policy.	Fisheries development combines principles of culture and capture fisheries.

(Modified from Jhingran 1986)

Trophic changes in reservoirs

Reservoirs, being man made, differ from natural lakes in their origin and trophic evolution and in morphometric and edaphic factors. Natural lakes commence with oligotrophy and evolve to eutrophy, the process being very slow. In contrast, reservoirs pass through three distinct phases, namely initial high fertility, trophic depression and final fertility (Neel 1967, Jhingran 1975).

The newly formed impoundment inundates vast tracts of forest and agricultural land. The decay of submerged vegetation releases nutrients causing initial fertility leading to intense development of fish food organisms. This initial surge which may last 2 to 3 years is followed by a state of trophic depression caused by rapid utilization of the nutrients. This phase is marked by low production of fish food organisms, lower fish growth, hence less production. Its duration is variable and depends on the climatic and hydrological conditions of the impoundment. In Russia trophic depression lasts 6 to 10 years in southern impoundments and upto 25 to 30 years in northern reservoirs(Lapitzky 1965). After the depression period the reservoir recovers with the accumulation of nutrients. The final fertility is reported to be much lower at half of the initial phase in some reservoirs of USA (Kimsey 1957).

In tropical Indian reservoirs the trophic depression phase lasts for much shorter period due to favourable climatic and drainage characteristics and the final fertility is also found to be of a much higher magnitude than the initial one (Ramakrishniah 1988).

Indices of Reservoir productivity

The factors responsible for potential productivity of freshwater bodies have long interested limnologists. The extensive work carried in Lake Survey in USA and Russia have given us valuable information about the indices of lake productivity. Moyle (1949)in his pioneering work in Minnesota ponds used the results on productivity interchangeably with those obtained in lakes. The results of these investigations formed the basis in evaluating the productivity of a number of ponds in eastern and central part of India on the basis of water quality (Bannerjee 1979) which were later adopted to reservoirs (Jhingran and Sugunan 1991).

Factors affecting the biological productivity could be conveniently grouped into 3 categories, namely climatic, edaphic and morphometric features (Rawson 1955). Edaphic factors determine the primary trophic status of the reservoir. The extent of drainage area, its rate of erosion and run off are the important limiting factors in the supply of nutrients and organic matter. Basin morphometry, particularly mean depth and climate to a considerable extent determine the utilization of nutrients. Rawson (1955) listed a combination of morphometric and limnological parameters as possible indices of lake productivity. They are area, mean depth, shore development, storage ratio, water level fluctuations higher mean temperature, average near bottom oxygen at mid-summer, average secchi-depth visibility, total dissolved solids and gases, average standing crop of plankton and bottom fauna per unit area average catch of fish in standard gill net.

Morphometric and drainage characteristics

Mean depth

Mean depth (volume/area) is considered to be the most important parameter which is indicative of the extent of euphotic-littoral zone. It is an inverse correlate of shore development and direct correlate of area and an exact correlate of volume when area held constant (Hayes 1957). Rawson (1955) has observed distinct inflexion in mean depth curves at 18 m which suggest that water mass below this depth serves a 'nutrient sink'. However, some of the deep reservoirs in India such as Gobindsagar (m.d=55 m), Nagarjunasagar (50 m) Aliyar (18 m) Amaravathy (13.7 m) were found to be productive. It appears that in Indian reservoirs depth is not a constraint for production.

Catchment

Catchment plays a major role in loading nutrients and organic matter into the reservoir. The amount of loading of allochthonous inputs is a function of the ratio of catchment to reservoir area. In Indian reservoirs it has been observed that the catchment largely determines the quality of water rather than the basin soil (Natarajan 1976). It can reasonably be predicted that higher the catchment to reservoir area higher is the productivity of the reservoir.

Flushing rate

Flushing rate is important since it regulates both the degree and regime of nutrient loading (Vollenweider 1969). Flushing rate defines the retention time of any unit volume of water within the lake and is determined by the size and shape of the lake basin as well as by the in-flowing and out- flowing streams.

Shore development

Shore development index ($S/2\sqrt{\pi a}$, where S = shoreline length, a = area of the reservoir) indicate the degree of irregularity of shore line. Higher the value, higher the irregularity. Reservoirs with sheltered areas like bays and coves have dendritic shore line and extensive littoral areas and likely to be more productive.

Volume development

Volume development index (3 x mean depth/max. depth) indicates the nature of the basin. If the value is above one, the basin is cup shaped with its walls concave towards water. On the other hand if the value less than one, basin is saucer shaped with the walls convex towards water. Deep reservoirs with less of littoral areas generally have the VDI more than one and likely to be less productive.

Limnological characteristics

Temperature

The climatic factors especially temperature has a profound influence on utilization of nutrients. It varies with latitude and altitude. Reservoirs at higher latitudes and altitudes are generally less productive than their counterparts at lower latitudes and altitudes. In tropics temperature is not a constraint in biological productivity. Thermal stratification is not generally observed in Indian reservoirs of lower latitudes, when occurred it is ephemeral. High bottom temperatures prevail in deep tropical reservoirs and the difference between surface and bottom is low. However, in warm temperate zone thermal stratification occur regularly in summer, being broken by flood water in monsoon and convection currents in winter.

Turbidity

Inorganic turbidity caused from suspended colloidal particles prevent light penetration and reduces trophogenic zone. Inorganic turbidity may be of autochthonous or allochthonous origin.

Dissolved oxygen

DO above 5.0 ppm considered to be good for fish life. Oxygen deficit at the bottom in summer is a characteristic feature of productive reservoir. The oxygen curve is the most dependable indicator of productivity of the reservoir. Photosynthesis at the surface and tropholytic activity at the bottom cause klinograde oxygen distribution and was recorded in all productive reservoirs in India. The strength of oxycline is a good index of the degree of productivity of reservoirs. In low productive waters oxygen curve is orthograde.

Apart from indicating the trophic status of the reservoir, the oxygen regime also aids in fishing operation. As fish prefer well oxygenated waters, a knowledge of vertical distribution of oxygen help operators to lay gill nets at appropriate depths.

pH, carbon dioxide and alkalinity

pH between 7 and 8.5 are favourable for production. Change in pH with depth is an index of productivity. In reservoirs with klinograde oxygen distribution the carbondioxide and bicarbonate concentration show a general inverse relationship with oxygen i.e., free CO_2 and HCO_3 increase with depth. Vertical difference in HCO_3 between the surface and the bottom indicate the utilization in the surface and accretion in the bottom due to trophogenic and tropholytic activity respectively.

The alkalinity is generally caused by carbonates and bicarbonates of calcium and magnesium. These with dissolved CO_2 in water form an equilibrium which play an important role in the productivity of the system. Based on the work in Minnesota lakes, Moyle (1949) classified lake productivity on the basis of alkalinity. Lakes with a total alkalinity upto 20 ppm as very soft waters and have low productivity, 20-40 ppm as soft waters with low to medium productivity, 41-90 ppm as hard waters with medium to high productivity and 100 ppm or more as hard waters with high productivity.

This classification has been extensively applied to reservoirs as well. However, in Indian reservoirs, it has been shown that alkalinity is not a dependable parameter in assessing productivity. Soft water reservoirs with low alkalinity (20-40 ppm) such as Amaravathy, Aliyar and some reservoirs with catchment of western ghats are found to be highly productive.

Essential nutrients

Nitrogen is a basic constituent of protein and occurs in water in free state N, NH_3, NO_3, NO_2 and organic nitrogen. It is observed that a dissolved nitrogen concentration of 0.2 to 0.5 ppm may be considered favourable for production. But many of the productive reservoirs in India have NO_3-N in low concentration, often in traces.

Another essential nutrient is dissolved phosphorus (PO_4-P). A concentration of 0.1 to 0.2 ppm is considered to be optimal in ponds and lakes for higher production. But in the most productive reservoirs of India this element was found in traces.

Organic matter

Organic matter in reservoir ecosystem comes from two sources - autochthonous through photosynthesis and allochthonous from the catchment through run off. Allochthonous input of organic matter is very important in reservoir ecosystem. The amount of loading of allochthonous organic matter is a function of relative size of the reservoir to its catchment. It varies from large visible particles to dissolved fractions. Organic matter functions as a i) food source for benthic feeding fishes and invertebrates, ii) as a substrate for bacterial growth and other micro organisms and iii) the dissolved organic compounds function as exogenous growth substances, vitamins and chelating agents. Organic matter by itself is of low nutritive value but it is often fortified by the colonising bacteria and fungi and make it more nutritious. It forms the major part of the energy requirement of zooplankton in reservoirs on account of its high concentration and is often considered as food larder for zooplankton (Moss 1980).

Plankton

Plankton community plays a significant role in reservoir productivity as it is directly taken by certain fishes while the dead plankton adds to the organic matter budget of the reservoir. Plankton shows a pattern of seasonal dominance in reservoirs. A plankton pulse with predominance of zooplankton generally occurs immediately after the monsoon inflows (Oct-Dec.) and the other during pre-monsoon months (Feb-May). In oligotrophic reservoirs zooplankton population dominates while in eutrophic reservoirs it is the phytoplankton. Bluegreen algae

(*Microcystis*) dominate in lower latitudes, dinoflagellates (*Ceratium*) in higher latitudes and green algae (*Pediastrum, Spirogyra*) in higher altitude reservoirs.

Copepods (*Diaptomus, Cyclops*) are the main constituents of zooplankton followed by cladocerans (*Diaphanosoma, Moina, Bosmina*) and rotifera (*Brachionus, Keratella*)

Bottom macrofauna

High shore line development , variable slopes and vegetation association produce a large number of benthic habitats in reservoirs. Molluscs, dipteran larvae (*Chironomus* and *Chaoborus*) oligochaetes constitute the major component of benthic macrofauna in reservoirs. Chironomids predominate in reservoirs which show frequent oxygen deficits at the bottom. Molluscs prevail in alkaline waters with high calcium concentration. The main energy source of the community is fresh seston (sum of particulate organic matter living and dead) which by the activity of the animals and bacteria is converted to more refractory sediment. Bottom deposits along with the fauna and flora account for the major fish food resource in reservoir ecosystem. The major carps *C. mrigala, L. rohita, L. calbasu, L. fimbriatus* and the common carp feed on this resource whereas molluscs are taken by *P. pangasius*.

Periphyton

Deposits of micro plants and animals on submerged substrate forms the food resource for browsing fishes such as *L. rohita*, *L. calbasu* and *L. fimbriatus*. The periphytic organisms are represented mainly by diatoms, green and blue-green algae. Presence of littoral aquatic vegetation enhances the substratum for periphyton.

Aquatic macrophytes

Aquatic macrophytes, generally do not take a permanent foot hold in reservoirs due to steep water level fluctuations. However, they do occur in old eutrophic reservoirs. Submerged species like *Hydrilla, Vallisneria, Potamogeton* and *Najas* were found in some reservoirs. A high density of macrophytes are undesirable as they lock-up essential nutrients and deprive them to phytoplankton. On the other hand a high diversity of macrophytes ensure diverse habitats for invertebrate fish food organisms, there by increasing the diversity of these organisms as well. When present in moderate quantities macrophytes increase the stability of the ecosystem. In reservoirs with submerged macrophytes *L. rohita* has done extremely well probably due to large browsing area provided by the macrovegetation.

Models for fish yield prediction

Prediction of fish yield potential is *sine qua non* for initiating scientific fisheries management of reservoirs. Such predictions may be approximate which could be refined during the process of development with the feed back obtained on the performance of different fish species.

According to Henderson et al (1973) timeliness in estimating fishery potential is more important than precision in the earlier period of development.

Several empirical models are available for the prediction of fish yield using morphometric and limnological parameters such as area, mean depth, total dissolved solids phosphorus, primary production and phytoplankton (Rawson 1952, Ryder 1965, Oglesby 1967, Hanson and Legget 1982). In Asian reservoirs Moreau and De Silva (1991) examined several parameters and concluded that morphometric features appear to be more valuable as fish yield predictors than biological features. According to them water shed area, by itself or in combination with other morphometric features such as mean depth appear to have potential for development of yield predictor models. Some of the widely used models are discussed below.

Morphoedaphic Index (MEI)

It is one of the simplest and widely used models. Proposed by Ryder (1965), MEI combines an edaphic factor, total dissolved solids (TDS) and a morphometric factor, mean depth (z). The relationship is expressed as :

$$\mathbf{MEI = TDS/z}$$

The fish yield is calculated from the regression equation of the form $Y = Kx^a$, where, Y=fish yield, x=MEI and K=a constant that represents a co-efficient for climatic effects and 'a' an exponent appoximating 0.5. MEI has provided a useful first approximation of potential yields in north temperate lakes and it was soon extended to lakes and reservoirs of Africa (Henderson and Welcomme 1974) and Sri Lanka (Wijeyaratne and Costa 1981). The model is a reasonable compromise between unmanageable complexity and ecological over simplification (Ryder 1982). Its appropriate application pre-supposes both a fisheries and limnological expertise. Ryder (1982) advocated development of regional and infra-regional models for homogenous data sets where TDS could be replaced with any other useful variable in that particular data set.

In Indian reservoirs TDS and its positive correlates total alkalinity and conductivity are found to be undependable to predict productivity. The regression equation of MEI (using alkalinity) on fish yield for Indian reservoirs has the following form :

$$\mathbf{Y = 7.738\ MEI^{0.469} \quad (r = 0.34)}$$

The low correlation is indicative of the low precision of the model. Jhingran (1986) and Sreenivasan (1989) pointed out that MEI model is not strictly applicable for Indian reservoirs.

Ramakrishniah (1990) modified the MEI substituting a drainage parameter, the ratio of catchment to reservoir area, in place of TDS and the new Index is called Morphodrainage Index (MDI) The regression obtained between yield (kg/ha at FRL) and MDI for 20 reservoirs has the following form :

$$Y = 4.012\ MDI^{0.902}\ \ (r = 0.77)$$

The exponent being close to one, the yield (Y) could be approximately taken at four times the MDI. This model appears to be suitable for Indian reservoirs as a fish yield predictor. Its utility lies in the fact that the parameters could be obtained from the dam authorities even before the formation of the impoundment.

Trophodynamic model

The relationship of fish yield to primary production has been described by Henderson et al (1973). They opined that most trophic transfer efficiencies may tend to be low in waters of low primary productivity and high in waters of high primary productivity. Melack (1976) drew a regression between fish yield (Fy) and gross photosynthesis (PG) for 15 Indian reservoirs which has the form,

$$\log Fy = 0.122\ PG + 0.95\ .$$

The superior predictive ability of PG was also recognized by Mc Connel et al (1977). Natarajan (1979) stated that 1% of gross production provides a fairly dependable limnological guide to fish productivity in reservoirs. However, even in best managed Indian reservoirs less than 0.2% of conversion of photosynthesis has been obtained as fish yield (Natarajan and Pathak 1983).

The trophodynamic model is likely to be effective in systems driven largely by autochthonous inputs. On the other hand reservoirs with high flushing rate where allochthonous inputs are sizable either MEI or MDI could be attempted to obtain a prediction of fish yield.

References

Bannerjee, S.M. 1979. Soil condition and water quality of man-made reservoirs of India. **In :** *Summer institute on Capture and Culture Fisheries of the Man-made lakes in India.* CIFRI Barrackpore, 7 July to 6 August, 1979.

Bhukaswan T. 1980. Management of Asian reservoir fisheries. *FAO Tech paper,* 207 : 69 p.

Hansen, L.M. and W.C. Legget 1982. Empirical prediction of fish biomass and yield. *Can. J. Fish. Aquat. Sci.,* 39 : 267 - 263.

Hayes, F.R. 1957. On the variation of bottom fauna and fish yield in relation to trophic level and lake dimensions. *J. Res. Board Can.*, 14 : 1 - 32.

Henderson, H.F., R.A. Ryder and A.W. Kudhongania. 1973. Assessing fishery potentials of lakes and reservoirs. *J. Fish. Res. Board Can.*, 30 ; 2000 - 2009.

Henderson, H.F., and R.L. Welcomme, 1974. The relationship of yield to morpho - edaphic index and numbers of fisherman in African Inland Fisheries. *CIFA Occas. Pap* (1) : 19 p

Jhingran, A.G. 1986. Reservoir Fisheries Management in India. *Bull. CIFRI,* Barrackpore, 45 : 65 p.

Jhingran, A.G. and V.V.Sugunan. 1990. General guidelines and planning criteria for small reservoir fisheries management. **In :** *Proc. of National workshop on Reservoir Fisheries*, 3-4 Jan. 1990, (eds. Jhingran A.G. and V.K. Unnithan). Asian Fisheries Society, Indian Branch, Mangalore : 1-8.

Jhingran, V.G. 1965. Report on Inland Fisheries Research and Management and Fish culture in the USSR. *Misc. Contr. Cent. Inl. Fish. Res. Inst. Barrackpore,* 5 : 27 p.

Kimsay, J.B.1957. Fisheries problems in impounded waters of california and the lower Colarado river. *Trans. Am. Fish. Soc.,* 87 : 319 - 332.

Lapitzsky, I.I. 1965. Development of Fisheries and the ways of raising fish productivity in big reservoirs. *Rep. FAO/UNDP (TA),* 2547 : 124-134.

McConnel, W.J., S. Lewis and J.E. Olson 1977. Gross photosynthesis as an estimator of potential fish production. *Trans. Am. Fish. Soc.,* 106 : 417 - 423.

Melack, J.M. 1976. Primary productivity and fish yield in tropical lakes. *Trans. Am. Fish. Soc.,* 105 : 575 - 580.

Moreau, J. and S.S. De Silva. 1991. Predictive fish yield models for lakes and reservoirs of the Philippines, Sri Lanka and Thailand. *FAO Fisheries Technical Paper*, No. 319 : 42 p

Moyle, J.B. 1949. Some indices of lake productivity. *Am. fish. Soc. Trans.* 76 : 322-334.

Moss. B. 1980. *Ecology of Freshwaters.* Blackwell Scientific Publications, London, 332 p.

Natarajan, A.V. 1976. Ecology and state of fishery development in some of the man-made reservoirs of India. **In :** *Symposium on the development and utilization of Inland Fishery resources.* Colombo, Sri Lanka, (27-29, October) *Indo Pacif. Fish. Coun.*,15 p

Natarajan, A. V. 1979. Ecosystem oriented approach for reservoir fisheries development in India. Souvenir on the ICAR golden jubilee year, CIFRI, Barrackpore India, part I, 107-111.

Natarajan, A.V. and V. Pathak 1983. Pattern of energy flow in freshwater tropical and sub-tropical impoundments. *Bull. Cent. Inl. Fish. Res. Inst.*, Barrackpore, No. 36 : p 27

Neel, J.K. 1967. Reservoir Eutrophication and Dystrophication following impoundment. **In :** *Reservoir Fisheries Resources Symposium* (April 5-7, 1967). American Fisheries Society, Washington : 322- 332.

Oglesby, R.T. 1977. Relationship of fish yield to lake phytoplankton standing crop, production and morphoedaphic factors. *J. Fish. Res. Board. Can.,* 34 : 2271 - 2279.

Rawson, D.S. 1952. Mean depth and the fish production of large lakes. *Ecology,* 33 : 513 - 521.

Rawson, D.S. 1955. Morphometry as the dominant factor in the productivity of large lakes. *Verh, Inst. Ver. Limnol.* 12 : 164 - 175.

Ramakrishniah, M. 1988. Observations on differeent trophic phases in a tropical impoundment : Nagarjunasagar, Andhra Pradesh. **In :** *Contributions to the Fisheries of Inland Open water systems in India* Part I (Eds, A.G. Jhingran, V.K. Unnithan and Amitabh Ghosh), Inland Fisheries Society of India ; 80-84.

Ramakrishniah, M. 1990. Morphodrainage Index, a fish yield predictor for Indian reservoirs. Paper Presented at the *2nd Asian Reservoir Workshop*, held at Hangzhou, P.R. China, 15-19 October 1990.

Ryder, R.A. 1965. A method of estimating the potential fish production of north- temperate lakes. *Trans. Am. Fish. Soc.*, 94 : 214 - 218.

Ryder, R.A. 1982. The morphoedaphic index - use, abuse and fundamental concepts. *Trans. Am. Fish. Soc.,* 111 : 154 - 164.

Sreenivasan, A. 1989. Principles of ecology and fisheries management in man-made lakes. P 96-105. **In :** (A.G. Jhingran and V.V.Sugunan eds.) *Conservation and Management of Inland Fisheries Resources of India*. Inland Fisheries Society of India.

Srivastava, U.K., D.K. Desai,V.K. Gupta, S. Sreenivasa Rao, G.S.Gupta, M. Raghavachari, S. Vatsala, Amarjeet Singh, V. Ravindra Bharathi, J. Martin Santhakumar and S. Suryachandra Rao, 1984. *Inland Fish Marketing in India, Reservoir Fisheries*. IIM , Ahmedabad study series vol. IV a. Concept publishing company, New Delhi : 403 p.

Vollenweider, R.A. 1969. Moglichkeiten and Grentzen elementarer Modelle der stoffbilanz von Seen. *Arch. Hydrobiol.*, 66 : 1-36.

Wijeyaratne, M.J.S. and M.H. Costa 1981. Stocking rate estimations of *Tilapia mossambica* fingerlings for some inland reservoirs of Sri Lanka. *Int. Rev. Gesamat. Hydrobiol.,* 66 : 327-333.

RIVERINE ECOLOGY, TIME SCALE CHANGES AND ESTIMATION OF FISH PRODUCTION POTENTIAL

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Introduction

Since time immemorial rivers are used by mankind more than any other type of ecosystem. Rivers offer a continuously renewable physical resource, the major source of water for multiple use such as agriculture domestic, industrial and for rapid removal of waste substances generated due to anthropogenic activities. They have also been subjected to other uses such as transport, harvesting of food and for recreational activities. Further rivers have also been regarded a hazards (petts, 1989) by flooding vast areas, changing course in response to processes of erosion and deposition, obstructing transport system across valleys and aiding in the transmission of water associated diseases.

Human race had irrationally exploited riverine resources together with their floodplains and had drastically altered them to save the urban areas and production systems. On account of this cultural eutrophication only a few large rivers system of the world retain their original functional integrity and many have probably lost much of their capacity to adjust and recover from severe perturbation. Rivers degradation is one of the most striking manifestation of the human failure to utilize renewable resources without deterioration of their natural basis when we examine the status of Indian rivers in the above context, we found the same is valid for our rivers too. Most of the Indian rivers specially where big cities are situated on their banks are under stress due to burgeoising anthropogenic activities. They have lost their natural purity of water and are loosing bio-diversity too. Even, fish production is steadily declining. The fish yield was estimated to vary from 640 to 1610 $km^{-1}yr^{-1}$ in 60's (Ganga-940, Narmada, 865.0; Godavari-1392 kg $km^{-1}yr^{-1}$) has come down to < than 600 kg ha^{-1} yr^{-1} in 1990's. Further, population of prized food fishes, *viz.*, Gangetic carps and large cat fishes has gone down drastically (26.62 kg ha^{-1} yr^{-1} in 1961 to 2.55 kg ha^{-1} yr^{-1} in 1995 for major carps) while those of weed fishes had increased manifold. Even qualitatively spawn (major carps) from river Yamuna has come down from 7385 ml in 1964 to a low of 606 ml in 1997 and qualitatively from a high of 84% to 38% during the above period. Similarly, plankton and benthos population has also been altered with an corresponding increase in bacterial population. These are the symptoms of degradation of water quality.

Thus, there is an emergent need of understanding the causes of ecodegradation and formulation of policies for recovery of aquatic wealth. Successful management strategies have to take into consideration of fish stocks and the dynamics of their population together with regulatory measures for fishing. Thus, the understanding of river's ecology and estimation of fish production and prediction for future catch become a basic pre-requisite for formulation of management policies.

1.0 Riverine fisheries

Nature has bestowed to India an extensive network of Indian rivers alongwith their tributaries, with a total length of over 45000 km constitute one of the major inland fisheries resource of the country. Indian rivers carry a surface run off 167.23 million ha metres which is 5.6% of the total run off flowing in the rivers of the world. The river system of the country comprise 14 major rivers, each draining a catchment of more than 20,000 km^2,44 medium rivers, having catchment between 2000 and 20,000 km^2 and innumerable small streams that have a drainage of less than 20,000 km^2.

1.1 Ecology of the rivers

The ecology of Indian rivers has not yet been properly understood. Though some sporadic work in isolation has been done by individuals on various rivers. (Jhingran, 1990, Natarajan, 1989, Khan et al. 1996). There is hardly available any data on time scale of any river except Ganga and that too in the middle and lower stretch. Mostly work on this river has been done by scientists of CIFRI, but off late, few universities have also conducted work on the rivers ecology under Ganga action plan. The paucity of the data on time series did not permit us to described in detail the ecology of any other river. Due to this reason, the ecology of river Ganga is describe by taken as an example of a case study. Ganga river system has a combined length of 12,500 km and harbour one of the richest fish fauna (265 species), while the Brahamaputra and Peninsular rivers have been reported to bear 126 and 76 fish species respectively. The ecology of the river and method for calculation of potential fish yield of the Ganga and other important rivers is described in the following discussion.

2.0 Abiotic characteristics of the water

2.1 Physico-chemical parameters

Data in respect of physico-chemical parameters spread over a span of thirty five years (1960-1995) is portrayed in Table 1. pH of the water over the years has not been changed much since 1960 except at Allahabad where it had registered moderate increase. Carbon-dioxide fluctuated in a narrow range, except at Allahabad where it had considerably increased, in 1988 but tumbled down again in 1995 to the level of 1960. Among the important chemical parameters which determine the productivity of the water, the role of total alkalinity is very important and it has significantly increased on all the centres. This reflects in qualitative changes in run off the river. Similarly, chloride increased (ppm) from 10 to 15 in Kanpur; 12.1 to 19.0 in Allahabad; 21.0 to 25.0 in Varanasi; 10.7 to 20 in Patna and 11.2 to 28.0 in Bhagalpur. Steep increase in the chloride content can be related to the discharge of sewage into the river.Sharp rise in specific conductivity and total dissolved solids, the two interrelated parameters suggest a radical change in chemical status due to heavy discharge of organic wastes.They also suggest, the qualitative changes in water due to the discharge of chemical effluents and the catchment modifications.

The magnitude of increase in the specific conductivity, dissolved solids, alkalinity and chloride was maximum in Kanpur, a highly polluted zone. Despite consistent increasing trend in all the other centres, the total alkalinity of Patna decreased from 141.75 to 139.65 ppm from 1960 to 1987. Similar, decrease can be noticed in case of specific conductance which decreased from 300 to 283.2 micromhos and the total dissolved solids from 148 to 138 (ppm). At Patna, the three main tributaries Gandak, Son and Punpun join the Ganga. Which has improved its water qualities. The deoxygenating effect of sewage pollution is clearly discernible in Kanpur and Allahabad in Kanpur, before the treatment the dissolved oxygen had decreased from 7.75 ppm in 1960 to 2.74 ppm in 1987 with a corresponding increase in CO_2 concentration from 2.2 ppm to 8.18 ppm. The nutrient status of the river in terms of phosphates and nitrates showed an increasing trend, but the magnitude of increase was very low as the fertilizer leaching in the basin is not very significant. However, slicate showed significant increase at all the stations.

2.2 Biotic communities

2.2.1 Plankton communities

In river Ganga details studies on plankton were conducted in 1960 in a stretch of 1052 km lying between Kanpur to Rajmahal by Pahwa & Mehrotra, (1966). They also related the abundance of plankton with certain hydrochemical parameters. These workers were able to detect a total number of 76 plankton species comprising 46 phytoplankton species (16-*Bacillariophyceae*, *15-Chlorophyceae*, 10, *Myxophyceae,* 2, *Chrysophyceae* and one each of *Dinophycea* and *Euglinophyceae*) and 30 zooplankton species (Rotifera, 16, Copepoda, 2, Cladocera, 8 and Protozoa 4,) they further reported a dominance of Bacillariophyceae followed by Chlorophyceae with the exception at Bhagalpur where condition were riversed. Later on, studied conducted by CIFRI in 1986-87 revealed a gradual decreasing trend in population of Bacillariophycea and increase in Chlorophyceae population. Myxophyceae also registered a slight increase in its population. However, in 1995 the trend was more or less similar to that of 1986-87 with the exception that Myxophyceae flora registered a further decrease from that of 1986-87 level. This probably may be due to the effect of Ganga action plan which was initiated in 1985 and is still continuing. Myxophyceae flora is generally considered as an indicator of 'Eutrophic' water however, in 1986-87 the organic load was more due to direct discharge of sewage in Ganga so Myxophyceae flora propagated but after 1986, it gradually started decreasing with a corresponding amelioration in water quality. Khan, *et al* (1996) reported, 52 species of phytoplankton as compared to 46 species reported by Pahwa & Mehrotra (*op. cit* 1966). This indicates that in recent time due to amelioration of water quality, the number of species has increased and hope that biodiversity would further enhance with the improvement of water quality. The percentage composition and average production of plankton (ul^{-1}) of the river Ganga is portrayed in Table-2.

2.2.2 Macrobenthos

Macrobenthos are considered an indicator of organic pollution besides a good source of food to many species of fishes. The abundance of annelids and chironomids is in an indicator of high organic load while molluscs and ephemeropterans denote a low level of nutrients. The production pattern of the benthos in a stretch of river Ganga is portrayed in Table 3 for the years 1960 and 1995. Average production ranges between 218 to 3476 um^2 being lowest at Bhagalpur and highest at Kanpur. The high production at Kanpur is due to high level of nutrients loading on account of cultural eutrophication. Generally, the insects population dominated throughout the riverine stretch.

Annelids and insects have been reported in great quantity around discharge point of *nallahs* with sluggish water current (Allahabad to Varanasi), molluscs were more where water was clean and current was comparatively fast (patna & Bhagalpur).

In the distribution of benthos current velocity plays utmost significant role. The nature of bottom soil and inflow of various pollutants are in no way less significant. All these factors, simultaneously, make the favourable or in unfavourable conditions for the macrofauna of stream to develop and thrive. On the basis of studies conducted by Khan *et al.*, (1996) and Jhingran *et al.*, (1989), the whole of the stretch lying between Kanpur to Patna is under influence of moderate to severe sewage pollution (H values between 0-2.6).

When production pattern is considered, it is observed that the production of benthos from Kanpur to Varanasi is lower in 1995 than that of 1960, while it has increased at Patna and Bhagalpur. Probably, persisting high organic load and comparatively sluggish water current is conducive for higher benthic production on the above centres.

2.2.3 Fish communities

The data on fish catch statistics for the period of 1960 to 1995 is available for only Allahabad centre, though discontineous data at a some time of scale is available for Kanpur, Varanasi Patna, Bhagalpur and Lalgola centres too. The fish catch trend indicates a declining trend for whole of the stretch. Particularly in case of major carps, large cat fishes and hilsa (riverine stretch). The catches of Allahabad and Patna landing centres are described to give an idea of status of presnet fishery and its deviation from the past. The same is valid for all other centres located on the riverine stretch of the river.

2.2.3.1 Allahabad

Presently the average production estimate in the middle stretch at Allahabad was obtained as 311.6 kg $km^{-1}yr^{-1}$ (major carps, 42.0; catfish, 84.0; hilsa, 2.6; others, 183.0 kg$km^{-1}yr^{-1}$). A critical evaluation of data indicated a severe setback to fishery both qualitatively and quantitatively. During last three decades the stock structure has experienced sharp changes. At Allahabad the production of prized major carps with the passage of time has come down to 46.2 kg $km^{-1}yr^{-1}$ from an average of 427.0 kg $km^{-1}yr^{-1}$ in 1961-66. The first setback to this fishery was observed during 1972-78 for which the production estimate was 123.6 kg $km^{-1}yr^{-1}$. *L. Calbasu* emerged as principal component of this group leaving behind mrigal which used to to contribute more than 50% of the major carps population. Probably the increase in organic load in water encouraged its propagation and remained in a stable state till 1986 despite a continuous fall in other major carps. All of a sudden *L. calbasu* also followed the declining trend and tumbled down to merely 0.98 t in 1993 from a maxima of 47.41 t in 1984. The fishery of large catfish also showed a continuous decline and production estimate came down to 55.4 kg $km^{-1}yr^{-1}$ for the present from 207.6 kg $km^{-1}yr^{-1}$ of 1961-68. Hilsa fishery after a sudden drop around 1970, stabilized at a very low level of few hundred kilograms from an average of 20 t. Thus, adversly affecting thousands of fishermen along the riparian stretches of U. P. And Bihar. The fishery of others group remained stable over the years with minor quantitative fluctuations (177.2-278.2 kg $km^{-1}yr^{-1}$). But qualitatively this group also reflected a serious change. The catches of commercially important species, such as *R. rita*. *C. Garua*, *E. vacha*, *P. pangasius*, *S. silondia*, *S. phasa*, *A. coila* and *O. pabda* showed a drastic decline and replanced by other species of less commercial importance, indicating symptoms of Pauly's ecosystem degradation syndreome. Some of the species of this group, *viz.*, *B. bagarius*, *P. coitor*, *O. pabda* and large sized prawns have almost disappeared from the catches.

2.2.3.2 Patna

Fish landings at Patna have also revealed a sharp decline and production estimate have come down to 629.8 kg $km^{-1}yr^{-1}$ (MC-76.0. CF-124.0, hilsa-1.8, others-428.0 kg $km^{-1}yr^{-1}$) from 1811.2 kg $km^{-1}yr^{-1}$ of 1961-66. Here also, the worst affected were major carps and hilsa for which production estimates have come down to 76.0 and 1.8 kg km-1yr-1 389.0 and 234.8 kg $km^{-1}yr^{-1}$, respectively. The contribution of large sized catfish also reduced to one third of 1961-68. For other groups the catches were almost half of the past.

3.0 Fish production assessment methods

A number of methods are available in literature for estimation purposes. These are mainly bassed on ecological and physical parameters *viz.,* current velocity, nature of bottom and the banks, obstacles to flow, channel morphology, catchment area, etc., as the main factors determining the choice of method in context to later method to be applied for such estimation.

For prediction of future catches, Welcome (1979) has summed up a number of methods based on statistical correlations between some environmental parameters and the catch assuming that the dynamics of fish populations as well as catch in large rivers is a close positive correlate of hydrological regime. These methods have been found to give fairly accurate results.

The mthods applied for computing fish yield from Ganga river system and some future approaches are given below.

Fish production in river Ganga was estimated in its middle stretch extending from Kanpur to Bhagalpur by means of (1) C^{14} technique (2) phytoplankton biomass estimation by measuring chlorophyll *a* concentration (Kanpur to Ghazipur only) (3) Catch estimation from wholesale markets at selected centres and (4) using relationships based on morphological features (Welcomme, 1976). Other methods available in literature and not used in the present communication are- creel census (killing of fish in a segment of river and their total counting), by tagging experiments and by using catch per unit of effort data.

3.1 Estimation of fish yield by C^{14} technique

Potential fish yield has been estimated of the river Ganga based on primary production, which has been estimated either by conventional dark and light bottle method (Strickland and Parson 1968) or by C^{14} technique. In river Ganga, Jhingran & Pathak (1988) have estimated fish yield in the mid-stretch of the river. They converted carbon values into calories by multiplying with 9.82 and fish production potential was calculated by assuming the energy at fish level as 0.5% of the net energy fixed by produceres (Odum, 1962).

The productrivity potentail of a water body depends on efficiency with which primary producers transform light energy into potential chemicals energy, and thus any change in the producers population or its energy transformation rate will have a direct bearing on the productivity of the system.

Considerable differences in energy transformation in different sectors of the the river on year to year basis have been observed. However, overall picture indicates a poor phytoplankton efficiency (0.077 to 0.316%). Consequently a poor harvest of the fish yield against a rich potential fish yield. When fish production estimates based on conversion of primary producers to fish flesh is compared with other large rivers of the world like Volga (0.033 to 0.077%), Mississippi (0.002%) and Solimoes river (0.031%), Ganges photosynthetic efficiency is better. Fish production is governed by a host of factors such as latitude, climate, type of basin (edaphic effect), temperature, affect of cultural eutrophication and fish species composition, whether dominated by herbivores, omnivores or carnivores, as the food chain lengthens fish production decreases. Management skill also plays an important role as intelligent management alone can double the fish yield. The void between fish potential and actual fish yield in Ganga can be filled by evolving suitable managerial techniques pertaining to local needs.

3.2 By primary producers biomass estimation

The biomass was estimated as chlorophyll *a* concentration expressed as ($\mu g l^{-1}$) or mg m^{-3} (Khan *et al.*, 1996). It is generally assumed that water rich in primary producers gives a high yield as fish and a good correlation (r=0.72 to 0.98) between primary producers and fish yield has been observed in various studies (Muller, 1966, Wolny and Grygierek, 1972).

In river Ganga chlorophyll *a* biomass ranged between 4.32 ugl^{-1} in summer to 19.02 ugl^{-1} in winter (Table 5), the average being 10.32 ugl^{-1}. This variation may be ascribed to seasonal fluctuations in primary producers population and kind to which they belonged. Wetzel (1975) reported that pigments concentration and types in a sample depend on the kind and quantity of plankton in the water.

On the basis of concentration of chlorophyll *a* whole of the stretch may be classified under eutrophic category. This is also supported by presence of phytoplankters like *Microcystis aeroginosa, Asterionella formosa* and *Oscillatoria* spp. All the above forms are associated with enriched organic waters. Myxophycean forms are associated with enriched organic waters. Myxophycean flora are considered as poor food to fish because they (flora) are enveloped in a gelatinous sheath which is impregnable to fish digestive enzymes and are passed out as such outside of the body. Thus, depriving energy to fish resulting in poor growth of the fish. However, they are utilized through detritus food chain, thus lowering the fish yield.

Indirect assessment of algal biomass may also be estimated by assuming that chlorophyll *a* is 1.5% of dry weight and carbon is 50% of organic dry weight. Thus, cellular carbon may be estimated as 35 times of the chlorophyll contents (Golterman and Kouwe, 1980). After assessing carbon value from chlorophyll *a* estimation, the potential fish yield can be estimated following C^{14} methodology described somewhere else in this paper.

3.3 Methods based on physiography of the river-future approaches

A number of studies on these aspects are available on important rivers of the world but in context of Indian rivers only meagre information is available. Standing stock estimates based on multiple fishing to the exhaustion of stock, mark and recapture experiments, and poisoning a sample area with piscicides (Welcomme, 1985) have their own limitations and the assessment of the total fish population by these methods is not wholly reliable due to sampling errors, but the combination of several methods and the taking of samples over large areas improves the reliability of estimates. The water regime plays a vital role and population densities are generally much higher during the low water regime than at higher when the fish are dispersed. In most rivers flows are too swift during floods that it is not possible to get accurate samples and most estimates have to be made during low water. Within main channel the estimates showed a wide range of fluctuations and attempts have been made to correlate other factors responsible for this. In general there is a progressive increase in biomass as one moves downstream. Malaisse (1969, 1976) estimated 1.3, 26.1 and 31.7 kg km^{-1} biomass in successive downstream reaches for Luanza river, Zaire. Much work has been done on the fish populations of temperate rivers to determine their ichthyomass. Mann (1965) found a biomass of 659 kg ha-1 in the river Thames. Backiel (1971) estimatred that total ichthyomass in the Vistula river may be between 200 and 1100 kg ha-1 in the river (1961) and Huet and Timmermans (1963) obtained estimates in between 130 and 300 kg ha-1 of fish by electrofishing in Belgian rivers. For river Ourthe, Philippart (1978) obtained an estimate of 315 kg ha-1. For Ganga, Jhingran and Pathak (1988) have estimated potential ichthyomass varying from 50 to 208 kg ha^{-1}. The mean biomass fluctuations may be ascribed to various factors such as temperature or depth of water but the main correlate was with channel width and the relationship were established as

$$\text{Ichthyomass} = 6.9669\ x^{1.8456} \quad (r=0.919)$$

An inverse relationship was established by Timmermans (1961) and Cuinat (1971) for French rivers:

$$\text{Biomass (kg ha}^{-1}) = 41.3 + 16.4SW^{-1}$$

Where

S = slope and W = width.

Philippart (1978a) suggested a modified model for Belgian rivers:

$$B = 295 + 0.19A + 5.72T + 17.58S + 16.8W$$

Where A = alkalinity; T= mean temperature; S= mean slope and W=mean width. Such relationships have been established for temperate rivers other than those of Europe (Allen, 1951; McFadden and Cooper, 1962; Mahon et al., 1979).

Welcomme (1976) in his study pertaining to African rivers found a good relationship between the drainage basin area of the river system and the catch. Excluding catches from exceptionally large flooded areas, the analysis conformed the relationship

or $$C = 0.03A^{0.97} \ (r = 0.91)$$

$$C = 0.0032L^{1.98} \ (r\ 0.90)$$

Where C= catch in tonnes, A =area in km^2, and L = channel length in km.

On the basis of above relationship for the stretch of river Ganga from Kanpur to Rajmahal (1090 km), the estimate of catch comes about 3300 tonnes which seems to be a reasonable estimate. If average estuarine production of 30,000 t is added to riverine stretch catch a figure of 33000 t emerged for whole of the Ganga. It is comparable to other large rivers of the world (nile, 40,840 t, channel length 6669 km; Niger, 7750 t, channel length 4183 km; Benue, 12,570 t, channel length 1400 km; and Senegal, 16,000 t channel length 1641 km). Potential fish yield based on drainage area and rivers length of some large rivers of India have been estimated and the same is portrayed in Table 6.

3.3.4 Fluctuations in catch between years and prediction

The year to year variations in fish stock abundance seems directly linked to the degree of variability of the water regime (Welcomme, 1985). In an early study, Antipa (1910) concluded that the fish production of the Danube delta was directly proportional to the extent and duration of floods. A similar situations was supposed for tropical rivers by many workers including Wimpenny (1943) in the Nile prior to its complete control.

Higher catches during low water regime are well known as the shallower waters favour the capture of fish. Arias (Welcomme, 1985) found a linear relationship for the Magdalena river whole fishery as

$$Catch_y\ (T) = 171779.36 - 23706.17 * Water\ Level_y.$$

Annibal (1983) obtained a relationship as

$$Catch_y\ (kg) = 5693 * DDF_y - 164206\ 9\ (r=0.84)$$

for the Plagioscion fishery of the Lago do Rei of the Amazon basin, where DDF is an index of the amount of water remaining in the system during the dry season. The impact of DDF index on fishery of subsequent years was established in a study by the University of Michigan (1971) and the relationship was found as

$$C_y = 6630 + \log_e DDF_y\text{-}1\ (r=0.77)$$

which was originally formulated for the years 1956-71, has continued valid through 1983 (Hayward, 1984) despite the construction of two sets of flow control dams in the intevening period. Welcomme (1975) obtained a highly significant correlation between catch in year Y and the flood regime in the Y-1 for Shire river and the central Delta of niger river. Correlations with flooding in the same year were not satisfactory. As the fisheries of most trorpical rivers are based on fish that are one or two years old, it might be expected that the flood regime inthe both preceding years might exert an effect on catch of any year and analysis of data accordingly lead to improvement in correlations. As a result it was finally concluded that catch in year Y is best explained by a combination of the flood histories of the preceding years. Dunn (1982) gave graphical evidence for a correlation between an index of catch in year Y and of the frlood five years previously for the Hilsa fishery of Bangladesh.

Accurate predictions for future fish yield have been made based on intensity of floods. The accuracy of the prediction improved with the increase in number of years of data added to regression. For example in case of Niger 14 years data was needed to accurately predict future trends (Welcomme, 1985).

The methods suggested above are simple in nature and do not need sopisticated tools and specialized manpower. As a basic step, methods may be used after making required modifications according to Indian needs. Much more complicated methods such as (1) analytical models based on catch per unit of effort (2) based on length frequency (3) age structured analysis (4) Bayesian methods, etc. may be tried at a latter stage and in selected segments of rivers.

REFERENCE

Allen K. R. 1951. The Horokiwi stream; a study of trout population. *Fish. Bull. N. Z.*, 10, 231 p.

* Annibal S. R. 1983. Avaliacao bio-ecologico e pesqueira das "pescadas" (Plagioscion squamosissimus Heckel, 1840 e plaigioscion montei Soares, 1978) no "sistema Lago do Re 1" Ilha do Careiro-AM-Brasil. Manaus, INPA (Institute Nacional de Pesquisas da Amazonia) Msc Dissertation., pag. Var.

* Antipa G. 1910. Regiunea inundabila a Dunarii. Starea ei actuala si mijloacele de a o pue in valoare. Bucharest, 318p.

Backiel T. 1971. Production and food consumption of predatory fish in the istula river. *J. Fish Biol.*, 3, 369-405p.

* Cuinat R. 1971. Pricipaux caracteres demographique observes sur 50 rivieres a truite francaises. Influence de la pente et du calcium. *Ann. Hydrobiol.*, 2 (2), 187-207 pp.

Dunn I. G. 1982. The Hilsa fishery of Bangladesh, 1982: an investigation of its present status with an evaluation of current data, FAO, Rome, FI: DP/BGD/81/034, 71p.

Golterman H. L. And F. A. Kouwe 1980. Chemical budgets and nutrients. *In the functioning of freshwat er ecosystems,* eds. E. D. Lecren and R. H. Lowe Mc Connell, Cambridge University Press, 133-35 pp.

Gupta R. A. And R. K. Tyagi 1992. Analytical approach to analysis of fish stocks of the Ganga River System, *J. Inland Fish Soc. India*, 24 (2), 20-27pp.

Hayward P. B, 1984. Status report on the Kafue fishery. In *development on the Kafue Flats: the last five years. Kafue Basin Research project*, Lusaka, University of Zambia, 58-73p.

* Huet M. And J. A. Timmermans 1963. La population piscicole de la semois inferieur, grosse riviere Belge du type superieur de la zona a barbeau. Trav. Stn. Rech. Eaux. For. Groenendaal-Hoeilaart (D), 36, 31p.

Jhingran A. G. 1990. Restoration of fisheries in the Ganga River System Proposed Action Plan. Working paper for the meeting of the Technical Sub-Committee of the Co-ordination Committee on Restoration of Fisheries in the Ganga River System.

Jhingran V. G.., Ahmad, S. H. And Singh, A. K. 1989. Application of Shannon Weaver index as a measure of pollution of river Ganga at Patna, Bihar, India, *Curr. Sci.* 58: 717-720.

Khan, M. A., R. S. Panwar, A. K. Mathur, R. Jetly 1996. Final Report on "investigation on biomonitoring and ecorestoration measures in selected stretches of the rivers Ganga and Yamuna, submitted to Ganga Project Directorate, Ministry of Environment, Govt. Of India, New Delhi.

Mahon R., E. K. Balon and D. L. G. Noakes 1979. Distribution, community structure and production in the Upper Speed River, Ontario, A preimpoundment study. *Env. Biol. Fish,* 4 (3), 219-44pp.

* Malaisse F. 1969. Les facies d'un cours d'eau tropical: La Luanza (Haut-Katanga, Rep. Dem. Congo). *Verh. Int. Ver. Theor Angew. Limnol.*, 17, 956-1040pp.

* Malaisse F. 1976. Ecologie de la riviere Luanza, edited by J. J. Symoens. Bruxelles, Cercle Hydrobiologique de Bruxelles, 151p.

Mann K. H. 1965. Energy transformations by fish in the river Thames. *J. Anim. Ecol.*, 40, 155-190pp.

McFadden J. T. And E. L. Cooper 1962. An ecological comparison of six populations of brown trout (Salmo trutta). *Trans. Am. Fish Soc.*, 91, 53-62 pp.

* Muller H. 1966. Die planktische primar produktion in karptenteichen unter Einfluss Verschiedener phosphat-dungung. *Verhandlungender Internationalen vereinigunfgur Theoretische und Angewantle Limnologie,* 16.

Natarajan, A. V. 1989. Environmental impact of Ganga basin development on gene-pool and fisheries of Ganga river system. *Can Spec. Publ. Aquat. Sci.* 106: 545-560.

Odum H. T. 1962. Relationship between struct ure and function in the ecosystem. *Jap. J. Ecol.*, 12, 108-18pp.

Pahwa, D. V. * Mehrotra, S. N. 1966. Observations on fluctutions in the abundance of plankton in relation to certain hydrobiological condition of river Ganga. *Proc. Nat. Acad. Sci,* India B 36(2): 157-189.

Petts, G. A. 1989. Historical analysis of fluvial hydrosystems: 2-18 In G. A. Petts, H. Moller & A. L. Rox, editors. Historical change of large alluvial rivers: Western Europe. John Wiley and Sons, Chichester.

* Philippart J. C. 1978. Evaluation des resources piscicoles et halieutiques dans les rivieres du basin de la Meuse. Definition d'une methode d'etude. *Paper presented at the Colloque International problematique et question des eaux enterieueres, Liege*, 16-19 May 1978, 11p.

* Philippart, J. C. 1978a. Etude des bases ecologique de l'amenagement piscicole de l'Ourthe, Grosse riviere de la zone a barbeau. Rep 8. Commission provinciale de liege du Fonds Piscicole, Liege, Universite de Liege.

Strickland J. D. H. and T. R. Parsons 1968. A practical Handbook of water analysis. *Bull. Fish. Bd. Can.* 167, 311 p.

* Timmermans J. A. 1961. La population piscicole de l'Eau Blanche. Petite riviere du type superieur de la zone a barbeau. *Trav. Stn. Rech. Eaux For Groenendaal Hoeilaart (D)*, 30, 16p.

University of Michigan 1971. The fisheries of the Kafue River Flats, Zambia, in relation to the Kafue Gorge Dam. Report prepared for the FAO/UN acting as executing agency for the UNDP. Ann Arbo, Michigan, University of Michigan Press, *FI: SF/ZAM* 11: Tech. Rep. 1, 161p.

Welcomme R. L. 1975. The fisheries ecology of African flood-plains. *CIFA Tech. Pap.*, 3, 51p.

Welcomme R. L. 1976. Some general and thoretical consideration on the fish yield of African rivers. *J. Fish Biol.*, 8, 351-64.

Welcomme R. L. 1979. *The Fisheries Ecology of Floodplain Rivers*. London, Longman. 317p.

Welcomme R. L. 1985. River fisheries. *FAO fish. Tech. Pap., 262*, 330p.

Wetzel R. G. 1975. *Limnology*, W. B. Saunders Co., 743pp.

Wimpenny R. S. 1934. The fisheries of Egypt. *Sci. Prog. Twentieth centur., Lond.*, 29(114), 210-27pp.

Wolny P. And E. Grygierek 1972. Intensification of fish ponds production. *In productivity problems of freshwat ers*, Eds. Z. Kajak and A. Hillbricst-Ilkonska, Warsaw and Krakow, Polish Scientific Publishers, 563pp.

Jhingran, V. G., Ahmad, S. M. & Singh, A. K. 1989. Application of shannon-weaver Index as a measure of pollution of river Ganga at Patna, Bihar, India. *Curr. Sci.*, 58: 717-20.

Natarajan, A. V. 1989. Environmental impact of Ganga basin development on gene-pool and fisheries of Ganga river system. *Can. Spec. Publ. Aquat. Sci.*, 106: 545-560.

* Indicates references not consulted in original

Table 1. Physico-chemical parameters of the water of river Ganga

Year	DO	pH	CO_2	TA	Sp. Cond.	TDS	Chlo-rides	Phos-phate	Nitrate	Silicate
Kanpur										
1960	7.80	7.90	2.20	148	328	170	10.0	0.14	0.14	11.30
1987-88	2.70	7.20	8.20	160	565	278	15.0	0.15	0.16	21.8
1994-95	7.26	8.39	2.85	197.16	366.5	183	-	0.11	0.07	10.60
Allahabad										
1960	8.40	8.10	1.50	142	285	148	12.1	0.15	0.17	11.9
1974	7.60	8.0	2.4	167	375	188	7.43	0.13	0.18	14.8
1987-88	8.0	8.12	0.68	171	398	198	19.0	0.18	0.22	18.1
1994-95	9.2	8.40	Nil	194	451	225	-	0.11	0.07	8.01
Varanasi										
1960	7.0	8.0	3.1	127	257	130	21.0	0.04	0.10	8.3
1987-88	7.6	8.1	0.6	179	436	2.6	25.0	0.22	0.17	12.8
1994-95	8.09	8.21	1.1	181	463	231	-	0.16	0.16	9.39
Patna										
1960	7.9	5.0	142	300	148	10.7	0.10	0.14	10.6	
1987-88	7.8	7.9	2.0	140	283	08	20.2	0.21	0.20	25.2
Bhagalpur										
1960	6.9	8.2	2.3	131	268	234	11.2	0.09	0.14	9.3
1987-88	7.2	8.1	2.5	142	310	158	28.3	0.12	0.18	13.5

Table 2. Plankton composition and average population (ul^{-1}) of primary producers in Ganga

Centre	Year	Plankton composition			Total U/l
		Bacllariophyceae	Chlorophyceae	Myxo-phyceae	
Kanpur	1960	77.9	15.8	6.3	85.21
	86-87	77.7	7.9	14.2	26.18
	1994-95	*40.0	27.0	3.3	1336
Allahabad	1960	72.3	22.9	4.8	6608
	86-87	51.1	35.8	12.4	5676
	1994-95	*28.43	51.06	7.56	1507
Varanasi	1960	83.5	11.4	5.1	2323
	1986-87	70.6	23.4	6.9	3765
	1994-95	46.1	26.2	6.21	3300
Patna	1960	48.3	46.8	4.9	143
	1986-87	37.4	15.0	11.6	850
	1994-95	NA	NA	NA	919
Bhagalpur	1960	25.7	70.0	4.3	557
	1986-87	24.0	69.5	6.5	1027
	1994-95	NA	NA	NA	1251

* percentage of zooplankton excluded

Table 3. Production of macrobenthos (um^2) in a stretch of river Ganga

	1960	1995
Kanpur	3476	1430
Allahabad	1121	702
Varanasi	880	1115
Patna	1593	1600
Bhagalpur	218	230

Table 4. Energy transformation, fish production potential and extent of utilisation of potential fish yield in river Ganga at different centres

Centre	Year	Av. Carbon production	Av. Rate of energy transfor-mation	Photosynthetic efficiency	Fish production potential	Actual harvest	Extent of utilisation
		$mgCm^{-2}$ day^{-1}	$calm^{-2}$ day^{-1}	%	$kgha^{-1}$ yr^{-1}	kgh^{-1} yr^{-1}	%
Kanpur	1987-88	234.5	1419	0.077	50.10	-	-
Allahabad	1974	-	4501	0.241	160.44	21.33	13.29
	1987-88	730.5	5906	0.316	208.70	28.69	13.74
Varanasi	1987-88	589.1	3243	0.173	112.20	-	-
Patna	1987-88	293.0	3534	0.190	122.40	30.84	25.19
Bhagalpur	1972	-	3586	0.186	120.68	31.64	26.30
	1987-88	420.0	4124	0.220	142.80	36.75	25.73

(After Jhingran & Pathak, 1988)

Table 5. Chlorophyll a concentration (ugl^{-1}) in water samples or river Ganga

Centre							
		Winter	Summer	Post Monsoon	Winter	Summer	Post Moonsoon
Kanpur	US	11.44	9.35	18.68	19.02	12.34	10.12
	DS	18.26	11.25	13.12	17.68	10.88	11.18
Allahabad	US	12.38	7.54	11.22	11.44	8.32	8
	DS	10.04	8	8.62	10.68	9.12	11.2
Mirzapur	US	10.32	7.3	10.02	10.66	8.16	7.6
	DS	9.12	5.2	8.42	9.88	6.4	10.22
Varanasi	US	9.76	8.44	10.26	10.004	8.12	12.66
	DS	9.28	10.7	9.38	10.18	8.64	9.04
Ghazipur	US	11.44	7.4	10.64	11.28	8.4	12.89
	DS	10.92	4.32	8.88	9.66	5.86	10
Average		11.3	7.95	10.92	12.05	8.86	10.29

US-upstream, DS-downstream

Table 6. Showing the potential fish yield from Indian rivers based on their length and basin area

River	Length (km)	Basin area (million km^2)	Catch	
			Area based tonnes	Strem length based tonnes
Himalayan river				
Ganga	2525	0.88	17443	17142
yamuna	1376	0.37	5243	8588
Brahamaputra	800	0.19	1782	3958
East Coast rivers				
Godavari	1465	0.31	5936	6364
Krishna	1401	0.26	5434	5365
Cauvery	800	0.09	1791	1917
Mahanadi	880	0.14	2088	2943
West coast rivers				
Narmada	1312	0.10	4844	2124
Tapti	720	0.06	1454	1294
Mahi	533	0.02	802	446

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TIME SCALE CHANGES IN WATER QUALITY OF RIVER GANGA AND ITS IMPACT ON PRODUCTIVITY

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The Ganga, a symbol of purity and an inspiration to millions, is today being chocked by the tons of dangerous chemicals and organic wastes which are emptied into it every day. The river which has served man faithfully for ages fed him, watered his fields and washed his sins is now a carrier of death and diseases.

Almost all the sewage of all the cities situated along the river is discharged into river which is responsible for about 75% of total pollution load. Further discharge of untreated industrial effluents and discharge from farms pesticides and fertilizers run off from the land-flow eventually into the river. In recent decades rapid development of agriculture and industry put severe strains on the river and to an extent resulted in some degradation of its quality.

The river has a total length of 2525 kms and a basin covering nearly 1/4 of the total land mass of the country is unfortunately dangerously polluted. It drains an area 861404 km^2 and over 37% of Indian's population lives in the Ganga basin which is putting strains as expected on the most sacred river. Due to gross pollution the flora and fauna of the river is dwindling very fast and water quality is being reduced to such an extent that for long stretch the "Purest liquid" is no more pure and not fit for human consumption.

Thus problems of pollution of water have not only surfaced but begun to assume serious dimensions in certain stretches of long course of the river, which is evidenced by spatio-temporal variations in nutrients and primary productivity. Primary productivity is the final out course of the metabolic actions of Abiotic and biotic parameters together depicts functional aspects of the river.

The main sources of pollution in river Ganga are industrial, municipal and agricultural effluents. The total quantity of frehswater being used in the basin is estimated at 142.6 million cubic metres, out of which 20% is finally discharged as waste water. Waste water generated in the irrigation sector is 26,896 million cubic metres compared to 1528 million cubic metres from the industiral, domestic and other uses.

Industiral effluents

Survey of Central Pollution Board in 1981 showed that 317 major industrial units operated all along the points of Ganga and its tributaries and only 30% of the units followed some control measures or other to contain the pollutional hazards. The total urban organic load due to industrial effluents expresed in terms of BOD has been estimated at 1.17 million kg day^{-1} for Ganga basin with UP accounting for more than three-fourth of the load.

Municipal effluents

The sewage generated in the 692 cities and large towns all along the Ganga basin is estimated at 1528 million cubic metres. The total load in Ganga basin from the urban centre is 2.504 million kg day^{-1} of which, the share of domestic sewage is 1.34 million kg day^{-1}. Uttar Pradesh having 256 urban centres contribute 31% of the total BOD load. Of the 692 urban centres in Ganga basin, at least 100 of them discharge untreated sewage into river. Sewage wastes and effluents receive by Ganga at Haridwar, Farukhabad, Mirzapur and Bhagalpur are 16 million litre day^{-1} while Allahabad and Varanasi receive 100 mld^{-1}, the load increases to 154 mld^{-1} at Patna and 275 mld^{-1} at Kanpur.

Impact of sewage pollution

The major adverse impacts of sewage pollution are deoxygenation, high BOD load, rapid eutrophication and accumulation of heavy metals in the environment. Sharp fall in dissolved oxygen (DO) in water puts the biotic communities under severe stress. While some species can tolerate a wide range of DO, many communities are highly sensitive to this parameter.

The agriculture sector in the Ganga basin drains fresh water to the tune of 134484 million cubic metre and generate waste discharge to the extent of 26,896 million cubic metres. It affects the riverine environment by an increase in salt and alkali levels in water, increasing the nutrients load due to residual effects of chemical fertilizers and accumulation of pesticides in the environment.

Nutrients

Nitrogen content of the fertilizers used in the Ganga basin is estimated at 887133 t followed by phosphorus (173445 t) and potassium (91 427 t). It is generally estimated that 10 to 15% of the nutrients added to the soils eventually find their way to the surface flow.

Pesticides

About 2573 t of pesticides are used in an year in the Ganga basin. Higher accumulation of DDT was 65-150 ppm recorded in molluscs followed by fish (31-460 ppb), plankton (15-150 ppb) and sediments (17-80 ppb). On the basis of ambient water, the bio-magnification values were 2500 in plankton, 3600 in gastropod molluscs, 7500 in fish and 15800 in bivalve molluscs. Among the pollutional hazard from the agriculture sector, the damage caused by the pesticides is the most lethal and interminable to the environment. The organochlorine pesticides are lipophilic, extremely toxic and non-biodegradable. Like heavy metals, they assume alarming proportions as they are prone to be biologically magnified and accumulated in fish, posing serious threat to the fish eating public. Most of the commonly used pesticides in India like DDT, BHC, endosulfan, ethyl parathion, methyl parathion, dimethorate, phosphamidon, carbaryl and 2,4-D have been screened to evaluate their toxicity. All of them have been found to be toxic to fish food organisms and fish populations. Sub-lethal concentration of DDT and BHC adversely affect the fish at tissue level. Damage of liver cells, besides decline in growth, RBC count, Hb, and PVC level in blood has been noticed in carps (*L. rohita* and *C. mrigala*).

Heavy metals

Heavy metals residues have been detected in the tissues of fishes, molluscs and crabs. Highest bioaccumulation detected in Hooghly estuary is that of Zn (295.1 ppm) in the kidney of fish followed by gonad (146.8 ppm). Ambient water in main Ganga around Kanpur has shown higher metal accumulation. Heavy metals were found in molluscs tissue in river Ganga. Accumulation of Zn in gonad at a high level (146.8 ppm) was found to be detrimental to fish health affecting its productive potential in the long run. Fish food organisms such as Cyclops and Daphnia are more sensitive to metals.

Thermal pollution

The adverse effect of heated discharge into the river causes mortality of fishes and absence of aquatic life within 50 m of dishcarge point owing to high temperature (48-53°C) of effluents. The heated dishcarge pushes up temperature by 8-10°C which may cause mortality of fish and fish food organisms. Temperature also exerts direct influence on toxicity. Thick mat of fly ash accrued on the bottom over years may seal the nutrients away from the water and thereby affecting productivity. The power plant emit harmful gases like carbon monoxide, sulphur dioxide and enormous quanity of fly ash into the atmosphere besides discharging heated wastes water, thus polluting both air and water. The discharge may destroy or reduce fish food organisms and breeding grounds.

Water quality changes

The physico-chemical parameters of river Ganga during sixties to that of 1995 in the middle stretch *viz.*, Kanpur, Allahabad, Varanasi, Patna and Bhagalpur have been presented in table. Although nummber of parameters have been studied but only those parameters were critically studied which showed significant variation over the years.

pH in Ganga did not change much since 1960 except for a slight reduction in the upper zone possibly due to a high buffering capacity of Ganga water.

Dissolved oxygen: A signficant change in the DO contents was observed almost at all the centres. These changes were studied by comparing the results obtained at the point above the city with the corresponding results at the point below the city in order to detect decisively the effect of discharge thrown by the city in the river. The study indicated that the water quality deteriorated at Kanpur and Varanasi upto 1992 and improved thereafter. The increase in organic load in Ganga due to discharge of sewage wastes can be seen even at Kanpur where DO level has reduced from 7.8 mg^{-1} to 2.7 mg^{-1} (1987). The decline of DO was followed by corresponding increase in CO_2 (2.2 to 8.8 mgl^{-1}) and BOD (241.8 mgl^{-1}). On certin occasion DO was found to be absent and CO_2 content reached to 36.0 mgl^{-1}.

Total alkalinity at Kanpur, Allahabad and Varanasi in middle stretch was signficantly higher during 1987 indicating the impact of industrial pollution. However, during subsequent years the contents drop signficantly and almost attained the same levels are recordded at the above city level.

The zone between Kanpur and Varanasi exhibited high phosphate and nitrogen contents particularly at the Ganga below the cities. The above nutrients level below the city indicated aquatic pollution. This trend continued upto 1992 and thereafter the phsophate level particularly came down indicating considerably improvement of the Ganga. The phosphate level was also low at Patna and Bhagalpur, indicating better environment. The nitrate nitrogen was generally under limit in lower stretch. Silicate values increased considerably at all the centres.

Chlorides increased from 10.0 to 25.6 mgl^{-1} in Kanpur, 12.0 to 24.0 mgl^{-1} in Allahabad, 21 to 30 mgl^{-1} in Varanasi, 10.7 to 22.0 mgl^{-1} in Patna and 11.2 to 28.3 mgl^{-1} in Bhagalpur which may be due to discharge of sewage into the river. The rise in Sp. conductivity and total dissolved solids, the two interrelated parameters suggests a radical change in chemical status due to heavy discharge of organic wastes.

Heavy metal study

Kanpur

Water: The average concentration of Zn, Cr and As ranged between 24.6 and 42.4 μgl^{-1}, 1.61 and 3.4 μgl^{-1} and 9.8 and 23.12 μgl^{-1} in polluted water respectively at Kanpur centres, indicating the maximum concentration of these metals at Jajmau (sewage) and lower at tannery from

1989-90 to 1992-93. The value of metals also reduced after 1989-90 at all the centres.

Soil sediments: The average (yearly) concentration of Zn, Cr and As fluctuated between 62.1 and 88.1 μgg^{-1}, 9.4 and 11.7 μgg^{-1} and 10.8 and 19.81 μgg^{-1} of soil respectively at Kanpur during 1989-90 to 1992-93. These values were recorded lower during 1992-93 indicating less deposition of organic matter at OF point.
Fish tissue: The concentration of Zn, Cu and As ranged from 14.54 to 30.6 μgg^{-1}, 2.32 to 6.03 μgg^{-1} and 1.8 to 4.74 μgg^{-1} in fish tissue (*Puntius* sp. and *C. reba*) respectively at Kanpur in 1989-90.

The average concentration of Zn, Cr and As ranged from 8.6 to 15.8 μgg^{-1}, 1.8 to 3.1 μgg^{-1} and nil to 1.8 μgg^{-1} in bottom biota (*Tubifex* only) during 1990-91 and 1991-92 indicating the highest concentration of Zn and Cr at Jajmau.

Allahabad

Water: The average yearly concentration of Zn, Cr and As ranged from 28.8 to 34.0 μgl^{-1}, 1.5 to 4.0 μgl^{-1} and 12.0 and 17.74 μgl^{-1} respectively indicating higher concentration of Zn and As at Mehdaurighat (sewage) whereas Cr was higher at Mavaiya (industrial impact). The concentration of these metals showed reduction during subsequent years except Cr from 1989-90 onwards.

Sediment: The concentration of Zn, Cr and As ranged from 61.0 to 80.87 μgg^{-1}, 8.82 to 15.8 μgg^{-1} and 10.0 to 16.36 μgg^{-1}, respectively from 1989-90 to 1992-93, showing the same trend like that of polluted water.

Fish tissue: The concentration of Zn, Cr and As fluctuated between 14.6 and 28.27 μgg^{-1}, 2.71 and 3.68 μgg^{-1} and 1.1 and 2.3 μgg^{-1} respectively in fish flesh of *C. reba* and *Puntius* sp. The concentration of metals did not show any definite trend of its fluctuation over the years.

Zn, Cr and As was detected between 11.4 and 13.8 μgg^{-1}, n.d. and 3.3 μgg^{-1}, n.d. and 2.2 μgg^{-1} of bottom biota (*Tubifex*) respectively from 1990-91 to 1992-93.

VARANASI

Water: The concentration of Zn, Cr and As fluctuated between 11.2 and 44.2 μgl^{-1}, n.d. and 3.4 μgl^{-1} and 7.4 and 29.6 μgl^{-1}, respectively at Nagawa and Rajghat from 1989-90 to 1992-93. The concentration of those metals were quite high at Rajghat. The impact of effluent was alarming at Rajghat as reflected by their values.

The concentration of metals in sediment, fish tissue and bottom biota were also high at Rajghat all the years of observation due to high load of pollution in this stretch.

Primary productivity

Kanpur

The average yearly gross and net carbon production fluctuated between 103.12 and 427.5 $mgCm^{-3}hr^{-1}$ and 37.5 and 313.5 $mgC\ m^{-3}hr^{-1}$ respectively at above out fall (AOF) and below out fall (BOF) of Bhagwatghat (textile) indicating highest production during 1991-92 (BOF). The average production was higher at AOF from 1986-87 to 1990-91 whereas it was highest at BOF during 1991-92 and 1992-93. This may be due to increase in number of primary producers.

Allahabad

Gross and net production at Mehdaurighat (BOF) ranged between 78 and 149 mgCm-

^{3}hr^{-1} and 40 and 119 mgCm^{-3}hr^{-1} respectively, showing highest production during 1990-91 and 1992-93. Respiration was 46 and 82 mgCm^{-3}hr^{-1}.

Gross and net production at non-polluted centres were 112 and 167 mgCm^{-3}hr^{-1} and 58 and 84 mgCm^{-3}hr^{-1} respectively from 1986-87 to 1992-93. Highest productin was found in 1991-92 which shows continuous increase from 1984-89 onwards and decreased slightly (163 mgCm^{-3}hr^{-1}) during 1992-93. Respiration was found in the range of 61 and 104 mgCm^{-3}hr^{-1}. Gross and net production ranged from 103 to 172 mgCm^{-3}hr^{-1} and 53 and 102 mgCm^{-3}hr^{-1} respectively at Mavaiya (Allahabad) from 1988-89 to 1992-93. Both gross and net production were found highest during 1990-91 showing incresing trend from 1988-89 onwards.

Varanasi

Primary production was measured at centres *viz.*, Assi/Nagwa and Rajghat. Gross and net production were 66 and 142 mgCm^{-3}hr^{-1} and 24 and 126 mgCm^{-3}hr^{-1} respectively from 1986-87 and 1992-93 at Nagwa indicating both values of production were high during 1989-90 at BOF. Higher vaues of production at this centre was recorded upto 1989-90 and later it was low. It may be attributed due to diversion at Assi nala towards Nagawa side. Respiration was 19 and 86 mgCm^{-3}hr^{-1} at Nagwa. Gross and net production at Rajghat (sewage wastes) was 19 and 140 mgCm^{-3}hr^{-1} and 12 and 119 mgCm^{-3}hr^{-1} respectively from 1987-88 to 1992-93 at AOF and BOF. As oxygen was completely utilized by consumer, no production was observed at BOF during 1991-93. Least production was also observed at BOF during 1989-90 because of the impact of sewage pollutants upto this centre.

The primary production during 1995 at Kanpur, Allahabad, Varanasi and Patna were recorded 156 mgCm^{-3}hr^{-1} (GP), 78 mgCm^{-3}hr^{-1} (NP) and 94 mgCm^{-3}hr^{-1} (Respiration) at Kanpur, 110 mgCm^{-3}hr^{-1} (GP), 47 mgCm^{-3}hr^{-1} (NP) and 65 mgCm^{-3}hr^{-1} (Respiration) at Allahabad, 125 mgCm^{-3}hr^{-1} (GP), 78 mgCm^{-3}hr^{-1} (NP), 56 mgCm^{-3}hr^{-1} (Res.) at Varanasi and 38 mgCm^{-3}hr^{-1} (GP), 26 mgCm^{-3}hr^{-1} (NP) and 38 mgCm^{-3}hr^{-1} (Res.) at Patna.

Productive potential and energy dynamics

The productivity potential of any water body depends on efficiency with which primary producers transform light energy into potential chemical energy. Thus any change in the producer population or its energy transformation rate will have a direct bearing on the productivity of the system. Considserable differences have been noted in respect of the energy transformation efficiency at various zones. At Kanpur the rate was very low 1.419 cal m^{-2}d^{-1} with photosynthetic efficiency being 0.77%. The rate of variation 136 (0.007%) to 4.156 Cal m^{-2}d^{-1} (0.371%) clearly shows the production potential of Ganga has decresed over the years due to deterioration in water quality. From Allahabad to Bhagalpur, there is considerable improvement in range of energy transformation by producers. Over two decases studies at Allahabad and Bhagalpur have shown that the efficency was gradually increased over the years. On an average of 0.259% of the incident light on the surface of river is fixed in this stretch. The rich phytoplankton observed during 1960 clearly reflect that the energy transformation rate must have been very high, especially at Kanpur but the potential has considerably declined over the lapse of three decades.

It may be concluded that the water quality parameters *viz.* pH, DO, alkalinity, nitrate and phosphate have shown significant improvement during 1994-95. The effect of other parameters *viz.* Sp. conductivity, TDS, hardness and silicate were not very significant. The concentration of heavy metals didn't show any definite trend in fish tissues though in sediments their values were higher. In respect to primary productivity it may be concluded that their values showed enhanced trend, but fish yield (as per report) were not reciprocal to these values and energy transfer efficiency. Reasons need investigation, but author is of the opinion that volume of water plays major role in not getting the yield.

Water quality in river Ganga over the years (average values)

Centre	Year	pH	DO mgl^{-1}	Alkalinity mgl^{-1}	CO_2 mgl^{-1}	Sp. conductivity $\mu mhoscm^{-1}$	TDS mgl^{-1}	Hardness mgl^{-1}	Chlorides mgl^{-1}	Silicate mgl^{-1}	Nitrate mgl^{-1}	Phosphate mgl^{-1}
Kanpur	1960	7.9	7.8	148	2.2	323	170	70	10.0	11.3	0.14	0.14
	1987	7.6	5.2 *	310	8.2	561	278	86	15.0	15.6	0.41	0.15
	1992	7.6	6.0 **	89	–	266	132	105	25.6	6.6	0.25	0.26
	1994	7.8	6.8	149	–	296	147	94	25.0	7.2	0.12	0.12
	1995	8.2	6.6	152	–	448	220	160	22.0	8.0	0.21	0.02
Allahabad	1960	8.1	8.4	142	1.5	285	148	68	12.1	11.9	0.17	0.15
	1987	8.1	8.0	264	0.7	398	198	70	19.0	18.1	0.22	0.18
	1992	7.8	8.4	179	–	438	218	–	–	6.9	0.22	0.22
	1994	8.3	8.0	162	–	382	190	91	–	6.8	0.12	0.13
	1995	8.4	7.4	146	–	412	204	140	24.0	4.0	0.22	0.01
Varanasi	1960	8.0	7.0	128	3.1	257	129	68	21.0	8.3	0.10	0.04
	1987	8.1	7.6	265	0.6	436	216	91	25.0	12.8	0.17	0.22
	1992	7.5	7.1	217	–	467	232	–	30.0	7.0	0.28	0.28
	1994	8.0	8.4	184	–	390	194	94	28.2	7.0	0.12	0.12
	1995	8.2	7.4	140	–	426	213	141	24.5	7.0	0.21	0.01
Patna	1960	7.9	7.0	142	5.0	300	148	76	10.7	10.6	0.41	0.10
	1987	7.9	7.8	150	2.0	283	138	125	20.2	25.2	0.20	0.21
	1990	8.0	7.1	146	0.6	276	144	–	22.0	–	–	–
	1995	8.8	6.8	159	–	442	220	132	22.0	7.0	0.17	0.01
Bhagalpur	1960	8.2	6.9	131	2.3	268	134	74	11.2	9.3	0.14	0.09
	1987	8.1	7.2	142	2.5	310	158	98	28.3	13.5	0.18	0.12

* Below city 2.7

** Below city 4.3

BIOMONITORING OF RIVERINE SYSTEM AND ANTHROPOGENIC PRESSURE

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INTRODUCTION

Rivers have been abode for wide bio-diversity catering needs *viz.* drinking water, recreation, irrigation, navigation, hydro-electric generation and raising fish and hence fostering civilization at their banks since long. In present scenario pollution is an axiom which is adversely affecting the riverine system throughout world, right from their rhithron to metapotman zones. Bizarre hydraulic features particularly soil erosion and anthropogenic pressure accelerate trophic and saprobic cascades from crypto to eutrophic condition, which finally affect biological webbbings right from micro to macrolevel, disturb the intricate bio-organismic cycle and thus hampers the desired tertiary product `fish' and other biota. It has been felt essential to restore pristine condition of rivers, protect and preserve their biodiversity for the benefit of mankind. To achieve the goals river management is must, and in this approach to monitor river for controlling pollution is first and foremost.

Monitoring pollution

To effectively manage river receiving polluting substance the following information are needed:

- the substances entering the river and their quantities, source and distribution.

- the effects of these substances within the river.

- trends in concentration and effects and the cause of these changes.

- How far these inputs, concentration affects and trend can be modified and by what means at what cost?

Ecological principles that are relevant for developing rational integrated approach to management are must. Since biota reflects functional characteristics of river by depicting means of hierarchy which begins with microbial decomposers, progress through primary producers and invertebrates (consumers) ends with fish and other large aquatic animals, it is, therefore, logical to monitor river by means of bio-indicators which will depict fault if any in the biotic intricacies due to pollutants.

Bio-indicators indicate the effect of the organic, inorganic nutrients, toxicants, physical factors, compatibility, relation of prey and predators. Some times they bring changes in their morphology and certain other characters for their survival. Some organisms may be good bio-indicators provided their morphology, frequency of occurrence, abundance, phenology and ecology are thoroughly studied in normal condition and variations therein due to change is nutrients condition (trophication), and putriscible organic matter (saprobication). After pooling these information together, bio-indicators may be categorised for depicting different trophic and saprobic conditions.

RELATION OF SAPROBITY TO TROPHICITY

Saprobity and trophicity are independent factors and must be studied separately in their development and interferences. Their features have been depicted in Table-1.

IMPORTANCE OF THIS STUDY

In view of the growing need of biological monitoring, the International Union of biological Science (IUBS) decided in its XXI general assembly, held in Ottawa in 1982 to initiate a World wide programme for identifying and applying biological indicators in environmental monitoring especially to evaluate the effects of hazardous substances. Further Indian National Science Academy (INSA) in association with the IUBS, organised an International Symposium on biological monitoring of the state of environment (bio-indicators) from 11-13 Oct, 1984 at New Delhi. Subsequently, several other conferences organised on International and National levels time to time.

CRITERIA FOR GOOD BIO-INDICATORS

Good bio-indicators should possess following criteria :

- should commonly be available.
- should be very sensitive.
- should have long life span.
- should easily absorb toxicant of even lower concentration and retain or accumulate the toxicants for long period in its body.
- should be sedentary, sessile or less mobile.
- should be endemic, because diversity of a continent may differ from other continents due to changes in their geographical conditions.

Some bio-indicators for survival and existence in the community during inter species competition, certain morphometric changes occur viz., Cyclomorphosis in rotifers (*Brachionus calyciflorus*) and Cladocera (*Daphnia* sp.) etc. may be minutely observed.

Considering qualities of good bio-indictors mentioned above benthic invertebrates are most ideal bio-indicators for monitoring fluviatile aquatic ecosystem including rivers. Though other communities viz. Phytoplankton, Zooplankton, Periphyton have also been used for bio-monitoring river water quality.

BIO-INDICTORS

i) Producers

Algae constituting phytoplankton as bio-indicators have been categorised by author as follows:

Gonatozygon kinhani, Tribonema spp., *Hormidium* spp., *Bumillaria* as bio-indicators of Oligotrophic and Oligosaprobic water. *Synedra ulna, Merismopedia Kutzing, Tabellaria* sp., *Pediastrum ovaum, Closterium aciculare* sp., *Scenedesmus quadricauda, Ankistrodesmus* sp., *Kirichineriella* sp. are indicators of *Y. eutrophic* and *Y.mesosaprobic* water. *Euglena viridis, Scendesmus acuminatus, S.opoliensis, Synedra ulna, Nitzschia palaea, Ceratium* sp., *Cosmarium* sp. and *Fragilaria* sp., *Hydrodictyon* sp. are indicators of ß- eutrophic and ß- mesosaprobic water. Chlorella vulgaris, *Scenedesmus obliquus, Euglena acus, Eunotia praerupta, Pinnularia gibba, Volvox globata* are indicators of α- eutrophic and α-mesosaprobic water. *Spirulina princeps* more than 10000 ul^{-1}, *Phacus* sp., *Trachlemonas* sp., *Eudorina* sp., more than 100 ul^{-1} and *Oscillatoria* sp. more than 10000 ul^{-1} are indicators of Hyper eutrophic and polysaprobic water such condition is rarely seen in riverine zone, except at outfall where the effluents (from tanneries, sewage, paper pulp, sugar factories) are discharged in river. *Gloeotrichia* sp., *Rivularia* sp., *Treubaria varia, Tetraedon hemisphere* are indicators of wetlands and sewage doped water heavily infested with macrophytes, *Dinobryon* sp. indicate highly enriched silica content water. With lesser nutrients N & P, *Lyngbya* sp., *Chaetophora* sp. and *Amphora ovalis* are indicators of acidic water.

Amongst Byophyte- Hepaticeae *viz. Riccia* sp., *Marchantion* sp. and mosses are found in damp littoral zone of river with enriched nutrients and Azolla (Pteridophhyte) with Anabaena are indicators of water rich in nitrate nitrogen. Ecological tendencies of Phytoplankton for categorizing algae as bio-indicators: Laal et al (1994) gave a concise information on the role of phytoplankton in monitoring water quality.

Periphyton

Periphyton acts as producers and fish browse over them. Periphyton facilitates objective description and comparison of community structure, and in theory, their use obviates the formidable alternative prospects of investigating each constituent species population in relation to abiotic factors. The structure of lotic periphyton or aufuchs community is sensitive to environmental conditions and in some cases have been found useful in characterising the biotic responses. Species diversity of periphyton as an index of pollution of river Ganga has been reported (Laal et al. 1982). Whiton & Kelly (1995) and Kelly et.al. (1995) also utilized periphyton for monitoring pollution. Pennales in general indicate eutrophic water, higher their population indicate higher degree of eutrophicity, centrals are usually indicator of oligotrophic, oligosaprobic water.

Characteristic algal association of digo-rophic and eutrophic lakes (Mason, 1983)

	Algal group	Examples
Oligotrophic lakes	Desmid plankton	*Staurodesmus, Staurastrum*
	Chrysophycean plankton	*Dinobryon*
	Diatom plankton	*Cyclotella, Tabellaria*
	Dinoflagettate plankton	*Peridinium, Ceratium*
	Chlorococcales plankton	*Oocystis*
Eutrophic lakes	Diatom plankton	*Asterionella, Fragilaria ordonesis, Stephanodiscus astraea, Melosira granulata*
	Dinoflagellate plankton	*Peridinium bipes, Ceratium Glenodinium*
	Chlorococcales plankton	*Pediastrum, Scendesmus* sp.
	Myxophyceae plankton	*Anacystis, Aphanizomenon, Anabaena*

Consumers

Zooplankton

Rotifers are small group of metazoa predominantly freshwater zooplankton, due to their ubiquity, diversity and substantial contribution in food web in aquatic ecoystem serve as good bio-indicators for water quality more authentic for monitoring pollution (Laal and Karthikeyan, 1993), A/c to author *Floscularia ningens* and *Rotaria neptunia* are indicators of sewage doped water bodies infested with macrophytes (hyper eutrophic and polysaprobic conditions). *Porales* sp. is indicator of α-eutrophic and α-mesosaprobic water. *Testudinella* sp.is indicator of ß-eutrophic and polysaprobic conditions. *Mytilina ventralis* is indicator of acidic water (eutrophic and mesosaprobic conditions). *Brachionus angularis* and *B. angularis* Var *Bidens* are indicators of α-eutrophic and α-mesosaprobic water. Their occurrance coincide with abundance of *Euglena gracilis, E. viridis, Scenedesmus accuminatus, Microcystis aeruginosa, Chlorella vulgaris* and *Oscillatoria* sp. *Brachionus havaenesis* is indicator of hyper eutrophic and polysaprobic water level when its population is below 100 ul^{-1},it is an indicator of α-eutrophic and α-mesosaprobic water. *B.quadridentatus* and *B. caudatus* are indicators of ß-eutrophic and ß-mesosaprobic water. *B. rubens* is indicator of hyper eutrophic and polysaprobic water bodies. *Asplanchna* sp. is indicator of α-eutrophic and α-mesosaprobic water and found in association with memebers of chlorococcales. *Lapadella ovalis, platyas patulus* are indicators of hyper eutrophic and polysaprobic water viz. wet lands or swamps. *Polyarthra ehrenberg, Synchaeta grandis, Keratella hiemalis* are indicators of oligotrophic and oligo saprobic water. *Keratella tropica, K. cochlearis, B. calyciflorus, Anuraeopsis fissa, Filinia longispina, F. opolienis* are having wide tolerance. They occur in almost all types of water, their population increase with increase in degree of trophicity and saprobity.

Members of cladocera are useful indicators. *Daphnia* sp., *Bosmina longirostris* are indicators for oligotrophic and oligo saprobic water. *Chydorus* sp., *Macrothrix* sp. and *Alona* sp. for α-eutrophic and α-mesosaprobic water infested with macrophytes. *Moina* sp. for hyper eutrophic and polysaprobic conditions. Their periodicity would help in selecting bio-indicators during particular period (Table 2).

Benthic macroinvertebrates

Detritus are the store house of energy in river and their source is litter waste from forest, pasture land and allochthonous city sewage and industrial effluents. It constitutes varied niches and being utilised by various benthic macro invetebrates. Their occurrence, density and diversity reflect the water quality. Invertebrates comprising bottom biotal communities have definite preferences for substrate and consequently as the type of substratum changes so does the fauna. Substrate is, therefore, one of important factor of dividing running water into an upstream rhythral zone with fixed rock, stone or gravel and fine sand, and down stream potamon zone with mostly sand or mud.

Some invertebrates are filter feeders and have evolved various sieving mechenisms to obtain particulate matter in suspension. Filter feeding is known in many trichoptera, ephemeroptera and diptera. Many species of plecoptera, trichoptera ephemeroptera and amphipods and some species of crayfish consume detritus and/or leafy material of terrestrial origin. Detrivores have been classified into functional group i.e. shredders, scrapers, filter feeders, collector and gatherers based on their preferable detritus feeding mechanism. Feeding of detritus from allochthonous material affect invertebrate population. Since benthic macro invertebtates provide valuable indicator of past and present water quality conditions because of their long life span and central position in the food chain, they have been utilized as very authentic and ideal bio-indicators for monitoring water quality. *Lamelidens marginalis, L. corrianus, Melenia striatella, tuberculata, M. plotia scarba* are indicators of oligotrophic and oligosaprobic water but when available in large number with lesser species diversity (H) they indicate L-eutrophic and L-mesosaprobic water. *Chironomus* sp. and annelids are indicative for eutrophic and mesosaprobic water. Trichopterans are indicators of eutrophic water in plain and oligo to eutrophic in rhithron zone. *Indoplanorbis exustus* indicate abundance of macrophytes found in quite wide range of trophic and saprobic condition.

Quantifying the bottom biotal communities in species diversity according to Shannon and Weaver (1964) i.e. H = ni/N $\log_2$ ni/N has been found very important in biomonitorng water pollution. The greater the species diversity values of conditions in locality the larger is number of speices which make up the biotic community stable and healthy is the principle behind this technique. Species diversity of bottom biota community for monitoring pollution due to community sewage waste on river Ganga has been reported by Laal et al. (1984). This gives information about dominance (c) evenness (j) too of the species in a community.

Decomposers play a very significant role in the regulation of bio-geochemical cycle in an aquatic ecosystem Bilgrami and Dutta Munshi (1979, 1985), reported altogether ninetyeight fungal forms belonging to different calsses from polluted zones of river Ganga, Bilgrami and Dutta Munshi (1979, 1985) reported total coliform, Faecal caliform, Faecal streptococci and *Escherichia coli* from river Ganga between Patna and Farakka. Decomposers are observed in eutrophic, hyper eutrophic and polysaprobic water.

UTILITY OF BIOMONITORING

Biomonitoring would be helpful in getting following information (1) Nature and type of soils (2) Nnutrients load of soil and water (3) Nature of bottom (4) Weed infestation their quality and quantity and associated fauna of varied ecological niches, (5) Nature and extent of allochthonous nutrients brought in or if the source of nutrient is autochthonous it would inform about the quality of the source. (6) These information would be helpful in river water management for keeping clean and stocking river with desirable fish to augment yield.

RIVERS OF INDIA

The different river systems in India have an estimated length of 45,000 km. form an anastomosis of canals that run into 11,26,554 km. The Ganga river system with its main tributaries like Yamuna, Ganga, Ramganga, Ghagra, Gomti, Kosi, Gandok, Chambal, Sone, Tons, etc. has combibed length of 12,500 km. and Brahamuptra has alinear drift of 4023 km. The peninsular rivers like Mahanadi, Godavari, Krishna and Cauvery have a length of 6437 km. River Narmada and Tapti and the west flowing drainages of the western ghats have a combined length of 3380 km. Based on the studies made by CIFRI in some selected stretches of the Ganga, Brahamputra, Godavari and Krishna, the fish yields from these stretches was estimated to vary from 0.64 to 1.61 tones per km.

ANTHROPOGENIC PRESSURE ON RIVER GANGA

Rhithron zone

In general hydrology of rhithron region of river largely depends upon riparian vegetation for the supply of particulate organic matter, terrestrial insects etc. to sustain the aquatic biota and ichthyfauna. Rhithron region of river Ganga, starts from Rishikesh and above. This study give information about gradient of the cahannel, its width, bed depth and courses marked by falls, rapids, cascades if any, followed by less st eep reaches made of alternating riffle pool sequences. Further study indicated that bed material are made of boulders, rocks cobbles, gravel and sand. Flora, particualrly bryophytes viz. liver worts and mosses are established in riffle zones; while rooted, floating and emergent vegetation, epiphytes establish upon rocks, submerged woods and in rifles and pool.

Potamonic zone

This includes the plain stretch of river and it may be divided in upper (epi), middle (meta) and lower (hypo) potamonic regions. Arbitarily the entire stretch of Ganga was covered under investigation. Plain is from Rishikesh to Farakka may be divided into epipotamon i.e. from Rishikesh to Allahabad, metapotamon from Allahabad (down stretch) to Barauni and lastly hypopotamon from Barauni to Farakka. The channel in potamic sector is braided, shows meandes and is prone to flooding. The channel substrate, shoreline and terrace are influenced by flooding pattern, erosion and deposition. Deposition of eroded mterial is also major cause for aising river bed level, influencing the hydrochemistry, hydrobiology and ultimately the fisheries of river. The irrational exploitation of forest resources of the upper zone (rhithron) compounded by erodable petrography of Himalayas resulted in a sedimentation yield as high at 1600 million yr^{-1}, the highest in the world.

POLLUTION

Impact of Industiral Wastes

The Ganga just below the rhithron segment is subjected to pollution by effluents dishcarged by antibiotic and heavy electrical factories at Rishikesh (9.02 MLD) and heavy pollution due to discharge of effluents from tanneries, woolen mills, textiles, jute mills, etc. at Kanpur (167 MLD). The middle stretch suffers from pollution through drainage of effluents from fertilizers plants (5.50 MLD) at Allahabad. In Bihar maximum industrial pollution of Ganga takes place near Mokamah-Barauni area where the effluents from Bata Shoe Factory, McDowell distillary and oil refinery are discharged into the river. Water pollution severely affected the aquatic life. Mass death of fishes at various points in Ganga ecosystem have been reprted from time to time. Toxic compounds adversely affect the spawning grounds of fishes. Destruction of spawn, fingerlings and fishes naturally means a substantial loss in the source of protein and also a financial hazard to thousand of fishermen.

Mass scale of destructon of fingerlings reduces the potentiality of fish yield by 100 times as it also diminishes the popultion of future spawners. Indiscriminate killing of aquatic life of river Ganga is leading to shrinkage of its genetic diversity. Many important species on way to extinction. Ecological significance of the threatened and link species needs proper evaluation.

Sewage pollution

Sewage effluents receive by the Ganga re 16 MLD from each of the citgies like Haridwar, Farukhabad, Mirzapur and Bhagalpur, 100 MLD from each of Allahabad and Varanasi, 154 MLD from Patna and 275 MLD from Kanpur. The total quantity of organic pollution load in terms of BOD all over the urban aras and factories in the Ganga basin amounts to 2.5 million kg/day, out of this, urban load contributes 53.40% i.e. 1.33 m kg/day and rest by industrial sources. The urban areas in the Ganga basin generates about 152801 m^3 of waste water per annum. The flow of BOD in the urban wastes comes to 22.8 kg/sec. Sewage is posing a serious threat to the riverine environment and is amajor source of deoxygeneration in the rivers and hence adversely affecting fish and their feeds. Apart from these, sewage pollution create unsafe situation for recreation as it provides conducive condition for pathogens which are health-hazazrd at the point where it is discharged in river.

If sewage flows through seperate channel before getting dishcarged in river Ganga, the sewage fed channel may be utilized for multiple utilization including fish culture. Fish culture in pens in Kol (drainage sewage to river Ganga) at Bhagalpur were conducted. 203 kg of fish were obtained from pens area of 0.1 ha in three months without the application of fertilizers and supplementary feeds. This experiment has proved that pen culture operation in sewage polluted channel hold bright prospect for augmenting fish production at minimum input cost; and such approach also lessens the impact of sewage pollution in river Ganga.

Thermal pollution

In Ganga basin ideal condition exist for setting up of thermal power plant due to availability of natural resources like coal and water in plenty. One of such power plant is at Singrauli, situated in the vicinity of Rihind reservoir. Environmental hazard loom large in Singrauli belt due to construction of four super thermal power plants viz. Singrauli (2000 MW), Vindhyanchal (2260 MW), Anpara (3130 MW) and Rihand (3,000 MW) in public sector and Renusagar thermal power sttion (210 KW) in private sector. Three more thermal power stations have also been set up viz. Barauni, Kahalgaon and Farakka in lower Ganga basin. At Kahalaon and FArakka there are National Thermal Power Corporation Plants. One nuclear thermal power station is also working at Narora, district- Aligarh. These power plants are discharging effluents in the Ganga and its tributaries. They emit harmful gases like carbon monoxide, sulpher dioxide and enormous quantity of fly ash into the atmosphere besides discharging heated waste water into the river/reservoir, thus polluting both the air and water. Fly ash makes a thick layer over the water surface and thus abstains light penetration thereby disrupting the normal food web and energy cycle involved in the formation of food web. It hampers yield of fish feed and ultimately the fish yield too. Further, deposition of fly ash make Ganga unsuitable for purpose of recreation.

HEAVY METALS AND PESTICIDES

According to Ganga Action Plan's (GAP) investigation report of river Ganga system based on observation from 27 different sampling centres between Rishikesh (U.P.) and Ulberia (W.B.) Spatio-temporal variations in 10 heavy metals and 12 pesticides both of organochloride and organophosphorus types during July 1986 to June 1991, findings were as follows. During this peirod regular spatio-temporal variations trend were not observed. Arsenic and cadmium levels and frequencies of their appearance in water samples were largely insignificant, except for a few locations; Rishikesh, Haridwar, Ram Ganga at Kannauj, Gandak at Patna, Baharampore and Dakshineshwar- copper, nickle and zinc levels in river water samples were usually below their permissible (WHO) limits (No limits prescribed for Ni) and in general have been insignificant. Iron and magnese both were very frequenly found present in the river water from all the locations and most of the time their concentration levels were above their respective permissible (WHO) limits. Chromium which mainly comes from the industiral and other anthoropogenic sources was usually detected in higher concentrations in water from Garhmukteshwar, Kalinadi and Ram GAnga at Kannauj, Kanpur (upper stretch), Allahabad (both stretches), Varanasi (both stretches). Lead levels were usually higher in river water from Garmuketeshwar, Kannauj (D/S), Kanpr (D/S), Allahabad (U/S) & D/S, Varanasi, U/S & D/S, Khurgi, Patna D/S, Rajmahal and Dakshineshwar. Mercury levels were also usually high in water from Kannuj, Kanpur U/S, Kanpur D/S, Allahabad U/S & D/S, Buxar and Patna near Gandhi setu. In general the concentration of heavy metals in river water were higher during monsoon (July-September) and their concentrations decline October onwards with time. Thus, it may be inferred that due to high run off during July-September from catchment including urban areas their concentration increase.

Among pesticides, D.D.T and BHC have been the most commonly detected pesticides in river water through out the above period (July 1986-June,1991) and in majority of these, their residue levels have been found above their prescribed criteria, Environemnt Protection Agency (EPA). Endosulfan has also registered its presence at most of the sampling sites but their appearance and residue levels have been comaparatively low. Residue levels of the pesticides were usually higher during the winter months as compared to the summer and rainy season. Probable factors suggested by GAP for such trends have been lower temperture and time of application of these pesticides.

In other tributaries like Ram Ganga is heavily polluted at Moradabad due to sewage discharge, at Gularia due to rubber factories waste, paper factories waste; and at Bareilly, Bajian due to sugar factories waste. Gomti is heavily polluted at Lucknow due to Mohan Meakins breweries waste, city sewage at Haidernallah and Indogulf's urea, paper, steel factories waste at Jagdishpur. River Ghagra is being polluted and thus, it is obvious that river Ganga and its tributaries are being used as dumping channel needs management to restore pristine condition of river.

REFERENCES

Bilgrami, K. S. & J. S. Datta Munshi (1979) *Limnological survey and impact of human activities on the river Ganges.* The Allied Press, Bhagalpur.

——————————————————(1985) *Ecology of river Ganges.*

Fjredingsted, E. (1965) Taxonomy and Saprobic valency of benthic phytomicro-organisms. *Int. Rev. Ges. Hydrobiol.* 50: 475-604.

Kelly, M. G., C. J. Penny & B. A. Whitton (1995) Comparative performance of benthic diatom indices used to assess river water quality. *Hydrobiologia* 302: 179-188.

Laal, A. K., S. K. Sarkar, A. Sarkar (1982) Species diversity of Periphyton as an index of pollution of river Ganga. *J. Inland Fish. Soc. India* 14 (1).

Laal, A. K., A. Sarkar, S. K. Sarkar and K. L. Shah (1984) Preliminary observations on species diversities of bottom biota community for monitoring pollution due to community sewage waste in `Kol' of the river Ganga and the main river Ganga. *Symp. Biomonitoring State Environ.* pp. 174-178.

Laal, A. K., S. K. Sarkar and A. Sarkar, (1988) The trophicity and Saprobity of the river Ganga and its Oxbow lake in relation to community sewage impact. *Bull. Bot. Soc.* 35 : 21-22.

Laal, A. K. (1992) Biomonitoring of environment. *Summer Institute on Aquaculture and Envoironmental CIFE, Bombay,* 20 July 3- August,1992. 9 pp.

Laal, A. K. and M. Karthikeyan (1993) Rotifers- Pollution or productivity indicators?. *Curr. Sci.* 65 (11): 874-75.

Laal, A. K., S. K. Sarkar, A. Sarkar and M. Karthikeyan (1994) Ecotendency of phytoplankton: an approach for categorizing algae as bio-indicators for monitoring pollution. *Curr. Sci.* 67(3): 193-95.

Mason, C. F. (1983) *Biology of freshwater pollution.* Longman.

Round, F. E. (1991) Diatoms in river water- monitoring studies. *A. Appl. Phycol* 3: 129-45.

Shanon, C. E. and W. Weaver (1964) The mathematical theory of communication. *Univ. Illinois Press.* 125 pp.

Whitton, B. A. and M. C. Kelly (1995) Use of algae and other plants for monitoring river *Aust. J. Ecol.* (in press).

Table 1: Comparison of saprobic and trophic levels (data shows the upper limits of each level)

Sl No.	Abbreviations		Planktonic algae individual	Chlorophyll	Primary production	Primary production
	Saprobity	**Trophic level**	*litre*$^{-1}$	*mgm*$^{-3}$	*mgCm*$^{-2}$*d*$^{-1}$	*gCm*$^{-2}$*yr*$^{-1}$
0.5	K	Kathrotatrophic	1	0	0	0
0.5	X	Ultra oligotrophic	100	0	50	10
1.5	O	Oligotrophic	1000	5	100	30
			[10000]	[20]	[1500]	[500]
		Intermediate	10000	20	250	100
		mesotrophics	[100000]	[100]	[4000]	[2000]
2.0	γ	γ-eutrophics	100000	300	500	150
2.5	β	β-eutrophics	[10000000]	[15000]	[12000]	[1000]
3.5	α	α-eutrophic	1000000	1000	15000	300
4.5	P	Polytrophic or hyper eutrophic	10000000	15000	12000	4000
Sewage and industrial		wastes exclusively	secondary product	ion		
5.5	I	Isotrophic	1000	3	100	30
6.5	m	Metatrophic= Thiotrophic	0	+	+	+
7.5	h	Hypertrophic= Methanotrophic	0	0	0	0
8.5	u	Ultratrophic= Atrophic	0	0	0	0

Table-2: Thermal affinities of some important planktonic bio-indicators in tropical region in Gangetic Belt Laal (1992)

PHYTOPLANKTON

STENO THERMAL		EURY THERMAL
COLD	WARM	
$15-22^{o}$	$30-39^{o}C$	$15-39^{o}C$
Closterium nitizsch	*Volvox globatum*	*Scenedesmus sp.*
	Chlorella vulgaris	*Pandorina sp.*
Cosmarium sp.	*Crucigenia sp.*	*Pediastrum duplex*
	Eudorina sp.	*P. simpex*
Ceratium sp.	*Euglena viridis*	*P.ovatum*
	Euglena acus	*Spirogyra sp.*
	Phacus sp.	*Lyngbya sp.*
	Trachlemenas sp.	*Ald.Bacillari-phyceae algae.*
	Oscillatoria chlorina	*Microcystis aeru-ginosa.*
	O. limosa	
	O. tenuis	
	Spirulina princeps	

ZOOPLANKTON

Rotifers

Filinia opoliensis	*Platiyas sp.*	*Filinia longispina*
Anuraeopsis fissa	*Lapadella ovalis*	*Filinia terminalis*
Porales sp.	*Pompholyx sulcata*	*Keratella tropics*
Rotaria neptunia	*Albertia sp.*	*K. cochlearis*
Trichocera sp.	*Synchaeta*	*K. heimalis*
Mytilina sp.	*Conochilus sp.*	*Brachionus-quadridentatus*
Floscularia sp.	*Brachionus caudatus*	*B. angularis*
		B. calyciflorus
		B. bakeri
Brachionus falcatus	*Hexarthra sp.*	*B. rubens*
		B. urceolaris
		Horaella sp.
B. forficula		*Lecane luna*
B. havanaensis		*L. ohiensis*
Colurella obtrusa		*L. monostyla*

Cladocera

Bosmina sp.	*Moina brachiata*	*Daphnia sp.*
	Moina macrocopa	*Ceriodaphnia sp.*
	Chydorus	*Scapholeberis*
	Macrothrix	
	A	

Riverine fisheries in India with special reference to Ganga river system

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India's vast network of rivers and rivulets has been source for the many species of fish providing livelihood to hundreds of thousands of fishermen. Riverine fishing has been popular in India since time immemorial as could be recorded from the mythological story of Matsya Gandha and Bhismpitamaha in the Mahabharat. The various river systems in the country have an estimated linear length of 45,000 km comprising 113 rivers and their tributaries, 80% of the length being contributed by the 14 major rivers. The riverine fishery resources of India comprise five major river systems (Fig. 1) as presented below:

River system (catchment area million km^2)	***Length (km)***	***Important rivers***
Ganga river system (0.98)	12,000	*Ganga, Yamuna, Ramganga, Gomti, Chambal, Ghagra, Rapti, Gandak Kosi, Son, Tons, Ken, Betwa*
Indus river system	small segment	*Indus, Beas, Sutlej*
Brahmaputra river system (0.51)	4023	*Subansiri, Dihrong, Jai-bhareli, Dhansiri, Manas, Kalong, Digru, Kulsi, Krishnai, Jinari*
Peninsular East coast system (1.21)	6437	*Mahanadi, Godavari, Krishna, Cauvery*
Peninsular West cost system (0.69)	3380	*Narmada, Tapti*

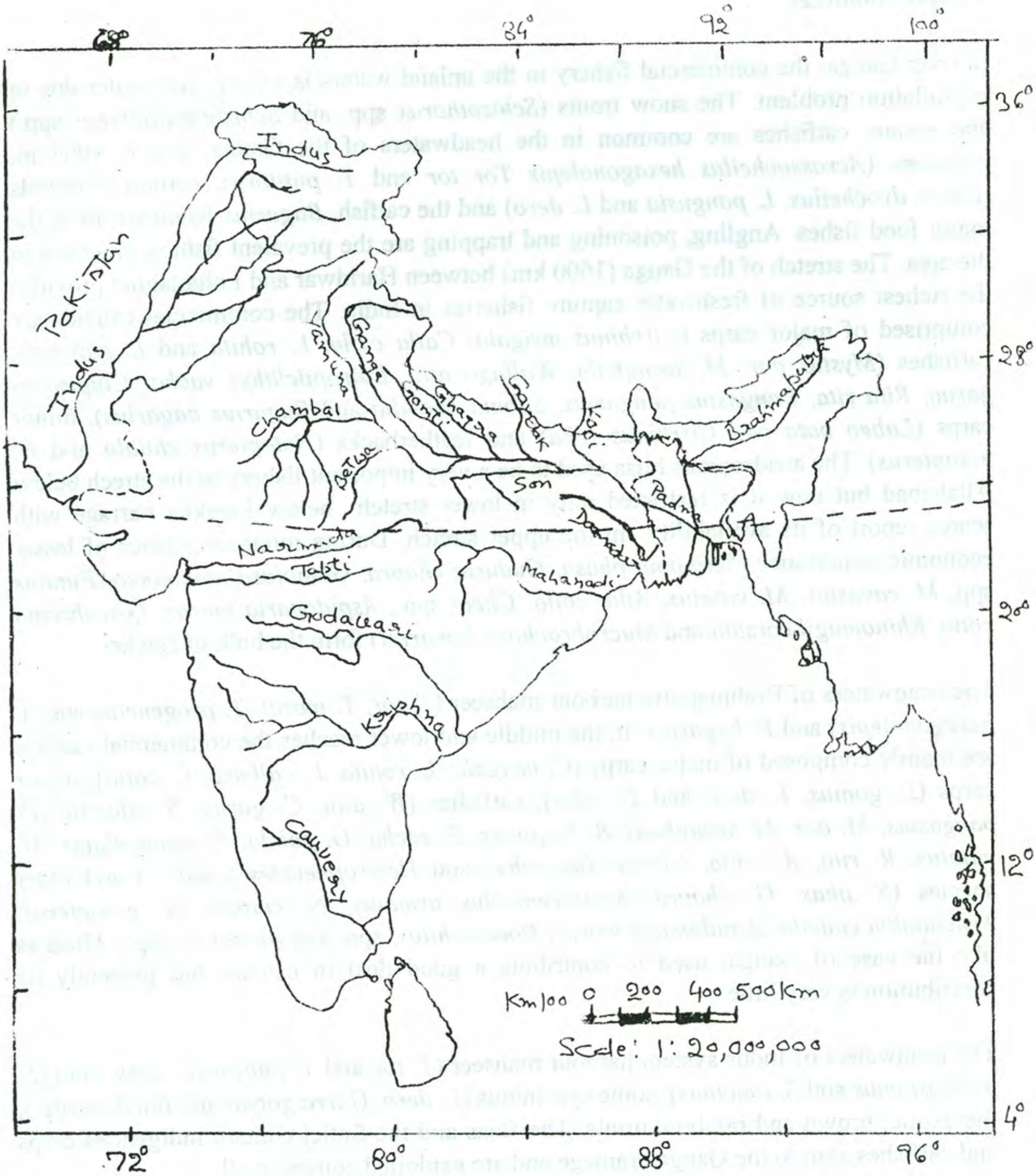

Fig 1: Major River Systems of India

Fishery resources

In river Ganga, the commercial fishery in the upland waters is of very low order due to exploitation problem. The snow trouts (*Schizothorax* spp. and *Schizothoraichthys* spp.) and certain catfishes are common in the headwaters of the Ganga. Below 1067 m, mahseers (*Acrossocheilus hexagonolepis Tor tor* and *T. putitora*), certain cyprinids (*Labeo dyocheilus, L. pangusia* and *L. dero*) and the catfish, *Bagarius bagarius*, form the major food fishes. Angling, poisoning and trapping are the prevalent fishing practices in the area. The stretch of the Ganga (1600 km) between Haridwar and Lalgolaghat provides the richest source of freshwater capture fisheries in India. The commercial catches are comprised of major carps (*Cirrhinus mrigala, Catla catla, L. rohita* and *L. calbasu*), catfishes (*Mystus aor, M. seenghala, Wallago attu, Eutropiichthys vacha, Clupisoma garua, Rita rita, Pangasius pangasius, Silonia silondia* and *Bagarius bagarius*), minor carps (*Labeo bata and Cirrhinus reba*) and featherbacks (*Notopterus chitala* and *N. notopterus*). The anadromous hilsa used to be a very important fishery in the strech below Allahabad but now it is restricted only in lower stretch below Farakka barrage with scarce report of its availability in the upper stretch. During monsoon, fishes of lesser economic importance (*Setipinna phasa, Gudusia chapra, Goniolosa manminna, Puntius* spp, *M. cavasius, M. vittatus, Ailia coila, Chela* spp., *Aspidoparia morar, Osteobrama cotio, Rhinomugil corsula* and *Macrobrachium lamarrei*) form the bulk of catches.

The headwaters of Brahmaputra harbour mahseer (*T. tor, T. mosal, T. progeneius* and *A. hexagonolepis*) and *B. bagarius*. In the middle and lower reaches the commercial catches are mainly composed of major carps (*C. mrigala, L. rohita, L. calbasu, C. catla*), minor carps (*L. gonius, L. dero* and *C. reba*), catfishes (*W. attu, C. garua, S. silondia, P. pangasius, M. aor, M. seenghala, B. bagarius, E. vacha, O. pabda, O. bimaculatus, M. vittatus, R. rita, A. coila, Clarias batrachus* and *Heteropneustes fossilis*) and other species (*S. phas, G. chapra, Mastocembelus armatus, N. chitala, N. notopterus, Xenentodon cancila, Aspidoparia morar, Noemachilus* spp. and *Ambassis* spp.). Hilsa as like the case of Ganga, used to contribute a good deal in catches but presently its contribution is very little.

The headwaters of Indus system harbour mahseer (*T. tor* and *T. putitora*), snow trout (*S. plagiostomus* and *S. esocinus*), some cyprinidus (*L. dero, Garra gotyla* and *Barilius* spp.), the exotic, brown and rainbow trouts. The Beas and the Sutlej contain indigenous carps and catfishes akin to the Ganga drainage and are exploited commercially.

Mahanadi is the largest river of east coast river system and in its headwaters, mahseer (*Tor mosal mahanadicus*), *B. bagarius* and *L. dyocheilus* are abundant, though no commercial fishery exists in this stretch due to rapids, gorges, temple sanctuaries and difficult terrain. In its middle and lower stretches, fish fauna similar to that of the Ganga drainage occurs in addition to a few penninsular forms (*Labeo fimbriatus*). Hilsa occurs only in lower reaches. In the lower and middle reaches major carps and larger catfishes constitute sizeable commercial fishery.

In river Godavari, the main species supporting the commercial fishery, are *Labeo fimbriatus* and Gangetic major carps, larger catfishes (*Mystus* spp., *W. attu, Silonia childreni* and *B. bagarius*). The anadromous hilsa used to make a significant fishery.

Tor khudree and *T. mussullah* occur throughout the Cauvery river barring deltaic region. The commercial fishery is made up of carps (*A. hexagonolepis, Tor* spp., *Barbus carnaticus, B. dubius, Labeo kontius*), catfishes (*Glyptothorax madraspatanus, Mystus* spp., *P. pangasius, W. attu* and *S. silondia*). Gangetic carps, transplanted into the river in the beginning of the century, contribute significantly to commercial catches.

Among the rivers of west coast river system, Narmada and Tapti are the principal rivers. In both the rivers, the fish fauna is akin to Ganga, excepting occurrence of *Rita pavimentata.* Among minor carps *L. fimbriatus* and *Labeo boggut* are important species.

The fishing gears and crafts

Gears: The riverine fishing gears are mostly simple in design and operation and as a whole are low energy fishing devices. Mechanised fishing gears and crafts are not used anywhere. As far as gears are concerned, numerous type of gears are employed depending upon environment and seasons, some selective to size and species and some not. The gears used in the river Ganga based on the manner by which the capture is effected can be classified as:

Type	***Sub-type***	***Local name***
Drag net	*With pocket*	Chanta
	Without pocket	Mahajal, Darwari, Karia, Chundhi, Do-dandi
Gill net	*With foot rope*	Gochail
	Without foot rope	Tiar
Purse net		Bara kamel, Chhota kamel, Sanghala jal
Cast net		Bhanwar jal
Scoop net		Jali
Hook and line		Jor
Traps		Kuriar, Gopal jal, Bandal, Sirki, Ujhki, Kohni

Fishing crafts

For fishing, two types of boats are used: big boat known as 'Katra' and small boat or Dongi. Big boats are used with big drag nets like Mahajal, Karia and Darwari. The small boat or Dongi is used with almost all other types of net. The boat is very light and handy in use. Coracle is the most common craft in river Cauvery.

Present status of riverine fisheries in India with special reference to Ganga

Barring the studies conducted by Central Inland Capture Fisheries Research Institute, no other information is available on riverine fisheries in India. In 1976, National Commission on Agriculture estimated the catch/km from various rivers based on the data collected by CIFRI. The catch ranged from 0.643 to 1.605 t/km with an average of 1 t/km. During the post independence era, river basins witnessed an expeditious pace of industrialization, agricultural development and urbanization. These developmental activities along with flood control measures have adversely affected the riverine habitat and its fisheries. For the present the estimates are far from the earlier estimates and based on the recent studies, it has come down to merely 0.357 t/km for Ganga. The decline was not only quantitative but qualitative also. The remunerative capture fisheries of the yester years no longer exists, reasons being: ***i.*** the major carps, which used to contribute around 50% of the total, have lost their prime position, contributing about 20% only, the average annual yield rate of major carps from the Ganga is estimated to have fallen from 245.2 kg/km of 1961-69 to only 43.4 kg/km; ***ii.*** the large catfishes yield rate has declined to 85.9 kg/km from 197.7 kg/km of the earlier period; ***iii.*** the hilsa fishery has tumbled down to merely 3.4 kg/km from an average of 176.7 kg/km; ***iv.*** the rest of the species also registered a decrease to 224.3 kg/km as compared to 310.1 kg/km of the past. Ecological aberrations have adversely affected the spawn availability which used to be the prime source of stocking material for aquaculture. Situation is more or less the same for all of the Indian rivers. Some of the rivers have lost their lotic character and for the major part of year they remain almost dry, especially among peninsular rivers.

The decline in fishery has further increased the hardships of poor fisherfolk, wholly dependent on this source for livelihood, needs to be lamented at national level to save the biological wealth and uplift the socio-economic condition of fishermen community.

Hydrological changes, fish population trends and production potential of Hooghly estuarine ecosystem with special emphasis of Hilsa

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Introduction

The Hooghly estuarine system located in the state West Bengal, India, between latitude 21-23^{0}N and longitude 88-89^{0}E is the largest among the estuaries on the Indian coast covering the gangetic delta called the Sunderbans. It is the world's largest delta which supports many important commercial fisheries. The Sunderbans area is criss-crossed by many major and minor estuaries and dominated by intertidal and flats as well as rich mangrove forests. The total area of the entire estuarine system is about 8,029 km^2. The principal components of the estuarine system are the main Hooghly channel, its five tributaries *viz.*, Jalangi, Churni, Damodar, Rupnarayan and Haldi and the adjacent estuaries *viz.*, Saptamukhi, Thakuran, Matlah, Gosaba, Harinbhanga, Ichamati and Raimangal situated in the lower marine zone. These estuaries are disconnected since long from the main Hooghly channel due to heavy deposition of silt in their upper reaches. The Hooghly main channel is a distributary of the Ganga which is considered as the second major river of the world in terms of suspended load, discharging 1451X10^6 tons annually. It is the main contributor of sediments to the Bengal Fan which is the largest deep sea fan in the world. The heavy deposition of sediments, carried by the Ganga-Hooghly resulted into formation of cluster of islands in the lower estuarine areas - the Sunderbans.

The Hooghly estuary is a positive estuary of mixohaline type and a pattern of increasing salinity towards the mouth of the estuary. The dynamic estuarine ecosystem is subject to rapid changes by natural or man-made interferences. A major change in the water quality and fishery resources was observed in the Highly estuarine system after commissioning of Farakka barrage across the river Ganga at Farakka. Prior to the construction of Farakka barrage both the river Bhagirathi and Hooghly estuary were deprived of receiving sufficient freshwater and gradually becoming in active as bulk of discharge used to flow through river Padma, the other off-shoot of river Ganga. After commissioning of Farakka barrage in 1975, the main Hooghly estuary is fed directly by the Ganga through man made feeder canal and Bhagirathi river. The additional discharge of freshwater into the system has sufficiently changed the ecology of the estuary. These changes significantly affect the biological and physico-chemical factors responsible for plankton, benthos and fish production.

Status of the estuary during pre and post-Farakka barrage period

The present study on water quality, plankton, macro-zoobenthos and fishery resources revealed that there is a considerable drop in the values of salinity as well as change in the availability of plankton, macro-zoobenthos in the estuary as compared to pre-Farakka barrage period. It is well known that salinity parameter of an estuary restricts the distribution limit of its flora and fauna. A critical analysis of the earlier works during pre and post-Farakka barrage period relevant to hydrology revealed that additional discharge of freshwater through Farakka barrage had changed the ecology of the system significantly by reducing the turbidity as well as salinity and converting the earlier gradient zone into almost freshwater one. Presently the salinity incursion of the Hooghly estuary was observed upto Diamond Harbour situated 60 km from the mouth of estuary. The estuary showed distinct levels of salinity gradient.

Presently, the upper freshwater zone has extended downward for a distance of 238 km from Nabadwip to Diamond Harbour. Nabadwip and Diamond Harbour are located 298 and 60 km respectively from the sea face. The middle gradient zone from Diamond Harbour to Kakdwip (35 km from the sea face) and lower marine zone from Kakdwip to sea face have been very much reduced and pushed back towards the mouth of the estuary (Fig. 1). On the contrary, during pre-Farakka barrage period the upper freshwater zone was extending from Nabadwip to Konnagar, middle gradient zone from Konnagar to Diamond Harbour and lower marine zone from Diamond Harbour to sea face. The present salinity values in the lower zone ranged between 15.7 and 27.8 g/l, while in the gradient and upper freshwater zones the values varied from 0.07 to 18.2 g/l and 0.04 to 3.3 g/l respectively.

As regards physico-chemical parameters of the estuary during pre and post-Farakka period an appreciable change in the values of certain parameters was observed.

At present an increase value of dissolved oxygen in the Hooghly estuarine system at Uluberia, Diamond Harbour and kakdwip was noticed as compared to pre-Farakka barrage period. This may be due to increased influx of freshwater in the estuary after commissioning of Farakka barrage (Table-1). Phosphate, nitrate and silicate contents of the estuarine waters were very low during pre-Farakka period, while after commissioning of Farakka barrage, the phosphate, nitrate and silicate contents increased and almost similar values were observed upto recent years.

Table - 1 : Physico-chemical characteristics of three centres of the main Hooghly channel during pre and post Farakka barrage period.

Centre	**Uluberia**		**Diamond Harbour**		**Kakdwip**	
Year	**1954**	**1996**	**1954**	**1996**	**1954**	**1996**
Parameter						
D.O. (mg/l)	2.3-4.6	6.0-6.8	2.1-5.0	6.3-7.0	3.4-5.1	8.0-8.2
Phosphate (mg/l)	0.002-0.003	0.05-0.10	Tr	0.07-0.10	Tr	0.06-0.08
Nitrate (mg/l)	Tr	0.08-0.26	Tr	0.07-0.22	0.03-0.11	0.05-0.11
Silicate (mg/l)	0.09-0.36	6.7-20.0	0.05-0.20	4.2-8.0	0.04-7.8	3.9-6.0

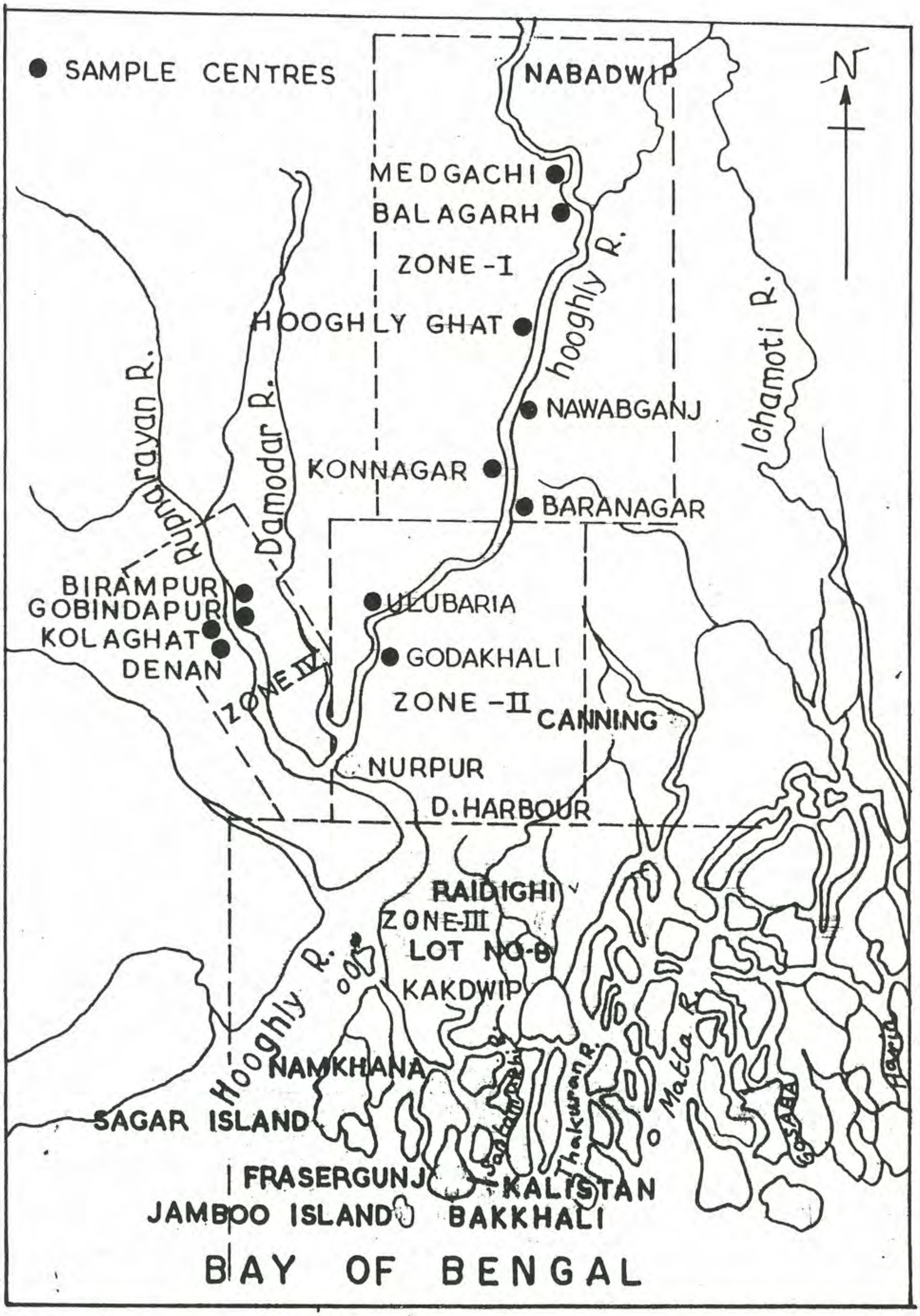

FIGURE-I. HOOGHLY ESTUARY AND ITS VARIOUS FISHING ZONES

Plankton

The overall plankton production in the Hooghly estuary during post-Farakka barrage period was high when compared with the earlier studies during pre-Farakka barrage period. The total plankton production for the Hooghly estuarine stretch was maximum at Frazerganj (1262 u/l) and minimum at certain stretches of freshwater as well as gradient zones of the estuary. The low production of plankton at these stretches may be due to discharge of industrial effluent which caused maximum adverse effect on production of plankton. The bulk of plankton in the Hooghly was constituted by phytoplankton. Bacillariophyceae, Chlorophyceae and Cyanophyceae are the principal groups in order of abundance. Phytoplankton production was maximum at Frazerganj in the Hooghly estuary as compared to other distributaries *viz.* Saptamukhi, Thakuran, Matlah, Roymangal and Ichamati.

Table - 2 : Maximum plankton density (unit/liter) in the Hooghly estuarine system during pre and post Farakka barrage period

Estuary	Zone	1956-61	1971-72	1996-97
Hooghly	Upper (Freshwater)	298	304	920
	Middle (Gradient)	293	223	414
	Lower (Marine)	61	145	1267
Matlah	-	356	-	585

Zooplankton communities were found to be represented by the copepods, rotifers and caldocerans and protozoans in order of abundance.

Macrozoobenthic fauna

Information on macrozoobenthic fauna of Hooghly estuarine system during pre and post- Farakka barrage periods are very scanty. At present the overall population of macrozoobenthos ranged between 182/m^2 and 1428/m^2 and the maximum production was observed in freshwater zone of the estuary at Nabadwip. The overall composition of the bottom macrofauna of the estuary was gastropods. The next important groups were annilids and *bivalves*. Among gastropods, the dominant species viz. *Thiara tuberculata*, *T. scabra*, *T. lineata*, *Bellamya bengalensis*, *B. dissimilis*, *Brotia costula*, and *Assaminea francassiae* were observed in the freshwater zone, while *Cerithidea cingulata*, *C. obtusa*, *Barnia candida*, *Neritina anriculata*, *Columbella duclosiana*, *Natica tigrina*, *Telescopium telescopium* were maximum in lower marine zone of the estuary.

Fishery

The annual average prawn and fish yield from the estuarine system has increased from 9,481 tonnes during pre-barrage period to 43,000 tonnes during post-barrage period.

A wide variety of fish and prawn diversity was observed in the freshwater zone, particularly in the lower stretch of this zone from Uluberia to Diamond Harbour being the admixtured of fresh and saline water, euryhaline species were also encountred in the region. The important fish and prawn fauna available in the upper freshwater zone were *Tenualosa ilisha*, *Mystus seenghala*, *Eutropichthys. vacha*, *Clupisoma garua*, *Setipinna phasa*, *Ailia coila*, *Mastacembelus armetus*, *Pangasius pangasius*, *Xenentodon cansula*, *Mystus cavasius*, *Ompok pavo*, *Mystus gulio*, *Notopterus notopterus*, *N. chitala*, *Wallago attu*. Among prawns *Macrobrachium rosenbergii*, *M.malcolmsomii*, *M.rude*, *M.villosimanus* and *M.lamarrci*, *M. mirabiles*, *M.birminicum birminicum*, *M.scabriculum* and *M.dayanum* were available in the stretch. The commercially important fish available in the lower stretch of freshwater zone were *Pama pama*, *S. phasa*, *T. ilisa*, *Polynemous paradiseus*, *Silago panijus* and *Rhinomugil corsula*. Among prawns, *Macrobrachium rosenbergii*, *M. mirabile* and *Metapenaeus brevicornis* were the most dominant species. *P.pama* and *S.phasa* were mostly abundant during October to November, while peak fishing season for *P. paradiseus* was March and April.

Dominant species in the gradient as well as marine zone of Hooghly including other estuaries of Sunderbans (distributaries of Hooghly) were *Harpodon nehereus*, *Trichurus spp.*, *T. ilisha*, *Setipinna spp. P. pama* and prawns (*Parapenaeopsis sculptilis*, *P. stylifera*, *Metapeneous brevicornis*, *M.monoceros*, *Peaeus monodon*, *P.indicus*, *Explaemon stylifera*, *E.tunifres*. Next to these other important fish species were *P.paradiseus*, *Eleutheronema tetradactylum*, *Lates calcarifer*, *Polynemus indicus*, *Coilia spp. Stromateus cinereus*, *Tachysurus jella*, *Ilisha elongata*, *Raconda russelliana*, *Chirocentrus dorab*, *S.panijus*, *Sciaena biauritus*, *Liza parsia*, *L.tade*, *Plotosus canius*, *Osteogeniosus militaris* etc. etc.

In the Hooghly estuarine system, fishing exploitation by migratory bagnet was an important feature of the lower estuarine zone during winter month from November to January. The winter migratory bagnet fishery contributed to the tune of 65-75% of the total yield of the estuary. More than 90% catches are marketed as dry fish. The dominant species contributing in the winter migratory bagnet fishery were *H. nehereus*, *Trichiurus* spp. *Setipinna* spp., *T.jella*, *P.pama* and *Coilia* spp. On the whole, the lower marine zone of the estuarine system during post Farakka barrage period contributed about 95% of the total catch of the entire Hooghly estuary and Sunderbans deltaic region and the maximum contributors were *H. nehereus* (23.5-26.7%), *Trichiurus spp.* (13.1-15.2%), *Setipinna spp.* (13.1- %) and Prawns (6.6-6.9%).

The present trend of catch statistics shows that some fish species viz. *Liza parsia*, *Lates calcarifer*, *Pangasius pangasius*, *Elutheronema tetradactylum*, *Harpodon nehereus*, *Trichirus* spp. of the estuarine system have shown a sharp declining trend or total absence in the upper and gradient zones of the estuary during post-Farakka barrage period. The average annual catch of *Polynemus paradiseus* in the post barrage period have increased significantly in gradient zone. *Harpodon nehereus*, *Trichiurus jella*, *Setipinna spp.* and *Pama pama* have also shown an improved catch in the marine zone during post barrage period. On the contrary certain freshwater fish and prawn species viz. *Eutropichthys vacha*, *Clupisoma garua*, *Rita rita*, *Wallago attu*, *Mystus seenghala*, *M. aor*, *Catla catla*, *Labeo bata*, *Macrobrachium rosenbergii* have made their appearance in the estuarine system. Contribution of dominant fish and prawn of Hooghly estuarine system during pre and post-Farakka barrage period is presented in Table-3.

Hooghly estuarine system is a potential source of estuarine fish or prawn seed. The marine fish production is by and large dependent on estuaries since these serve as breeding and nursery grounds for important sea fishes and prawns. The seed of commercially important prawn *Penaeus monodon* are available extensively alongwith seeds of other important penaeid (*P. indicus*) and Metapenaeid (*Metapenaeus brevicornis* and *M. monoceros*) prawn as well as fishes (*Liza parsia, L. tade* and *Lates calcarifer*). At present, the upper limit of availability of the marine fish and prawn seed has become restricted to 50-60 km while during pre-Farakka barrage period seeds of *P.monodon* and *P.indicus* were available from Uluberia and Nurpur centres of Hooghly main channel located 113 and 83 km respectively above the mouth of the main estuary. The ranges of salinity around Nurpur and Uluberia fluctuated between 0.09 and 21.15 g/l and 0.50 and 9.45 g/l respectively (Chakraborty *et. al* 1982) while during post-Farakka barrage period the salinity had gone down which varied between 0.021 and 2.25 g/l at Nurpur and 0.014 and 0.04 g/l at Uluberia (Table-4).

Thus reduction in salinity due to increased freshwater discharge is apparently the probable reason for this. The overall availability of seed in the Hooghly estuarine system was found to be declined (Table-5).

Table - 3 : Contribution of dominant fishes and prawns (in t) of Hooghly estuarine system.

		Pre - Farakka barrage period		**Post - Farakka barrage period**
Sl. No.		**1960-61 to 1962-63**	**1966-67 to 1974-75**	**1984-85 to 1994-95**
1.	**Hilsa** *Tennalosa ilisha*	743.9	1457.1	2336.6
2.	Mullets *Liza parsia* *L.tade*	39.5	30.8	18.2
3.	**Threadfin** *Polynemus paradiseus* *P. indicus* *Eleutheronema tetradactylum*	74.4	63.9	296.7
4.	**Perch** *Lates calcarifer*	45.9	24.5	49.9
5.	**Sciaenids** *Pama pama* *Sciaena biauritus*	118.9	203.7	4327.7
6.	**Catfishes** *Osteogenious militaris* *Tachysurus jella* *Pangasius pangasius*	152.5	109.6	992.9

		Pre - Farakka barrage period		Post - Farakka barrage period
Sl. No.		1960-61 to 1962-63	1966-67 to 1974-75	1984-85 to 1994-95
7.	**Other clupieds** *Setipinna spp.* *Ilisha elongata* *Chirocentrus dorab*	136.2	437.8	4081.6
8.	**Ribbon fish** *Trichiurus sp.*	83.1	454.0	2835.5
9.	**Bombay Duck** *Harpodon nehereus*	797.1	2067.9	5301.0
10.	**Prompet** *Stromateus cinereus*	Recorded under others	71.6	866.3
11.	**Prawns**	574.1	1338.3	2939.3
12.	**Others**	438.4	3222.3	9295.7
13.	***Total***	***3204.0***	***9481.5***	***33341.4***

Table - 4 : Maximum abundance of prawn seed at Nurpur and Uluberia centres of Hooghly estuary during pre and post Farakka barrage period

Centre	Species	Pre-Farakka barrage period	Post-Farakka barrage period
Nurpur	*P. monodon* *P. indicus* Salinity (g/l)	1,169 30,485 1.90-21.15	78 Absent 0.021-2.25
Uluberia	*P. monodon* *P. indicus* Salinity (g/l)	504 1,380 0.50-9.45	Absent Absent 0.014-0.04

Table - 5 : Maximum numbers of seed collected per shooting net per hour at different stretches of the estuarine system during pre and post Farakka barrage period.

Species	Pre - Farakka barrage period	Post - Farakka barrage period
P. monodon	56-2,000	64-2,332
P. indicus	80-30,485	9-8,940
M. brevicornis	7-1,910	43-2,240
M. monoceros	77-2,590	18,1,386
L. persia	11-28,077	14-456
L. tade	10-300	4-31
L. calcarifer	40-598	2-25
C. chanos	8-1,292	Absent
Salinity range (g/l)	23.94-34.59	12.81-21.12

On the contrary, seeds of *M. rosenbergii* were moderately available during May to July in certain areas of Sunderbans, which was not reported from Sunderbans prior to construction of Farakka barrage, as the species started their downstream migration towards sea face for spawning purposes. The range of downstream migration of the species during pre-Farakka barrage period was found upto Uluberia and Nurpur. Reduiction in salinity in Sunderbans might be one of the probable reasons for its extended downstream migration.

Hilsa fisheries

The ecological changes in the Hooghly estuarine system as a result of increased freshwater discharge into the system through the Farakka barrage have an influence on the biology and fishery of the anadromous hilsa. The general habitat of migratory hilsa in the estuarine system has improved for its migration, breeding and growth. The average annual landings of the species which remained at 1,500 tonnes prior to 1975 has increased to more than 5,000 tonnes in recent years. Hilsa is the major component of estuarine fishery accounting 15-20% of the total yield from Hooghly estuary. The up-stream migration of hilsa towards the Hooghly estuary from the foreshore area is mainly for spawning. The upstream migration of Hilsa in the estuary is found with the advent of South-West monsoon *i.e.* July to August and continuous upto February to March. The upstream migration of the fish is found associated mainly with the state of sexual maturity as well as volume of freshwater discharge from the estuary caused by rains or melting of the snow. Hilsa is a prolific breeder. Though the peak spawning period of the species is remarkably noticed during September to early November, the spawning is extended for a prolonged period upto February/March. With regard to the size and age composition of migratory hilsa, it is revealed that hilsa fishery is contributed mainly by the individuals belonging to size range from 340 - 419 mm (3 years), 420-451 mm (4 years) and 460-479 mm (5 years) and formed 37-42, 22-23 and 11-16% by numbers. During post-Farakka barrage period, the species spawns in the entire freshwater zone by the estuary (Daimond Harbour to Nabadwip), while earlier observations inferred that the lower and upper limits of the spawning grounds of hilsa in the river were Baghbazar (Calcutta) to Madgachi a distance of about 155 and 250 km respectively from the sea face. The probable raeson for extension of spawning ground, observed during post barrage period may be due to increased discharge of freshwater into the estuary. The barrage has changed the ecology signaificantly by reducing salinity as well as turbidity and converting the gradient zone into almost freshwater zone. This change makes the environmental condition of the Hooghly estuary more conducive for the spawning of hilsa.

Methodology for stress detection and prevention of major fish and prawn diseases in inland open waters

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Introduction

Mortality of fish or decline in a fish population in a water body is at present the sole indicator that the effects of environmental stress factors are exceeding the acclimation tolerance limit of fish. However several physiological and whole animal changes occur that can be used to provide prior information that the effect of stress will exceed acclimation tolerance limit of fish and lead to dysfunction such as impaired fish health, growth or survival. These changes are a direct or indirect result of the physiological response to environmental stress and can be quantified and used as predictive indices.

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 it is adaptive in nature and are required for acclimation. Collectively these phenomenon has been termed 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.

Haematology : 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

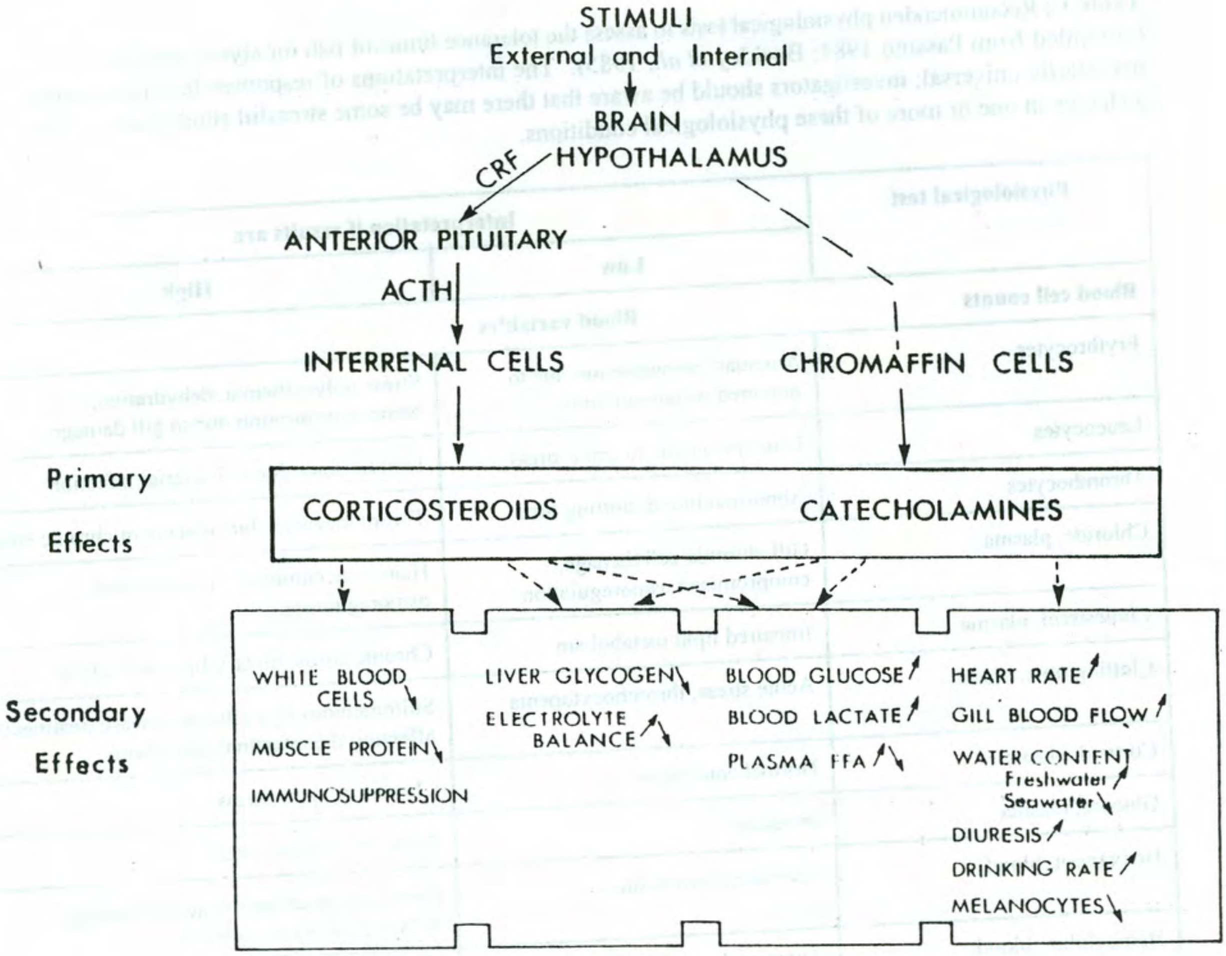
STIMULI
External and Internal
BRAIN
HYPOTHALAMUS
CRF
ANTERIOR PITUITARY
ACTH
INTERRENAL CELLS
CHROMAFFIN CELLS
Primary Effects
CORTICOSTEROIDS
CATECHOLAMINES
Secondary Effects
WHITE BLOOD CELLS
MUSCLE PROTEIN
IMMUNOSUPPRESSION
LIVER GLYCOGEN
ELECTROLYTE BALANCE
BLOOD GLUCOSE
BLOOD LACTATE
PLASMA FFA
HEART RATE
GILL BLOOD FLOW
WATER CONTENT
Freshwater
Seawater
DIURESIS
DRINKING RATE
MELANOCYTES

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	Thromobcytosis 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

Inventory and diagnosis of pathogens causing various diseases in inland fishes/shrimps

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Environmental deteriorations caused due to pollution, anthropogenic factors and intensification has lead to many types of disease outbreaks in inland fisheries and aquaculture in recent past. The economic impact of the disease, besides affecting the production directly affects the subsistence of fishermen and indirectly, the people engaged in fish transport, marketing, distribution, processing, net-making, in other fishery-related business which involve financial losses, either due to direct mortalities or consumer rejection. In most cases, these outbreakes are predisposed by stressors such as poor water quality or deteriorating environmental conditions, inadequate nutrition, improper levels of dissolved gases, improper handling and transport procedures and algal blooms.

Mass awareness has been created in recent past to produce more fish for sustainable development to ensure proper use and management of biodiversity and bioresources. Enterpreneurs seldom can avoid loss if the fish stock suffers from acute diseases caused by environmental, or pathogenic agents, but diseases caused by protozoan, trematodes and crustacean parasites can efficiently be avoided with prophylatic measures or cured by various treatments. An account of common fish diseases(causative organisms, diagnosis and control) is given below :

Fin fish diseases

The identification of causative orgnism for diagnosis of fish diseases is an important aspect in aquaculture management. There are certain fish losses due to sudden fluctuations of temperature or salinity of water or due to virulent pathogens. Regular fish health monitoring will help to solve the problem of diseases of fishes. Environmental management and supplement of nutrious diet will pay dividends.

Bacterial diseases

Red spot diseases

Causative agent : *Vibrio anguillarium*

Diagnostic feature : Due to bacterial infections, fingerlings and juveniles of milk fish are generally affected in winter with Hemorrahagic spots on body surface; exopthalmic and hemorrahagic eyes respectively. Significant mortality associated with bacteria found in liver and kidney, mild congestion of eroded fins and belly affect fish growth.

Preventive measure : the causative organism is reported to be sensitive to chloramphenicol. Control of blue green algal bloom has proved to be effective to combat the disease.

Fungal disease

Causative agent : *Saprolegnia* sp.

Diagnostic feature : Fry or fingerling of fin fish are affected with missing scales, whitish or greyish fungal growth on body, especially on margins of fins.

Preventive measure : Bath in malachite green or methylene blue mixed water will be effective in controlling the fungal attack.

Protozoan parasite

Causative agent : *Trichodina* sp., *Scyphidia* sp.

Diagnostic feature : Gills are generally infested with the aforesaid parasites. Secretion of mucous, irritation on gills and body surface are some of the characteristic features of this disease.

Preventive measure : as the fish fry and fingerlings are susceptible to attack by these parasites, dip treatment with formalin @ 1 ppm is to be done according to size and condition of the host.

Trematode infection

Causative agent : *Heplorcchis varium*

Diagnostic feature : The parasites are encysted in muscles of juveniles of fish of zoonotic significance.

Preventive measure : As the adult stage of the parasites remains in the fish eating birds, the final hosts are not to be allowed nearer to the pond.

Crustacean parasite

Causative agent : *Lernaea cyprinacea, Nerocila* sp.

Diagnostic feature : Parasites observed protruding from nostrils, skin of fin, bases of tail of fish. Such parasites are encountered in water bodies having lot of muck and aquatic vegetation which serve as substrate for laying eggs by the parasites.

Preventive measure : Adult stages of the parasite are to be eliminated through pond drying as well as liming. Crustacean parasites are sometimes controlled by gammexene (10% active ingredient) @ 2 ppm.

Routine examination of fish health is of foremost importance for surveillance and fish health monitoring as well as taking earliest opportunity of combating any fish disease outbreak.

Shell fish (Shrimp) diseases

Prevalent diseases of *Penaeus monodon*

Prawn disease may be caused by microbial agents which are easily transmitted under crowded conditions, such as those present in intensive culture systems, or by physical and chemical factors in the environment. Microbial agents consists of viruses, bacteria, fungi and protozoans. The physico-chemical factors are non-pathogenic disease agents which include nutritional deficiency, poor pond water and soil conditions as well as environmental pollutants. The basic features of these diseases are discussed below with particular emphasis on the causative agents and methods of prevention and treatment.

Hepatopancreatic parvo-like virus (HPV)

Causative agent : *Hepat. opancreatioc parvo* - like virus (HPV)

Diagnostic feature : Juvenile and sub adult are generally affected. Mass mortality within 2-3 days.
Preventive measure : To avoid using infected post larvae, if any

Monodon baculovirus (MBV)

Causative agent : *Monodon baculovirus* (MBV)

Diagnostic feature : Pale bluish-grey to d ark blue-black colouration and yellowish white hepatopancreas

Preventive measure : To use MBV - free seed which can be obtained by disinfection of eggs with suitable chemicals at the hatchery, ultra violate irradiation of water and maintaining farm hygiene. No specific treatment is known.

Baculovirus penaei (BP)

Causative agent : *Baculovirus penaei* (BP).

Diagnostic feature : Infected epithelial cells of hepatopancreas and less commonly anterior midgut, causing high mortality in the post larval stage.

Preventive measure : To avoid manmade disease introduction. Limit access only to authorized personnel. Through disinfection and drying of tanks, equipments and complete dry out of facility at least for 5 days.

Baculovirus midgut gland Necrosis Virus (BMNV)

Causative agent : Baculovirus midgut gland necrosis virus (BMNV)

Diagnostic feature : Affects epithelial cells of hepatopancreas as well as anterior midgut, causing high mortality in the post larval stage.

Preventive measure : No specific treatment is known.

Infectious hypodermal hematopoitic necrosis virus (IHHNV)

Causative agent : Believed to be caused by a member of the family Picaraviridae.

Diagnostic feature : Erratic swimming hebaviour, rising slowly to the water surface, hanging and rolling over until ventral side is up.

Preventive measure : To avoid using infected post larvae and adhere strictly to quarantine procedures.

Yellow Head disease (YHD)

Causative agent : Yellow head baculovirus (YBV)

Diagnostic feature : The attack may take place at any stage of life of the prawn. Head become yellowish in 65-72 hrs. It can cause 100% mortality within 3-5 days of the clinical signs. There are decreased feeding and weakness pale body colour, with swollen cephalothorax, swollen-brownish gills. It causes systemic destruction of many vital tissues, including the haemocytes, gills, connective tissues, lymphoid organs, heart etc.

Preventive measure : To improve general management. Initial disinfection of the water to kill possible wild prawn virus carriers, proper pond preparation between crops.

White spot disease (WSD)

Causative agent : Systemic Ectodermal and Mesodermal Baculovirus (SEMBV)

Diagnostic feature : White cuticular spots, often also with reddish body discolouration. The disease occurs in ongrowing juvenile prawn of all ages and sizes (3 gm - 40 gm) but mostly from one to three months after stocking in the grow-out ponds. White spot disease outbreaks occurs almost in all farming systems having stocking densities (extensive 4-6 pc./sq.m.; semiintensive 10-25 pc./sq.m.; intensive >25 pc./sq.m.) and irregardless of water quality conditions (mostly within normal range) and salinities (0-40 ppt). The moribund prawn were first seen to swim to the surface of the water and gather at the pond dykes. Typical clinical sign includes broken antennae, circumscribed whitish spot pinpoint 1 mm in diameter in the cuticle or shell that first started in the carapace and fith-sixth abdominal segments and later the entire body shell or reddish body discolouration, empty guts and sometimes body shell/gills cuticular epibiont fouling, sometimes lymphoid organ swelling. Prawn are being affected by the disease during the pre-moulting (pre-ecdysis) stage. The white spots were noticeable about 2 days after the prawn first appeared to get sick and a few had died. The prawn could still be feeding until the start of mass mortalities. The high mortalities occur within 3-5 days (range 2-7 days) with massive numbers of dead prawns found at the pond dykes or pond bottom.

Preventive measure : There is no way of treating SEMBV in the prawn, no chemicals or drugs are found to be effective presently. Horizontal transmission is suspected via the water, careers such as wild prawn e.g. Krill, *Palaemon* sp. and other crustaceans (e.g. crabs), the cultured prawn feeding on these and dead prawn with the disease. Vectors such as birds or dogs spreading infected prawn carcasses, careless workers using contaminated equipment.

Avoidance of infection and contamination is the prime method of disease prevention. These are as follows :

a) To use closed or semi-closed and recycle system.
b) To convert some culture ponds into a reservoir and avoid using water directly from the sea, river and canal.
c) To minimize water exchange.

d) Water in the reservoir or treatment pond can be sedimented, disinfected and aerated prior to use in the culture pond. Disinfection includes elimination of potential virus carriers such as wild prawn. The ideal disinfection method must still be worked out, but chlorine at 30 ppm. (Calcium hypochloride 60% active ingredient) is usually used.

e) To prevent entry of the wild prawn, crabs or fish into the culture pond.

f) To disinfect the contaminated water that had the disease, before discharge.

g) To remove top layer of the pond bottom sediment, drying at least 14 days and apply disinfectant for good pond bottom preparation.

Good management technique that could help to avoid a disease problem include :

i) Careful selection of healthy post-larvae.
ii) To avoid overstocking.
iii) To maintain good and stable water quality such as optimal DO, pH, alkalinity and plankton turbidity.
iv) Good feeding programme with nutritionally complete pelleted feed, avoiding the use of fresh (potentially contaminated) foods.

v) to maintain a clean pond bottom by having a proper feeding and sufficient/proper placement of aerator. Farmers in all areas are urged to cooperate more closely with one another especially with regard to disinfecting contaminated pond water before discharge to the environment in attempt to prevent and control the disease outbreaks further.

Bacterial disease

Bacterial infections of prawn have been observed by different workers. It has been noticed that bacterial infection in the blood or body fluids is an event that usually follows weakening by some other conditions. Currently, some recognised bacteria in cultured tiger prawn with major economic impacts are cited below :

Vibriosis

Causative agent : *Vibrio alginolyticus*

Diagnostic feature : It occurs one month after stocking post-larvae because of poor preparation of bottom and bad water quality which increases bottom algal blooms. Prawn becomes weak because of increase in pathogenic bacteria. Diseased prawn often exhibit brown or black spots on the carapace. Some prawn show white spots underneath the carapace. It causes septicaemic conditions and retards growth. This condition also aggravates due to high stocking densities, over-feeding and less water exchange. Those with white spots underneath may be looking healthy when they die. Mortality of those attacked by disease may have a range of 5-80% within 2 or 3 days. At first stage of infection diseased prawn move to the water surface at the pond slope and exhibit dark colouration of the carapace with an empty gut

Preventive measure : To clean the pond bottom, decrease organic load, maintain optimum density of phytoplankton, balancing water exchange and feeding the prawn properly with good quality diet. Antibiotic treatment with Oxytetracycline in feed for 7 days has given satisfactory results. Frequent water exchange, reducing feed level and compound diets with antibiotics such as Chloramphenicol may prevent disease. Treatment involves mixing of Furacin @ 1 mg per litre of water and tylosin at 100 mg active ingredient per kg of feed for 10-15 days.

Luminous disease

Causative agent : *Vibrio harveyi* and *V. splendicus*

Diagnostic feature : Affected prawns are luminiscent in the dark and suffer mortalities.

Preventive measure : Disinfection of pond water with chlorine, elimination of waste materials at the bottom. Nitrofuran has cured the disease in the laboratory.

Brown spot shell disease

Causative agent : *Vibrio sp., Pseudomonas* sp. and *Beneckia* sp.

Diagnostic feature : Brown colour start appearing on the shell.

Preventive measure : To provide water of good quality, remove dead and infected prawns, reduce stock and feed adequately.

Filamentous bacterial disease

Causative agent : *Leucothrix* spp.

Diagnostic feature : This may be found on the external surfaces of shrimps and thrives in water which in organic and inorganic substances. Vibrio and Aeromonas spp. Are found on the eroded areas of the shell of the juveniles and adults. The pathogens are also present in sea water and could be the secondary invaders after physical trauma of the shell and underlying membranes.

Preventive measure : Disinfection of pond water with chlorine, elimination of waste materials at the bottom as well as changing of water frequently. Nitrofuran has cured the disease in laboratory conditions.

Black splinter disease

Causative agent : *Vibrio vulnicus*

Diagnostic feature : This occurs in low salinity ponds of less than 10 ppt. Black splinters appear in the muscles, sometimes extending out of the carapace. Splinter consists of dense connective tissue surrounding the infected area, associated with melanin pigment, haemocytic aggregations and having bacterial colonies inside the splinter. Chronic inflammation is also noticed.

Preventive measure : To avoid stocking during the low salinity season and improved pond hygiene. At the first stage of infection when carapace have only black spots, and oxytetracyline medicated diet may effectively control the disease.

Fungal disease

The knowledge of fungus infection of prawn has advanced recently and several fungi are now known as prawn pathogens. One group infests larval prawns whereas another attacks the juveniles or larger prawns. The most common genus affecting the larval prawns is Lagenidium and the most common fungus affecting larger prawns is Fusarium. The well known disease is :

Larval mycosis

Causative agent : *Lagenidium* spp., *Fusarium* spp.

Diagnostic feature : The fungi may replace the internal tissues of the prawns and may cause 100% mortality within 2 days. The disease is noticed in hatcheries and rearing ponds, causing extensive mortality from 20 to 100%. The infection starts from a spore which attaches itself to the eggs and germinates. The mycelium grows, ramifies through the body wall of larva, develops rapidly, replaces muscle and soft tissues in it.

Preventive measure : Chemical prophylaxis includes disinfections of spawners with Treflan R (5 ppm for 1 ha). Chemotherapy consists of Treflan R or Trifuralin baths @ 0.2 ppm for 24 hours. Application of Malachite green @ 0.001 to 0.006 mg per liter of water may also be effective.

Protozoan disease

Several protozoan diseases of prawn have been recorded parasites and commensals of prawn may be grouped as Microsporidians, Gregarines, Body invaders, Apostome ciliates and Ectocommensal protozoa.

Microsporidiosis

Causative agent : Microsporidians, *Agmasoma* spp.

Diagnostic feature : It induces sterility, exhibits whitish muscle where the striated muscle is destroyed and replaced by causative organisms. Definitive diagnosis is by Methyl blue staining of the tissues or histological techniques. Those infected with microsporidians are referred to as *'milk'* or *'cotton'* shrimp.

Preventive measure : Disinfection of culture facilities with Iodine or chlorine is recommended. No satisfactory chemical treatment has been developed as yet. Usage of 0.0075 mg per litre malachite green in static condition for post larvae are tried with some success. Commercial bleach (purex - Fleecy or white bleachh) with 5-25% may show effective results. Sodium hypochlorite can also be used. Improving water quality and following strict husbandry measures are essential.

Gregarines

Gregarines are protozoans that are common inhabitants of the guts of wild and cultured prawn. They are present up to 75% in the prawns and do not cause serious damage. It should be remembered that this species need a mollusc host to complete their life cycle, therefore, the occurrence of molluscs should be minimized in the ponds and corals.

Body invaders

Protozoa have been noted to invade a prawn body and wander throughout. Two protozoa (*Parauronema* sp. and *Leptomonas* sp.) have been noted in weakened larval prawns. Advance effects of these protozoa are not fully understood.

Apostome ciliates

Apostome ciliates are typically commensals rather than true parasites. They exist in resting stage on the body surface of a living crustacean. When the crustacean moults, the protozoan is released and completes the life cycle within the shed exoskeleton before entering the resting stage on a new crustacean. Apostome has been noted frequently in resting stage of Penaeid prawns.

Ectocommensal protozoa

Ectocommensal protozoa such as *Epistylis* spp., *Vorticella* spp. and *Zoothamnium* spp. Are found frequently on host body surfaces, including gills, of an infested prawn.

Causative agent : *Epistylis* spp., *Vorticella* spp., *Zoothamnium* spp.

Diagnostic feature : Appearence of fuzzy mat on shell and gills. Larvae may not moult resulting ultimately in death. The heavily infected prawn may show pink to orange discolouration of gills.

Preventive measure : Maintain good quality of water by avoiding high organic loading in the pond. If necessary, 25-30 ppm formalin can be applied in the pond at one day interval for three times. During the treatment, monitoring of dissolved oxygen in the pond must be maintained to prevent oxygen depletion in the water. A large amount of water exchange is required after treatment.

Metazoan disease

Metazoan diseases that have been found in prawns are recorded as trematodes (flukes), cestodes (tape worms), nematodes (round worms) and crustaceans. Some species are more prevalent that others and yet none have been observed to cause widespread mortality. The parasites may be found in various parts of the body of the host.

Trematodes

Trematodes (flukes) are present in shrimp as immature forms (metacercariae) encysted in various body tissues. Metacercariae of trematodes of the families Opecoelidae, Microphallidae and Echinostomatidae have been reported from commercial species of penaeid prawn. One species *Opecoeloides fimbriatus,* has been noted to be more common than others.

Causative agent : *Opecoleloides fimbriatus, Microphallus* sp.

Diagnostic feature : Tapeworms usually associated with tissues covering digestive gland. Round worms are in and outside of organs in cephalothorax, but also in and along outside of intestine. Flukes are commonly encysted in tissues adjacent to organs in cephalothorax but also found in abdominal musculature and under exoskeleton.

Preventive measure : To strike the weak - link of the life cycle of a shrimp fluke, *e.g., Opecoeloides fimbriatus* as follows :

9 infective stage or cercaria penetrates shirmp - Cercaria migrates to the appropriate tissue and encysts forming a stage called metacercaria - Shrimp infected with metacercaria is eaten by fish which releases metacercaria of digested shrimp and metacercaria stage undergoes development until it forms an adult - Eggs laid by fluke pass out of fish with wastes. Eggs hatch and infective stage known as a miracidium is released. The miracidium penetrates a snail and

multiplies in number within cysts called sporocysts - Cercarae develop within sporocyst. When fully developed, cercarae leaves the sporocysts and snail and swims in search of a prawn. If contact is made with a prawn within a short period, the life cycle is completed.

Cestodes

Tapeworms in shrimp are reported as occurrence of the species of the genera *Prochristianella, Parachristianella* and *Renibulus* are common. An uncommon tapeworm of the Cyclophyllidean group has been observed recently in wild shrimp.

Causative agent : *Prochristianella* sp., *Parachristianells* sp.

Diagnostic feature : Tapworms in shrimp are associated typically with the digestive gland. They are usually found imbedded in the gland or next to it, in the covering tissue. In prawn, tapeworms are present as immature forms, while adult forms are found in fish. Also, a small pear - shaped worm is common in the intestine. Tapeworms are most often encountered in wild prawn. Differentiation between tapeworm group is made in general body form and tentacular armature.

Preventive measure : To break the life cycle of the tapeworm *i.e.,* prawn eats a copepod or other small curstacean infested with larval tapeworm - tapeworm develops into advanced larval stage in tissues of prawn - fish ingests infected prawn - tapeworm develops into adult in gut (spiral valve) of the fish and begins to release eggs - eggs pass out of the fish and are eaten by copepod - eggs hatch and larval worm develops inside copepod.

Nematodes

Nematodes occur more commonly in wild prawn than in cultured prawn. The degree of infection is probably related to the absence of appropriate hosts in prawn culture system.

Causative agent : *Thynnascaris sp., Spirocamallannus* sp.*, Leptolaimus* sp.and *Ascaropsis* sp.

Diagnostic feature : Nematodes will occur within and arround most body organs, as well as in the musculature. It is the juvenile stage of nematodes that infects prawn with the adult occuring in fishes.

Preventive measure : To pull down the vulnerable stage of the biology of the roundworm of prawn e.g. prawn eats a copepod or other small crustacean infested with larval roundworm - roundworm develops into advanced larval stage in tissues of prawn - fish ingests infested prawn - roundworm develops into adult in gut of fish and begins to release eggs - eggs pass out of the fish with faeces and are eaten by copepod.

Crustaceans

A bopyrid isopod stands as a good example of a parasite on prawn. Different species of bopyrids infest various prawn species in nature and cause considerable damage to the culturists. The parasite detracts the value of prawn.

Causative agent : *Palaegygae* sp., *Probopyrus* sp.

Diagnostic feature : The colouration and large swelling on the side of the carapace of a host make an infested individual obvious. The large, distorted female isopod nearly usurps the host's entire branchial chamber.

Preventive measure : The complicated life cycle of bopyrid parasite shows that the dwarf mature male remains near the posterior end among the female's pleopods. It broods many larvae within its marsupium. When the host moults, many individuals of the first stage larva (epicardian) are liberated and swim toward light. After attaching to the copepod intermediate host, the larva metamorphoses into another larval stage which grows rapidly at the expense of the copepod, and when several are present, may even surpass the host-copepod's mass. That larva moults to form the larva (cryptoniscus) infective for either a larval or young prawn. Disruption of host-symbiont may be able to control the degree of infestation. Before releasing prawn seed in the culture system, it is better to eliminate the infested prawn.

Miscellaneous conditions

Barnacles

Barnacles have been noted on the exoskeleton of prawn but the condition is rare. It is thought that frequent moulting of prawn does not allow enough time for barnacles to become established on the skeleton. No known remedy. Frequent change of water may help.

Blisters

This condition is characterized by a fluid - filled blister forming on the side portion of the carapace. The cause of this condition is yet to be worked out.

Cramped prawn

This is a condition described for shrimp kept in a variety of culture situations. The tail is drawn under the body and becomes rigid to the point that it cannot be straightened. The distal portion of the abdomen may become infected and turn into *'tail rot'*. The cause of cramping may be due to handling of shrimps in air warmer that the culture water; overcrowding; low oxygen levels; severe gill fouling and non-congenial salinity. Environmental conditions are to be improved.

Darkened prawn

The conditions of darkening may be due to melanin pigment which is deposited at the sites of darkening. Tissue may be killed by toxic agents and subsequently turn dark. Gills are particularly prone to darkening due to their fragile nature and their function as a collecting site for elimination of the body's waste products. Gills darken upon exposure to metals at toxic levels and as a result of infection by certain fungi (*Fusarium* sp.). Prawn appear darkened as a result of semitransparent nature of the exoskeleton. Nutritional inadequacies are to be improved.

Gas bubbles

Gas bubbles will form in the blood of prawn if subjected to waters with large differences in gas saturations. If large amount of bubbling occurs in the blood, death will result.

Golden prawn

Another rare condition in penaeid prawn is a golden appearence in prawn tissue. The cause is unknown but some suspect that is hereditary. The golden colour appears throughout the tissue and is not confined to the exoskeleton or tissues next to it.

Spontaneous necrosis

When prawn are exposed to stressful conditions, such as low oxygen or overcrowding, the muscles lose their normal transparency and become blotched with whitish areas throughout. Opaque muscles are characterisitc of this condition. If prawn are withdrawn from the adverse environment before prolonged stress exposure, they may either return to normal or die within a few minutes. In moderately affected prawn, only parts of the body return to normal; other parts, typically the last segments of the tail, are unable to recover. These prawn die within one or two days. Prawn muscles with this condition are known to undergo necrosis (death or decay of tissue). The whitish condition can be confused with milk prawn (microsporidian infection).

Tumors

Conspicuous body swellings or enlargements of tissues have been reported in prawns. In most cases affected individuals are captured from polluted waters. Occurrence of prawn with evident tumors is rare in commercial catches.

Other organisms attached to prawn

The colonial hydroid Obelia bicuspidata, the blue-green alga *Schizothrix calcicola* and a leech, *Myzobdella lugubris* leidy are some of the organisms found attached to prawn. These orgfanism probably attach to prawn as a convenience when they are present in great numbers in the vicinity of the prawn. Leeches may be particular, however, they have been noted as common residents of the exterior of shrimp.

Abiotic factors

a) Dull hardshell disease indicates impending disease attack. This is attributed to excessive calcium and phosphorus mobilisation due to over feeding. Application of good balanced feed in needed quantities, cleaning the pond bottom as well as changing the polluted water may improve the pond ecology.

b) Nephretic carcinoma of prawn may be due to magnesium deficiency resulting in impurity of blood. Calamine phosphate may yield better result.

c) Anorexia condition and choked gills of prawn are due to very low or high pH value and turbid water respectively. Frantic movements for respiration, resulting in sudden mortality of the stocked prawn. Application of Sunalum (non-ferric) may be tried to get optimum level of pH and transparency of water.

Gross clinical signs of disease

Healthy prawns have clean shells, greenish-brown in colour with yellowish white and black bands. There are many signs of unhealthy prawn which can be observed in growout ponds. The following are examples of gross clinical signs :

a) Lack of food in the intestines. Shrimp that are very sick cease to eat and those which are becoming sick will eat less than usual. Empty intestines are a sign of diseased shrimp while those with nearly empty intestines may be in the first stage of disease.

b) Tail not extended. Shrimp will not *'flick'* strongly and their tails will not curl. When base of the tail is grasped, it will not extend fully.

c) Dull body surface and whitish opaque muscle tissue. Shrimp that are becoming diseased will have dull hard shells and shrimp in the stages of sever infection will have murky whitish or reddish coloured muscle tissue.

d) At night before the last feeding, the farmer should examine the edges of the ponds for shrimp. Prawn which are becoming sick will often come up and float by the edges of the ponds. If the shrimp's eyes appear red then the prawn is healthy. Normal prawn will swim away when light is directed near them. Diseased shrimp will take a longer time to escape the light and will have paler eye colour. If the eyes are almost white then they are already severely affected.

Conclusion

Although, it has been said that viruses and bacteria, are by far, the most important causative agents, emerging trends show that mycosis and parasitosis play significant roles in mortality. As we know, prevention is far easier and more effective than cure. In many cases, cures are unknown, and it is therefore vital that strict vigilance to be maintained on water quality and stage of the animals in the ponds. The slightest problem should be reported and taken care of. This habit of reporting all incidents must become second nature if we are to prevail against the ever-increasing list of diseases that affect shrimps in culture system.

ECODYNAMICS AND IMPORTANCE OF MANGROVES IN SUSTAINING THE COASTAL FISHERIES AND AQUATIC BIODIVERSITY

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Introduction

Mangroves, the unique ecosystem, spread over an estimated area of about 14 million hectares in the tropical and sub-tropical regions of the Globe ; of these, the dominant mangrove zones in the world are restricted within the latitude 30°00′ S and 31°00′ N of the Tropical and Sub-tropical deltaic lands, sheltered bays, coast lines, estuarine mouths and edges of the islands, where these lands are frequently or periodically inundated with tidal sea water and also wash with up stream freshwater or bath with the frequent monsoon precipitation .

In these mangrove zones, generally the temperature fluctuates between 20°C and 35°C, though these temperature ranges occasionally varies in some scrub-mangrove zones, *i.e.*, 2°C- 4°C at 38°4′ S latitude in S. E. Australia (with the dominant species like ***Avicennia marina***) and 31°0′N latitude in Japan (with the dominant species like ***Kandelia candel***) The most dominant world mangrove zones are reported from this Old World, the Indo - West Pacific regions, *viz*., East African coast, Malagasy, Seychelles, Pakistan, Maldives, Sri Lanka, both east and west coast of India, Andaman & Nicobar Islands, Bangladesh, most of the coastal zones of S.E. Asian countries, Tropical Australia, New Zealand etc. The other important New World mangals are also reported from west coast of Africa, both the east & west coasts of tropical S. America, Mexico and the coastal areas of N. America .

Most of these world mangrove zones and areas have also been reported as the productive ecosystem with diverse groups of salt water loving flora and fauna; which are also very much important in regards to its interesting bio-diversity or being the world's most important heritage site within this sea-land interphase mangrove ecosystem (Naskar, 1996). The ideal mangrove ecosystem alternately inundate with tidal sea water during high tides and also exposed during tidal receding time or low tides. As such, these mangrove soil is saline, silty clay and semi-fluid to compact in nature; where large group of both aquatic and terestrial fauna find their preferred habitats for food and shelter. Besides these, large number algal flora also grow in these soil substratum as benthos and most of these algae are identified as the most preferred natural food for both shell fish and fish species of these estuarine ecosystems or mangals.

Tomlinson (1986) had reported only 40 species as the '**major and minor elements of mangroves**' or '**true mangrove species**' of the Old World, while in the New World the true mangrove species are only 8. But, Chapman (1976) had reported the total mangroves of the World as 90 species; furthermore, **UNESCO** (1983) had reported only 65 true mangrove species from the tropical and sub-tropical zones of the World. In another publication, Mepham & Mepham (1984) had reported more than 900 angiosperm flora from the world mangrove zones and they had grouped these 963 species either under the list of true mangroves, mangrove associates, back mangals and others. Mepham & Mepham (1984) had also raised several pertaining questions regarding the definition and strict boundary of these world mangroves. These important mangrove zones or the ecosystems are the natural habitats, breeding and grazing grounds or the nursery beds for large number of estuarine and off-shore shell-fish and fin-fish species, insects, reptiles, amphibians, birds, mammals etc. ~~(Mac Nae,1968)~~. Mac Nae (1968) had also mentioned that "**mangroves are the natures' own aquaculture system**" and he had cautioned that "**no mangrove no prawn**"'; that is the prawn farming cannot be viable without the existence of mangroves. Tomlinson (1968) had mentioned '**the sea-land interphace, inter-tidal or tidal habitat tropical and sub-tropical woody plants are mangroves**' and '**the community of these mangroves are mangals**'. Lear & Turner (1977) had also suggested that '**mangrove is the coastal ecosystem in a holistic manner**', which includes its common habitat or inhabiting flora and fauna; this mangrove is the depository of diverse flora and fauna.

As such, it is now worth mentioning that mangroves or the mangrove ecosystem or mangals includes certain group of flowering plants, cryptogamic flora, *viz.*, fungi, algae, bryophytes, ferns and varied groups of fauna, *viz.*, aquatic, mud-dwelling, terrestrial, tree living animal species and / or Avi fauna. Biotic communities of this composite ecosystem thus can be grouped in a broad sense as flora and fauna of the mangroves or mangals. All these have vital and great role in moulding the mangrove ecosystem in a perfect and holistic manner.

Definition of Mangroves

Several mangrove workers have recognised and defined the term '**mangrove**' differently; but for the clear idea and understanding the uniform characterization of these mangroves are essential. Few of these definitions of these mangroves are as follows :

a) Davies (1940) defined the mangrove as - " **Plants which live in muddy, loose, wet - soils in tropical tide waters are mangroves".**

b) Mac Nae (1968) defined the mangrove as - " **Trees or bushes, growing between the level of high water of spring tide and level close to but above the mean sea level**". Mac Nae (1968) had also used the term '**mangal**' for referring to the mangrove forest community, while the term '**mangrove**' for individual kind of tree species.

c) Aubreville (1970) defined the mangrove as - **"Mangroves are the coastal tropical formations, found along the border of the sea and lagoons, reaching upto the edges of the river to the point where the water is saline, growing in swampy soil and covered by sea water during high tides".**

d) Geriech (1973) reported that, mangrove occur at the edges of the tropical and sub-tropical seas, in bays, lagoons and estuarine regions. Thus **"Mangroves are trees of various species of several families, which grow only where they come into permanent contact with sea water or brackishwater"**.

e) Blasco (1975 & 1977) defined mangrove as - **"The mangrove is a type of coastal woody vegetation that fringes muddy saline shores and estuaries in tropical and sub-tropical regions".**

f) Arroyo (1977) defined the mangrove as - **"A small group of true mangrove plants and associated species belonging to systematically unrelated families, possessing similar physiological characteristics and structural adaptations with common preference to the inter tidal habitat"**. The term '**mangrove**' is also used for the -

(i). Forest Ecosystem ,
(ii). The Component Vegetation, and
(iii). Both Forest Ecosystem and Forest Vegetation.

g) Clough (1982) defined mangrove as - **" They are the only trees amongst relatively small group of higher plants, those have been remarkably successful in colonising the intertidal zone at the inter phase between land and sea".**

h) Tomlinson (1986) referred the term mangrove -**'Either to the constituent of plants of tropical intertidal forest communities or to the community itself'.** Tomlinson (1986) had critically analysed and stated these mangroves on the cosmopolitan basis; these are basically three types, *i.e.*, a) **major elements of mangals**, b) **minor elements of mangals**, c) **mangrove associates**, including the coastal species like back mangal, salt marsh flora, wet coastal communities, beach or coastal communities, low land swamp species, coastal swamps and swamp forest flora.

Mangrove in the more limited sense may thus be defined as - the **'Tropical trees restricted to intertidal and adjacent communities'** or **'Mangroves is a community that contain mangrove plants'**.

(i) Mepham & Mepham (1984) had also critically analysed 963 Angiosperm plants and fern species of the tidal and above tidal forests of the Indo-West Pacific Regions and highlighted them thoroughly, citing several most interesting examples, as well as, raised several debatable questions between the relationship and correct definition of '**Mangroves**'.

In this context, it is very much urgent to ascertain or draw a clear cut boundary line or define the term mangrove, prior to initiate any discussion on mangroves or mangals.

Area and Geographical Position of The Mangroves In Indian Sundarbans

Sundarbans, the largest deltaic tropical plain of India, is located in the southern part of both the districts 24- Parganas South and 24 Parganas North and in the coastal belt of West Bengal. It lies between the longitude 88°10'E and 89°10'E and latitude between 21°30'N and 22°15'N. These tidal delta Reserve forest area is about 4267 sq km, including both the mangrove forest land and water ways; of which, 1750 sq km is under the tidal rivers, creeks and brackishwater lagoons. The actual mangrove forest area in the estuarine belt/ deltaic zone of Indian Sundarbans is about 2179.05 sq km (with dense mangrove covers = 1952.87sq km + 226.18 sparse mangrove covers) and the rest is the naked beach or river flats. The entire area is intersected by large number of criss -cross network of tidal rivers, canals and creeks, which divides the region into 75 forest compartments under about 54 mangrove dominated islands futhermore, about 50 islands of these deltaic region were converted to human habitation, agricultural field. The denuded forest bed lying on the river banks, sand chars, forest floors and sea-shores is about 216.6 sq km (Naskar & Guha Bakshi, 1987). The delta embraces several true estuaries and off-shoots of the Bay of Bengal, *viz.*, Hooghly, Baratala or Muriganga, Saptamukhi, Thakuran, Matla, Goasoba, Harinbari etc. along with large number of east to west flowing tidal rivers, creeks and canals (Naskar & Guha Bakshi,1987).

Since the later half of the eighteenth Century, more than 50% of the mangrove forests in the Indian Sundarbans were cleared or reclaimed for the human habitations, agicultural lands and brackishwater fisheries etc. (Naskar,1985). Out of the total 9630 sq km Sundarbans regions of the Indian part, 13 rural blocks in the South 24 Parganas and 6 rural blocks of the North 24 Parganas are now densely populated with more than 32 lakh rural people (Census,1991); majority of them were migrated from the adjacent district Midnapore and also the refugees from Bangladesh. Most of these rural people are living much below abject proverty and they are solely or partly dependant on these virgin, fragile and degraded mangals of the Indian Sundarbans. Inspite of providing the longterm natural resources, *viz.*, shell-fish and fin-fish, timber, fuel wood, honey and wax, these coastal facing dense mangrove forests act as the wall and protect this newly silted up and frequent tidal inundated cyclone prone and problem stricken areas. But, poverty and greediness of the local people and business classes these nature's most interesting and world's most important heritage site are ignored while the protection measures and /or conservation activities are less feeble in these Sundarbans mangals.

Considering these ecological roles, economical potentialities and degrading nature, since 1973 about 2585 sq. km S.E. part of the Indian Sundarbans was declared as the 'Sundarbans Tiger Reserve', since 1976 the estuarine crocodile, ***Crocodilus porosus*** was also breeded and reared in the crocodile farm at Bhagbatpur at Namkhana Range and 3 Wildlife Sanctuaries, *viz.*, Sajnakhali, Holiday Island and Luthian Island started functioning and the Sundarbans mangrove forest was also declared as the 'National Park' since 1987. Besides these, with the objectives of overall conservation of the Sundarbans, *i.e.*, 9630 sq km is declared as the '**Sundarbans Man and Biosphere Reserve**'.

As such, for detailed clarification of different zones of the Sundarbans areas alongwith the population are shown below:

Total Sundarbans Areas	**= 9630.00sq km**
Total Mangrove Areas in Sundarbans	= 4266.60sq km
Mangrove Forest Zone	= 2179.05sq km
Estuarine Rivers, tidal creeks & canals	= 1800.00sq km(approx.)
Naked mudflats, sea-shore & river banks	= 277.55sq km(approx.)
Mangrove Reclaimed Zones & Human habitations	= 5363.40sq km(approx.)
Total Population in the Sundarbans (19 Rural Blocks) is about 32 lakh (Census -1991)	

All these interesting and unique flora and fauna of the Sundarbans mangals and the mangroves of the other regions have some close relationship or interaction with each other. These mangrove flora and the mangrove habitat faunal biodiversity have immence value and most economic potentialities in the sustained production of large number and huge quantities of the natural resources for the human soicety, which need only careful observation and for undertaking sympathetic conservation of all these biota.

Climatic And Physiognomic Factors Of The Mangroves

The mangrove species preferably grow in the saline soil and brackishwater zones, with the ranges 10 to 45 ppt, but for the effective mangrove seed germination and in the juvenile conditions, these mangroves thrive well in the less saline conditions. As such, most mangrove species bloom during the winter and summer months and the mature seeds become ready for germination during onset of the monsoon months, when the soil and water salinity becomes less due to monsoon precipitation and also due to adequate supply of upstream freshwater. These mangrove zones are spread over in the tropical and sub-tropical zones, with the average temperature ranges between 20°C and 35°C along with the average monsoon precipitation, *i.e.*, 1000 mm to 3000 mm annually; these also require coastal aeridity and high humidity; but the mangrove cannot thrive well or cannot show better growth in the lower temperature ranges or near the freezing point or on the frost. Besides these, the silted up clayee, loamy soil and the river carried sediments are also preferred by most of these mangrove species. For having the salt excretory mechanism, salt accumulation techniques, *viz.*, the adaptations like - salt exclusion, salt intrusion and salt accumulation, the major mangroves develop some specialised morphological features like develoment of air breathing and mechanical supporting pneumatophores, knee roots, buttress roots, stilt roots, bow roots, blind root suckers, plank like roots, pneumatothods etc. The adaptations, like viviparous germination, fleshy and leathery leaf textures, sunken stomata are also the unique morphological characters; all these help these mangroves to grow and survive in these salt water and saline soil phases, where other non mangrove plants can not grow.

Topography and Physiognomy

The Sundarbans fall under the Ganga - Brahmaputra delta system; the tidal flushing of sea water from Bay of Bengal through the network of tidal rivers and creeks have turned the water and soil of this deltaic land highly saline (Sah, *et. al.*, 1987). The river Hooghly in the west and the Ichhamati-Bidya in the east mostly carry fresh water from the upper stretches (Ganga-Brahmaputra system). The land evolution of this estuarine delta is very much devastating due to limited supply of fresh water from the upper streams; which is also reported for having the tilting effect (neo-tectonic movement) of the flow of the river Bhagirathi-Hooghly towards Padma of Bangladesh. Large areas in these deltaic mangrove forests are flooded with salt water during high tidal phase, while these vast tidal wetlands are covered by dense mangroves or halophytic herbs, shrubs and trees and the flat river beds or sand dunes are naked without any forest coverage, remain exposed during low tide (Naskar, 1983). These typical estuarine halophytic zones play dominant role in protecting the coastal areas. However, due to neo-tectonic, geomorphic, edaphic factors and rapid increasing human pressure and several other biotic interferences, several hectares mangrove free denuded tidal lands remain fallow as waste wetlands, which show higher salinity levels in comparison to mangrove forest covered areas (Deb,1956).

Soil Phase In The Mangals

The coastal strip extends to about 50 km - 70 km width from the Bay of Bengal. Coastal saline soils having an area of about 0.82 M ha have shown silty-clay to silty-clay-loam texture, chloride and sulphate of sodium (Yadav *et al.*, 1983); the coastal saline soil is deficient in Nitrogen and richness in Potassium (Bandopadhyay & Bandopadhyay, 1984). Coarse sand to clay or clay loam soil texture with varying organic matter have also been reported in the soil of the mangrove delta (Natarajan & Ghosh, 1985). Rudra & Halder (1987) while studying the soil characteristics of Sundarbans have indicated a good percentage of acid soil and a variation of soil texture from heavy clay to light soil in a few blocks. Adhikari *et al.* (1987) have detected appreciable amount of copper, manganese and potassium and low concentration of nitrogen. Detritus derived from molluscan and crustacean shells and especially mangroves decomposing leaves in tidal river basin soils deserves the study as it adds to the fertility of the soil (D'Souza and D'Souza, 1979) and for sustaining the growth of the mangrove herbs, shrubs and trees, besides fish and prawns (Choudhury, 1978). The electrochemical proportion of the mangrove muds of the Sundarbans were studied by Sah *et. al.* (1985). The percentage of organic carbon and humus carbon in the surface muds of the intertidal mangrove forests are due to the dense growth of the mangrove flora and very dominant mangrove dwelling biota.

Water Phase In The Mangals

Water salinity plays a dominant role on the survival and growth of different species of mangroves and algal flora and recruitment of certain types of fishes and prawns. Richness in nutrients in brackishwater of the Sundarbans has been found favourable for growth of a variety of euryhaline fishes and prawns from their larval stage to fingerlings (Ghosh, 1980).

Stresses on the Indian Mangroves

Mencer and Hamilton (1984) have reported that during the last two centuries vast areas of these mangrove ecosystems of the World have been reclaimed to shrimp farms in the S. E. Asian countries. Saengar, *et al.* (1983) emphasised that over increasing population pressure and pollutant discharge from industries, oil refinaries, tanaries and urban areas caused dramatic change on these mangrove ecosystems, throughout the world. Naskar (1985) has reported that during the last two centuries more than 50% mangrove areas in the Indian Sundarbans are reclaimed and converted to agricultural fields, brackishwater fisheries and rural habitations. Chanda (1977) has also reported that the mangrove areas of the undivided Sundarbans reduced to more than 50% during the last two centuries.

During the recent times and for the sake of development of port and harbours, roadways, tourism and for other human needs vast mangrove areas in India and all over the globe have been converted dramatically which have very detrimental effect in this fragile ecosystem. As the mangrove habitat and the tidal influenced water are ideal for development of seed farm, several hectares mangrove habitat lands have been cleared and reclaimed for prawn farms and brackishwater fisheries or for crab culture purposes throughout the S. E. Asian countries and in Indian mangals, as well. For making more profit, dramatic and drastic collection of prawn seeds and exploitation of other prawn and fish juveniles have been identified as an alarming situation throughout the mangrove habitats in India and other S. E. Asian countries. Besides all these, leaking of oil from the country boats and the pollutant discharge from the urban areas have also several alarming effect on the natural habitats of mangrove flora and fauna.

Roles Played by these Mangroves

Large number of fin-fish and shell-fish (prawns, crabs and molluscs) species are found as the common inhabitants on the mangrove waterways (rivers, creeks, canals, marshes, lagoons and wetlands) or these estuarine, off-shore and marine species are fully or partly dependent on these unique mangrove ecosystem. But it was not possible to assess or draw a clear demarcating line between these species of mangrove-dwelling, mangrove dependent, non-mangrove dependent and obligatory dependent on mangroves.

These quantitative estimation of mangrove dwelling and mangrove dependent fish and fisheries are very much limited, as most of these fin-fish and shell fish species are used to migrate from place to place during different season and different parts of their life-cycle. The only exceptions are the commercially important species of molluscs and resident crabs, gastropods etc. The present day's fishery statistics are mostly based on the fish landing data, collected from the different seasons, times and from the different parts of the mangrove habitats. All these data are not much much authentic, as because these data collections are based on different heterogenous group of workers, whose collected data may have over or under estimation. Besides these, the use of diverse fishing crafts, gears and mesh size of the nets and also the fishing operations (effort) or the degree of involvement of fishing community from zone to zone or from country to country these landing data may reflect a different picture and that may not be correlated with the mangroves of different parts of the Globe.

The only possibilities for near accurate estimation and quantification are to investigate critically the habits and habitats of different species of fin-fish and shell-fish species of these mangrove habitats and comparison can also be made with that of the mangrove cleared or reclaimed coastal or estuarine areas. Besides these, the investigation on the life cycle of each and every individual species along with their food habit, estimation of their migratory pathways and abundance or dominant harvest may help in this quantitative processes.

In these context, few important and well documented publications are mentioned for supporting the views of the direct correlation of mangroves with abundance of shell-fish species in the Indo-West Pacific regions, where mangroves are dominant on the estuarine mouths, sheltered coasts and lagoons. These important publications are -

(i) **Mac Nae (1968, 1974)** reported that the rivers, canals and lagoons in and around the dense mangroves are the natural habitats and nursery grounds of varied fin - fish and shell - fish species, which are commercially much important; among these few most important species are *Chanos chanos, Mugil* spp., *Hilsa* spp. and *Pomadasys* sp.

(ii) **Macintosh (1982)** reviewed the different publications of different workers of the different countries and highlighted an average 100 mangrove dwelling fish species from the different mangrove habitats. These important publications are made by Odum & Heald (1972) for Florida, Ong (1978) for Malaysia, Prince Jeyaseelam & Krishnamurthy (1980) for India, Collette & Trott (1980) for New Guinea. Jothy (1984) has also reported that 29 commercial fin-fish species under 23 families from the Malaysian mangrove waterways; among these few mentioned can be made for the *Chanos chanos, Hilsa macrura, Lates calcarifer, Epinephelus tauvina, Liza* spp., *Plotosus canius*.

(iii) Besides these, **Jothy (1984)** has listed 13 commercial species of shell fish and five commercially important species of molluscs from the Malaysian mangrove waterways. These important edible molluscs/ cockles of the Malaysian mangroves are *Anadara granosa*; the other Oyster species are *Crassosthea* spp. and green mussel is *Perna viridis*.

(iv) **Hall (1962)** also attempted to relate marine prawn fisheries in the mangrove habitat water ways and **Namin (1977)** has also explained that higher yield of prawns were desired from mangrove associated tropical coastline.

(v) **Daughery (1975)** had also highlighted that the destruction of mangroves is one of the major constraints for the declining trends of prawn catches.

(vi) **Jana *et al*.** (1974) supported and explained that several important fishes and prawns are now declining from the Indian Sundarbans mangals or estuarine zones due to deterioration of the mangrove vegetation.

(vii) **Umali, *et al*. (1987)** have also highlighted that mangroves not only support or export the fishery within its own ecosystem boundary, but also supply or export nutrients in the fisheries of the adjacent coastal areas; these mangrove waterways and mangrove ecosystems are identified as the nursery grounds for many fish species.

Among the large number of important observation and publications few mention may be made here for the mangrove dependent fish and fisheries in India in general and the Sundarbans mangals of West Bengal in particular. These important workers and publications are Naidu(1942), Hora & Nair(1944), Mukherjee, *et al.* (1940), Pillay(1954), David (1959),Gopalkrishnan (1968), Ghosh (1973), Luthar (1973), Annonymous (1978), Ghosh (1980), Chakraborty, et al. (1981), Jhingran (1982), Natarajan (1983), Naskar & Chakraborty (1984), Chakraborty & Naskar (1986), Naskar & Guha Bakshi (1987), Naskar & Ghosh (1989), Sanyal (1996), Das & Nandi (1996) Naskar & Ghosh (1997) and several others. All these publications have highlighted the direct correlation of the mangroves and the dominance of estuarine or off-shore fish and fisheries in and around the mangrove habitats of the Indian Sundarbans.

In addition to these economic and potential values, the mangrove forest flora also yield strong,durable hard timber and wood; mangrove reclaimed land is also identified as fertile land for paddy cultivation in several S.E. Asian countries, though in some cases these mangrove renovated areas has the problem of acidity, particularly the dominance of acid sulphate soil. Mangroves have several other economic and most valuable role in the human society, *viz.*, mangrove bark yield tannin, mangrove flower nectar produce honey and wax, mangrove forest is the only preferred habitats for large number of threatened, endemic, endangered and rare fauna in three tier system,*i.e.*, aquatic form from tidal water, terrestrial form from mangrove forest flora and avifauna like birds and others. As such, the mangrove ecosystem and forest areas are the attractive place for the tourist to meet their aesthetic needs, scientists and the ecologist for their virgin field for investigations and the fisheries scientists, as well. For all such reasons, these are unresolved conflict between the workers of these diverse fields and each of them claim mangrove ecosystem is their own and they may think that they are the authority and mangrove should be under their domain or jurisdiction.; though these complex ecosystem is not the property of any individual group.

Besides all these direct economic impacts, mangroves also protect the coastal zones from the cyclonic thrust and surges from the bay, alongwith the mitigation role played by these mangroves by protecting the deltaic lands from gradual erosion process of soil with the tidal flashing and also abate pollution.

Need for Conservation of Mangroves

During the recent times mangroves and the mangrove ecosystem are identified as the centre for rich diversity of different, interesting groups of flora and fauna. For their immense value, the mangroves and the mangrove ecosystem are now considered under strict protection and conservation measures for sustainable productivity and coastal land stability. The mangrove is the world's most important heritage site and the importance of several flora and fauna are identified as most essential for the well being of human society.

Remarks and Comments

On the basis of previous observations and studies, it is felt very much imperative to undertake few measures by imposing strict rules and making the rural people aware to protect the environment, natural resources and educating them for healthy living and thinking for their own existence. The following line of works may be suggested in this above context:

a) Assure their daily meal by improving agriculture, aquaculture, goaterry, piggery, dairy, poultry etc., based on the available local resources, possibilities and by providing training, financing, marketing and transport facilities. These approaches must provide employment opportunity for large number of rural people including rural women, those who mostly belong to S.C./S.T./OBC/Minority communities.

b) Need to stop monoculture of prawn and to encourage the fishery owner in polyculture, like the earlier years, by adopting the scientific methods formulated by the Central or State Fishery Research Institutes. These polyculture practices must help to stop prawn seed collection and damage of natural fish and prawn juveniles and the forest destruction must be checked.

c) Strict ban on operation of fine mesh nylon nets is essential and it is also necessary to stop netting of brood fish and prawn during the breeding season.

d) Exploitation of mangrove wood for fuel requires to be banned on an urgent basis as the growth of mangroves is very slow in this saline soil and tidal inundated mangrove forest zone. These mangrove forests of the Sundarbans are already suffering and getting degraded since the last two centuries or more, due to tilting effect and neotectonic movement of the freshwater flow of the river Ganga towards Padma, since the 16th Century. Large scale forest destruction, clearing of forest area for human habitation or agricultural or brackishwater fish cultural purposes during the last two Centuries, *i.e.*, since the time of Tilman Henckel (1781) and migration of the refugees from Bangladesh, Midnapore, Orissa and Chhotanagpur Hill are identified as the main cause for destruction of Sundarbans mangal; the Sundarbans is now over populated with a total population of more than 32 lakh (1991 Census) in an area of about 5000 sq km., *i.e.*, about 650 people / sq km. This Sundarbans area is also situated in the tidal/cyclone prone coastal belt of Bengal and these mangrove forest act as the buffer agent and are known to minimise the cyclone effect by about 50 - 60%; the existence of the dense coverage of the mangrove forest flora on the silted up flat deltaic intertidal lands also add nutrients via decomposition and mineralisation processes of the mangrove litters, which is also estimated by others to be about 6000 t /ha/yr.

Besides all these, fish, prawn, crab, honey and wax, wood and timber and other natural resources, *viz*, fertile agricultural and aquacultural lands of the Sundarbans directly and indirectly help the rural economy. So, only for the fire wood purposes the Sundarbans mangrove forest exploitation is uneconomic and illogical use of the natural forest products, particularly when the forest is in an alarming state.

e) Without education, these rural people cannot be made conscious about their entity as human beings and cannot think about living as civilized human beings and this results in unlimited population growth, health hazard, scarcity for domestic place, ill mentality and all these together must be reflected on the civilized people in the urban areas.

1 2 3

"Socio-Economy <> Education <> Population Growth"

These three urgent questions need to be solved urgently giving uniform stress on these three points simultaneously; otherwise, by single or by limited approach beyond these three urgent points may not solve the problems of the Sundarbans mangals and it is sure that if the present trend of exploitation continues for another 50 years, the so many important 'gene pool' will get vanished from these Sundarbans and the glamour of 'world heritage site' will be lost within no time. Man is the highest biotic component in any ecosystem, so without protecting the interest of man the ecosystem protection will be a fruitless effort.

CONCEPTS AND APPROACHES FOR ENVIRONMENTAL IMPACT ASSESSMENT IN INLAND WATERS

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Introduction

Man himself, due to his uncontrolled population growth and indiscriminating use of the natural resources is greatest threat to his environment. Though every spheare on the earth is exposed to human contamination, the environmental problems concentrate by and large to the water may be subsurface or underground resources. What so ever may these pressure be on the environmental naturality, the developmental activities are inevitable; and man has to determine, however wisely, what pollutional changes are acceptable. In determining such acceptability, adequate informations regarding the probable impact of environmental alterations on its inhabitants must be in record.

The gross pollution of water is clearly an immediate hazard to many aquatic resources, a hazard that can be documented biologically with relative case. Lesser environmental changes may also be immediately determined to aquatic life, and as because they produce measurable changes in the species involved, they can often be evaluated. Changes not likely to be harmful in near future may in the long run be destructive to aquatic environments. In vast ecosystems like rivers, lakes, estuaries, reservoirs etc., the ultimate effect of environmental distorsion like hyperthermastasis, eutrophication and accumulation of biologically stable metals, pesticides or radioactive substances are difficult to predict. Researches over the years lead to establish a comprehensive method of tackling the problems to a acceptable limit by Environmental Impact Assessment (EIA) of the ecosystems.

What is EIA ?

Environmental impact assessment is a procedure for assessing the environmental implications of a decision to enact legislation, to implement policies, plans and development projects. The broad objectives of the procedure are (i) identification and examination of significance of environmental impacts and (ii) assessment of whether or not the impacts can be mitigated. Finally, recommendation of preventive and corrective measures is the moto of environmental impact assessment.

Till seventies the main concentration of aquatic pollutional research was on toxicity evaluation of contaminants in relation to different test organisms. With advancement in thinking about the problems, the concept changed to regularity in ecosystem testing to better insight into how intricating populations within a community respond to contaminant exposure. Main objective of such testing necessiates careful attention to the boundaries of potential impact, the major ecological components affected, and what state variables affect base line conditions.

Herricks and Cairn (1982) recommended a close coupling of prediction and monitoring, and the incorporation of appropriate toxicological testing in biomonitoring programmes of EIA. Upon the ideas of several researchers in the field most acceptable monitoring programmes to assess damages to an aquatic ecosystem should have criteria like,

i) *As simple as possible*
ii) *Most economical*
iii) *Should predict population and community responses*
iv) *Generate data appropriate for inclusion in mathematical and statistical models.*

Assessment measures

Evaluation of environmental impact in aquatic ecosystems consider numerous problems; local, regional and of national perspective. As a result, the programmes include acute, long-term and large-scale monitoring to assess the conditions at points, regions and the aquatic system in totality.

Acute toxicity assessment

Acute toxicity considers 'rapid damage to the organisms by the fastest acting mechanism of poisoning, fatal unless the organisms escape the toxic environment at an early state'. Mortality of exposed organisms in 96 hrs. is the accepted method of acute toxicity evaluation of the contaminants. Such experiments termed 'bioassay' are useful for toxicity evaluation in field conditions *i.e., in situ* as well as controlled conditions of laboratory. Flow-through laboratory tests are designed for the bioassay to replace toxicant and the dilution water either continuously or at intermittent intervals. Flow through tests are generally thought of as being superior to static test because they maintain much higher water quality and ensure the health of the test organisms. *In situ* acute toxicity bioassay performed in natural flowing water for a discharged effluent, exposes test organisms in small enclosures at selective points adjoining the discharge resource considering variability in the dilution rates. The resutls for *in situ* and laboratory acute bioassay are expressed in terms of lethal time (LT) or lethal concentration (LC) which ever is appropriate considering the nautre of toxicants and the mode of their contaminating the environment.

Chronic toxicity assessment

In chronic toxicity tests the organisms are exposed to a toxicant/contaminant over a significant portion of their life cycle, typically one tenth or more of the organisms life time. Chronic studies usually measures contaminant's effect on growth, reproduction and also changes in behaviour, physiology and biochemical constituents under sublethal concentration. These studies exposed embryos and young ones to toxicants. The early embryonic developmental stages of major carp have been most effectively used as test organisms for acute toxicity bioassay in laboratory conditions for various toxicant and *in situ* experiments in evaluating the toxic effect of effluents in river ecosystems.

Long term ecotoxicological assessment

For toxicity bioassay there has been lacking in field toxicity and exposure assessment on community structure sensetive to the complex aspects of chemical and physical environments. Most advance method to measure these aspects involves rating of community structure on index values. The criteria for selecting indices of ecosystem and recevery include :

i) *Intrinsic importance, emphasising endangered or commercially important species.*
ii) *Early warning indicators,*
iii) *Sensetive indicators,*
iv) *Process indicators.*

It may be noted that the more complex the ecosystem, the more field data are required to understand the cause and effect relationship. Such complecation in environment arises when ability to regulate water quality remains insufficient or ineffective in some respects due to tremendous number of chemical in use. It becomes difficult to predict *in situ* toxicity under conditions of pulsed releases from complex mixtures in areas such as hazardous water sites or from nonpoint sources affecting the down stream aquatic communities. Complecated relationships between the environment and the organisms in such a situation can be drawn on understanding the water and soil quality contamination, bioconcentration, bioaccumulation and stress effect evaluation in the organisms of different trophic levels.

Water and soil quality monitoring

The principle media for aquatic sustinance; water and bottom sediments, control qualitative also quantitative distribution of the organisms. Physico-chemical qualities like temperature, transparency, dissolved oxygen, pH, alkalinity, hardness, chlorinity etc. are adequate in predicting the inhabitant population structure. For sediments, richness in nutrients, organic percent and mechanical compositions are indicative of the possible flora-faunal composition on the bottom of the aqutic systems. Spatio-temporal monitoring of water and sediment qualities provides information in time scale shifting in biocommunity structure with environmental changes.

Contaminant assessment

Organic refuses which form bulk of contaminants are non-persistant and non-residual materials and thus produce toxicity effect for restricted period limited to the areas of contamination. Problems are with non-biodegradable contaminants like metals, pesticides and radioactive material. However, toxic effect may have on the biocomponants, these contaminants toxify the water and sediments first which immediately or in the long run contaminate the inhabitant population. Advancement in sofistication of instruments and analytical methods resulted simplified and percised estimation of toxicants from water, sediments and biotic samples.

Biocontration estimation

Bioconcentration is the accumulation of water born chemicals by the aquatic animals and plants through non directory routs *i.e.,* as the result of competing rates of chemical uptake and elimination. The bioconcentration of metals and other nonbiodegradable materials varies greatly with the species and the specific contaminants. Size of organism can also influence bioconcentration rate. Metals initially accumulates in the gills of both invertebrates and fish. Putting altogether, bioconcentration is considered a complex system dependent upon the species or organism, exposure concentration and period, environmental factors and the specific toxicant. Methods of various toxicant estimation are available for suitable adoption.

Stress effect evaluation

In ecotoxicology the stress effect evaluation is a complex process utilising the biological state of affairs for ascertaining time scale changes in individual biological constituents and community structure as a whole. The reasons of such testing undertaken are to assess responses of individual and population of a community under actual exposure conditions, to assess the potential contaminant for indirect and sublethal effects; and to determine if threshold levels for effect, measured in the laboratory, have any validity for ecosystem.

In ecotoxicological biomonitoring programme a sound experimental design is critical to the assessment of ecological damages (Rarr, 1991). The design requires an understanding of the complexity of the aquatic system such that confounding factors like current velocity, depth, transparency, organic matter, nutrients etc. are accounted for in sample comparison. Sampling approach need be unbiased for better ascribing of changes in the flora and fauna to anthropocentric activities. The index of biotic integrity designed to reveal the integrative nature of fish communities responding to changes in water quality has been developed for application. Problems in biological activies like growth, reproduction, and recruitment potential of fish are also ascertained as suportive evidneces for changes in community structure.

References :

Herricks, E.E. and Cairn, J., Jr., Biological monitoring. III. Receiving system methodology based on community structure, *Water Res.,* ***16,*** 141, 1982.

Karr, J.R., Biological integrity : A long-neglected aspect of water resource management, *Ecol. Appl.,* ***1,*** 66, 1991.

Toxicology and biomonitoring as a tool for ecological management with river Ganga as a case study

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Introduction

The present era is the era of industrialization and overpopulation. To meet the population demand there has been over-exploitation of natural resources. Consequently, adverse environmental effects like species extinction, deforestation, acid-rain, green-house effects, hazardous waste disposal problems, intense eco-imbalances are on rise. It is a good sign that human race have become aware of resource crunch and environmental degradation. Many programmes focussing on the conservation and monitoring of environment have been initiated both by developed and developing countries.

Conventionally, environmental monitoring are carried out by chemical analysis. However, with time it has been noted that physical or chemical methods of monitoring are insufficient to measure the stress or toxicity on biota or life-processes from pollutants. Even the most sophisticated chemical analysis are just inadequate to indentify all the biologically active compounds present in waste. Hence, besides chemical analysis, biomonitoring of effluents, wastes or natural resources like water have been undertaken by many countries to see the totalatarian effect of pollution or ecodegradation and formulation of suitable management practices.

In the present discussion we shall restrict ourselves on biomonitoring of aquatic ecosystem with exphasis on the river Ganga.

Definition of terms

The term *'water pollution'* can be referred to the addition to water of an excess of mateiral (or heat) that is harmful to humans, animals or desirable aquatic life, or otherwise causes significant departures from the normal activities of various living communities in or near bodies of water. The undesirable effects of pollutants on life processes is called toxicity or toxic effects and monitoring of such pollution by studying toxicity/stress on biota is biomonitoring. Various factors which cause pollution to water bodies are (i) sewage waste containing human excreta and house hold disposals, (ii) industiral effluents and heavy metals which change the physico-chemical properties of water, (iii) agrochemicals such as fertilizers and biocides and (iv) radioactive wastes which are mutagenic, carcinogenic and teratogenic.

Toxicology is the study of adverse effects of chemicals or other agents on living systems. Any chemical or biochemical in abnormal dose and abnormal route is toxic - is the true definition of toxin/toxicant applied in pharmacology and toxicology. However, we shall discuss only about the toxicants present in the environment. These commonly enters the physiological systems through natural routes. Extent of toxicity on the living systems depends on dose and duration of exposure. Toxicity of a chemical is greatly influenced by animal species, age, nutritional and hormonal status of the individual and interaction between genetic and environmental factors.

Methods of biomonitoring

As mentioned, water pollution can harm all the life processes, particularly aquatic flora and fauna directly, and higher plants and animals directly and indirectly. Gorwth and population of aquatic flora and fauna can be monitored qualitatively as well as quantitatively to measure the pollution.

a) Algal assay : Algae are the primary producer in food chain and are very sensitive to pollutants. Hence algal bioassay are widely practised particularly for measuring chronic effects of contaminants over a span of several algal generations. In chemical specific approach which identify toxic chamicals, a diluent concentration series of test chemicals in prepared with the growth medium. The test alga is then grown on it for a definite period of time (ranging from 3-15 days). The growth response (growth rate, biomass production) is then converted to '% form of growth - inhibition'. When these are plotted against the chemical concentrations on a logprobit graph paper, a regression line can be drawn. The concentration of chemical that inhibits 50% growth of test alga (EC_{50}, the effect concentration) is used to set the guidelines for the maximum allowable chemical concentration in the receiving water. In the whole effluent approach waste effluent water is diluted serially (for *eg.*, 100%, 75%, 42%, 32%, 24%, 18% ...... 0%) like a pure chemical; toxicity of the water can be measured, but lacks quantitative analysis. Cu-equivalent approach can be adopted to quantify the toxicity of a 100% test water. Toxicities caused by metal or organic pollutants can be interpreted by complexation approach using chelators or quenching agents, like EDTA or hyamine respectively. *Selenastrum* spp., *Chlorella vulgaris, Microcystis aeruginosa, Anabaena flos-aquae, Synedra* sp.etc. are used for toxicity tests.

Like other biota algae are sensitive to heavy metals and are used for bioassay. *Selenastrum capricornutum* have been widely recommended for toxicity assay. The most common algal response to increased levels of heavy metals is a decrease in growth rate. In heavily polluted water or effluents the algal population changes quantitatively, and/or there is change in algal species dominating the ecosystem, or change in algal cell morphology.

b) Diatoms and periphytons : Frequency distribution of diatom flora have been correlated to water quality by many workers. Nygaard observed that centric diatoms are commonly found in eutrophic water, whereas pennate diatoms predominate in oligotrophic water. Centric diatoms/pennate diatoms ratio of 0.00 to 0.30 indicates oligotrophy, and a value of 0.00 to 1.75 indicates eutrophy. Reports on particular diatoms indicating a particular pollutant are numerous. Organic nitrogenous materials have been shown to support the growth of large population of *Nitzchia kuetzinquiana, N.palea* and *N.thermalis.* Under anaerobic conditions there is an abundance of *N.thermalis* and disappearance of *Achuanthes minutissima*. The pennate diatom *Navicula accomoda* was reported to indicate sewage pollution. *Navicula, Pinnularia* and *Nitzchia* develop profugely in water rich in pollution of animal origin. Diatoms thrive best in mesasaprobic zone. It is a general finding that the number of species comprised of diatoms in an ecosystem depends on regional geological environment of a water body and does not change much over time unless drastic environmental changes occur. So, caution should be taken in extrapolation of results.

Periphytons arte assemblages of attached form of algae occuring in all aquatic environments. These communities respond immediately to the pollutants like heavy metals, pesticides and fungicides, and also react to temperature and turbidity changes.

c) Bryophytes : Bryophytes are able to grow in many freshwater habitats in the presence of high concentration of heavy metals and acid conditions. They have high capacity of accumulating heavy metals which can be detected in these plants by chemical analytical methods. Although a direct relatiionship between water metal concentration and those in bryophytes may not always be apparent, the accumulation in bryophytes facilitates analysis of contaminants which may be present in very low concentration in water samples.

d) Protozoa and rotifers : Environmental quality can be assessed by qualitative and quantitative analyses of protozoan colonization of artificial substrates like polyurethane; the entire microbial community, instead of individual species should be studied.

Rotifers, the trochhelminthes, live mainly among aquatic vegetation and serves as indicator of water quality, especially the part dealing with saprobity (BOD_5). One is able to characterize each taxon with quantitative saprobiological data consisting of saprobic valence (with ten balls for each taxon), indicative weight of species, and the individual saprobic index. Zenosaprobic and oligosaprobic rotifers indicate at the same time, the oligotrophic conditions and beta- and alpha-mesosaprobic rotifers are indicators for eutrophic conditions.

e) Zooplanktons : Monitoring heavy metal pollution - Among aquatic organisms both phytoplankton and zooplankton play major role in the biogeochemical cycles of trace elements either by bioaccumulation and later transfer to higher levels, or by resdistribution. Zooplankton metal levels respond to corresponding changes of metal concentration in the environment. For determination of zooplankton heavey metals, the zooplankton samples are collected by towing a plankton net (mesh size 250 - 350 μm), dried at 60-70°C, powdered, weighed, digested in acid and metal concentration estimated by atomic absorption technique and expressed in μg/g dry weight.

Zooplankton bioassays are also carried out to test the toxicity of different metals to evaluate permissible limits of heavy metals in aquatic ecosystem for protection of aquatic life. 4 types of tests exist : i) acute lethal and sublethal tests in the laboratory (30 sec to 4 days 'screening test') using a single species (most commonly *Daphinia* sp.), (ii) Chronic sublethal tests in laboratory (several weeks, single species), (iii) chronic microcosm tests under simulated field conditions which measure responses of zooplankton populations to low levels of materials as heavy metals, and (iv) acute or chronic in situ test ('effect monitoring' approach). Lethal, behavioral, developmental (rate, success, morphological aberations) and reproductive responses are probably simplest to include in zooplankton assay.

Pollutants alter the community structure in an ecosystem in various ways, including a reduction in species diversity, disappearance of certain species, with others assuming dominance and changes in the total biomass in the community. All these changes, unless drastic, may be natural, and without constant and long term study it is difficult at times, to distinguish between pollution induced and nature induced changes.

Study in fishes

So far, studies on some aquatic organisms, other than fish, have been outlined. Studies of aquatic pollution and toxicology using fish as model at organismal, cellular, genetic, physiological, biochemical and at community level are exhaustive and are sensitive also.

a) Behaviour study : Fish population behaves varyingly to different environmental situations, which can be studied at laboratory or in natural ecosystem. However, study in natural ecosystem needs laboratory confirmation. Fish response to different stressors are of following types :

i) fish can pass through the pollutants with no apparent reaction
ii) avoidance to pollutants/toxicants
iii) dart or increased speed after encounter
iv) lethality or twitching or spasm.

At community level there will be less or least fish population in the polluted area of the water body which fish tries to avoid.

b) Fish bioassay : Man-made chemicals eventually find their way into the aquatic environment where they are proving to be toxic to many organisms. In aquatic toxicology, fish have been widely and popularly acclaimed as a test species for evaluating the potency of toxicants to cause lethality (acute toxicology) or many other sublethal responses, using selected behavioral, biochemical or physiological and haematological responses.

Acute or lethal toxicity : This is used to determine the level of the toxic agent that produces an adverse effect on a specified percentage of the test species in a short period of time. Acute toxicity is measured experimentally for 50% mortality of test species during 24, 47, 72 and 96 hours exposure time. Results are expressed as 96 hours median lethal concentration (96 hr LC_{50}).

Chronic or sublethal toxicity assay : This type of bioassay demonstrates the effects of long term exposure of test species to toxicant concentrations much lower than the lethal levels. The effects may produce conditions that may interfere with some of the normal life functions, which can be measured or monitored, rather than killing the organism directly. The data are useful in risk evaluation and development of a water quality criteria for protection and conservation of aquatic life. However, the tests are time and money consuming and need expertisation.

i) *<u>Life cycle tests</u>* : The test species are normally exposed to a constant level of poison during their entire life span under controlled conditions. The most sensitive developmental stage in the life cycle can be determined.

ii) *<u>Growth rate measurement</u>* : Growth rate measurement, by taking repeated reading of length and weight over a period, is a good indicator of health or the presence of stress factors. Length-weight relationship, relative condition factor etc are also of great significance.

iii) *<u>Histopathological changes</u>* : It is one of the important study area for assessing toxicity or stress. Changes at cellular and subcellular level can be studied by simple histological or histochemical or immunocytochemical changes. Also, the site of action of toxicant can be located. For *e.g.*, high concentration of heavy metals induce gill damage with hyperplasia and degenerative changes in secondary lamellae. Excess mucus production has also been noted. Phosphamidon toxicity results in hepatocyte necrosis and glomerular hypoplasia.

iv) *<u>Haematological changes</u>* : Haematological changes in response to various toxicants in fish is not well documented. Generally, in stressed situations these are depression in total WBC, RBC count and also in haemoglobin % and haematocrit values. However, under heavy metal stress increase in RBC, haematocrit, clotting time and hepatosomatic index has been recorded. Leucopenia, thrombocytopenia and decrease in ESR have also been noted. Haemotological responses to various pesticides vary.

v) *<u>Biochemical and physiological changes</u>* : Changes in various biochemical and physiological parameters in response to various stress factors are the new study areas in aquatic/fish toxicology. Generally, in stressed situation there is significant decrease in total serum protein, liver and muscle glycogen content, and hepatic Na, K, Ca, phosphate and iron reserve. Cu cause depression of liver SDH activity and increase in blood glucose level. Mn has been shown to cause liver damage and possibly myocardial damage and increase in GPT activity and cholesterol content. Pituitary gland cell type changes in Cd toxicity. The cells become deformed, vacuolized; diameter of thyrotroph and gonadotroph cells decrease.

Metallothionein level greatly increases in heavy metal toxicity. Level of acetylcholine estrase enzyme decreases significantly in organophosphate and carbamate poisoning. However, the list in endless, but study of these changes need proper controls and expertizations.

vi) *<u>Immunotoxicology</u>* : Like any other body system immune system also can be a target for toxic damage. It will either become downgraded, leading to degrees of suppression, or upgraded producing autoallergic reactions and hypersensitivity responses. Generally, effects of the toxicants like heavy metals or insecticides on this vital system is very slow and progressive and are overlooked until some major disorders or disease outbreak occurs. Less severe immunosuppression may be confused with other problems like low grade infection and resultant reduced growth etc. Some insecticides like DDT, BHC etc. have been shown to suppress the immune response, with consequent effect of disease outbreak.

vii) Reproductive toxicity and teratogenicity : Reproductive toxicology in fish, unlike in higher vertebrates in less clearly known, as is the nature of various toxicants and their effects on this system. There may be reduced spawn size, hatchability, development and survival of the youngs. Ultimately, changes in species population may be engineered through this physiological system in an polluted ecosystem.

Teratogenicity is most commonly seen with radioactive wastes polluting the ecosystem. However, very little progress has been made in fish biology over this topic. Fish may be used as a model for teratogenicity study. In frog embryo teratogenicity assay (FETAX) using Xenopus embryo, mid-to-late blastula stage embryos are exposed to test agents in water for upto 4 days and are assessed for mortality, pigmentation, growth, extent of development and abnormalities.

Studies on cellular damages by different chemicals in reproductivbe organs of fish are lacking. However, studies in other laboratory animals are many.

Some of the xenobiotics such as DDT, β-hexachlorocyclohexane, polychlorinated biphenyl (PCB), 7,12-dimethylbenzanthracene (polycyclic aromatic hydrocarbon), 4-nonylphenol, coumestrol (phytoestrogen), synthetic estrogenic compounds of domestic origin are estrogenic in nature. Most of these substances are hydrophobic and tend to bioaccumulate in aquatic organisms and are often transfered through the food chain. Though most of these are weakly estrogenic, but at least a few have been shown to stimulate vitellogenesis in both male and female fishes, and may alter natural sex differentiation ratio. Thus they may have some potentially deleterious consequences in fish population.

Zn, Cu and Al toxicity : Like other biological systems fishes are also sensitive to heavy metals. Here, toxicity effects of 3 heavy metals have been outlined as representative.

Fish uptakes Zn through gills and g.i tract. However, fish can tolerate a very high dose of Zn orally. Thus only Zn dissolved in water is of toxic concern. Acute lethality of dissolved Zn increases with decreasing water hardness and [H^+]. At very high concentration of Zn fish dies from hypoxia caused by gross morphological damage to the gills - edema, inflammation, cell-sloughing and fusion - effects common for heavy metals at 'industrial' concentrations. At low grade and chronic toxicity there is impairment of branchial calcium uptake which leads to a hypocalcemia that may become terminal. The most sensitive gross effect is an impairment of reproduction.

Though traces of Cu is essential part of some enzyymes, marginal increase in its concentration is toxic. Severe Cu exposure in characterized by collapse and oven fusion of the lamellae and sloughing of lamillar epithelium. There is excess mucus secretion and a concomitant swelling of the mucous layer around the gill. Mucus secretion is a common stress response to a variety of environmental factors including heavy metals, ammonia and salinity changes. The increase in gill permeability leads to passive ion efflux and severe ionoregulatory disturbances.

Fishes exposed to Cu and Al experience elevated plasma ammonia levels and decreased swimming performance.

Gill is the main target organ of Al toxicity in acidic soft waters. Branchial toxicity has been suggested to result from the precipitation of insoluble $Al(OA)_3$ on the gill membranes and/or the interaction of gill ligonds with positively charged Al.

Effects of nitrite : Concentration of nitrite in typically low in unpolluted water but may increase in hypoxic lakes and ponds and in water bodies containing decaying organic matter. Fishes actively bioaccumulate nitrite. Elevation of environmental chloride levels protects against nitrite accumulation and toxicity. Nitrite induces oxidation of haemoglobin to methaemoglobin that cannot transport oxygen. Nitrite does not disrupt reversible oxygen binding of haemocyanin of crustaceans to the same extent with haemoglobin.

Depletion of extracellular chloride is a characteristic effect in nitrite exposed fish & crustaceans. The active branchial Cl^- uptake is replaced by NO_2^- uptake, but the passive Cl efflux persists, leading to a net chloride loss at the gills. Due to NO_2^-, K^+ is released from intracellular compartments leading to decrease in red cell K^+ content, depletion of muscle K^+ and increase in plasma K^+. This affect membrane potentials, neurotransmissions, skeletal muscle contraction and cardiac function.

GANGA - AS CASE STUDY

The Ganga is a very important river system in India. Enormous studies have been carried out on floral and fauna population in this river systems and the literature is exhaustive. Only a few salient points related to biodivbersity and biomonitoring of river Ganga will be mentioned.

Biological profile

Extensive reviews have been made on biological profile of the river Ganga by many workers.

Coliform count in various calender months show a systematic pattern. The count varies with site of collection and the season of collection. An increased coliform count has been recorded in pre-monson season than post monsoon period, the count range from 0.10-11.40 x 10^4/. Premonsoon fecal coliform count is higher than in postmonsoon, and the count ranges from 0.10-9.0 x 10^4/. Fecal coliform count has been higher in densely populated areas.

Algae - A total number of 577 algal species spreaded over 151 chlorophyceae, 198 cyanophyceae, 223 chrysophyceae and 5 euglenophyceae have been recorded from Ganga water. A very large number of planktonic algae including diatoms formed broad chunk of algae. Plankton count shows existence of 199 to 44800 cells/lit. However, algal infestation shows marked variance in time and space, kind of water, nutritional and pollutional extent. Qualitative algal species shows there is sequential gradual increase from winter to summer months upto April. There is increase in number of algal species from Nov. To April. But during May-August gradual decline in 3 classes (chlorophyceae, bacillariophyceae and cyanophyceae) and then gradual increase from September to October could be registered. In main stretch of Ganga myxophyceae, bacillariophyceae and chlorophyceae predominate. About 27.26% desmids, 4-8% copepods, 11-12% cladocera, 1-11% rotifer, 1-9% protozoa have also been recorded. Gastropods, bivalves, chironomids etc. have also been found to variable extent.

Diverse algal forms exhibit a clearcut periodicity and succession. They may be grouped broadly into summer, winter and rain forms of either annuals, perennials or epimerales nature.

Macrophytes - A total number of 36 macrophyte species have been recorded during different months of the year.

Fish - There is a good deal of diversity in quantitative and qualitative distribution and occurrence of major and minor carps. The fishes migrate and transmigrate in time and space. A total number of 25 fish species have been recorded during different months. Some of the % occurrence of fish population is as follows:

Mystus tangra 20-21%, *Bagarius bagarius* 19-20%, *Eutropiichtyes vacha* 14-15%, *Chela laubuca* 26%, *Labeo bata* 4-5%, *Labeo rohita* 2-3%, *Channa gachua* 4-5%.

Algae and Pollution

Algae of high acidity	-	4 chlorophycean and 1 bacillariophyceae.
Eutrophic algae	-	12 chlorophycean, 7 bacillariophycean, 1 euglenophycean and 6 cyanophycean.
Sewage algae	-	37 sewage algae - 17 chlorophycean, 11 bacillariophycean 2 euglenophycean 7 cyanophyceanform
Allergenic algae	-	25 species
Taste and odour algae	-	30 species
Toxic algae	-	4 cyanophycean

Definition, classification and productive potential of floodplain wetlands and their importance in aquatic ecosystems

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Introduction

Wetlands are unique ecosystems representing the transitional phase between the terrestrial and aquatic systems as the water table is usually at or near the surface or the land is covered with shallow depth of water. Depending upon the state of wetness and its duration, the pattern of ecological succession operates in such systems and accordingly categorisation of its use as resource is delineated. The wetland ecosystems have been of prime concern to ecologists because of their fragile nature. The wetlands which have the substrate of pre-dominantly undrained hydric soils, due to perennial coverage of water, are highly productive in nature owing to extended Eu-photic zone right up to its bottom and thus support rich biological diversity including fish fauna. Fisheries though one of the major activities in such water bodies, practiced since time immemorial, the wetlands have much wider spectrum of utilities such as:

-re-charging & de-charging of ground water, accumulation of flood water, shore-line stabilisation, trapping of toxic substances, trapping of nutrients, abode for many plants & animal species, sources of direct or indirect entertainments, protection & development of aquatic food chains,breeding, grazing grounds for riverine fish stock, regulator of local climate and so on.

The floodplains of Ganga and Brahamputra basins of India have extensive distribution of wetlands of different origins and of various categories. The people living in these parts of the country have very intimate relationship with the wetland ecosystems since centuries as most of their economic activities of rural population be it agriculture, horticulture, fisheries or cottage industries are wholly or partially dependent on these water bodies. To be precise the utility and importance of wetlands should be viewed under three broad aspects such as *economic*, *aesthetic* and *cultural*. In recent years, however, the wetlands have been subjected to indiscriminate exploitation in the face of ever increasing human population and subsequent developmental activities in and around such water bodies. Changing characteristics of river valleys on account of changing demographic and land use patterns have made the situation still grave due to conflicting demands and as a result the process of degradation has been accelerated many folds through- out the globe in general and developing countries in particular. Most of the wetlands are reeling under the threat of their extinction at an alarming rate. Utter neglect in the past and over exploitation in the present have made such ecosystems highly vulnerable in relation to their production functions and biodiversity. Currently the floodplain wetlands are passing through a critical phase of eutrophication leading to swampification at a faster pace. The sustained destruction of all-important wetland ecosystems for one reasons or the other has starting posing many environmental problems in the areas of their existence. It is time that a concerted efforts are being made to conserve the wetlands so as to conserve not only the aquatic biodiversity but the human civilization as a whole.

Definition of wetlands

The concept of wetlands, which covers a wide range of water bodies, is rather hazy. Framing of a precise or definite definition for wetlands, therefore, is very difficult. Many persons have attempted to define wetlands in their own way and as a result many definitions came to the fore (Maltby, 1991, welcome, 1979, Hutchinson, 1967, Leopold,1964 etc.) . According to Ramsar Convention, however- *the marshes, the fens, the peatlands(either natural or artificial, permanent or temprory, static or flowing, fresh, brackish or salty) are the areas covered under wetlands* . One fact, however, has been accepted by one and all that wetlands are transitory systems, representing both aquatic as well as terrestrial characteristics thereby neither can be defined exclusively as aquatic nor purely terrestrial. But referring wetlands in the context of fish and fisheries is automatically implied to such ecosystems where fishery is an important component and thereby it must be an aquatic system with reasonable water depth.

Floodplain wetlands

The floodplain wetlands are considered as one of the prime fishery resources besides being the repository of very rich biodiversity.The floodplain wetlands or the floodplain lakes as commonly referred to are the continuum of rivers, hence play a pivotal role in the development and conservation of fish germ plasm of riverine stock. There can't be a separate or specific definition for these water bodies except the fact that these are associated with the floodplain of certain major river systems. The nomenclature of floodplain lakes or floodplain wetlands, as may be called, has been coined for the sake of operational convenience only. The Ganga and Brahamputra river systems of India have the distinction of being very rich in floodplain wetlands (c 2 lakh ha) because of the geo-morphological features of the land-scape. Locally these lakes are known by different names such as *mauns*, *chaurs*, *Dhars*, *tals, jheel* (Bihar); *Jheel, tal* (Uttar Pradesh); *beel* (Assam & West Bengal);*pat* (Manipur) and so on. The local population of these States of India are associated with such lakes from time immemorial for economic gains and, therefore, the floodplain lakes have tremendous bearing on the social and economic spheres of the society.

Origin of floodplain lakes

Three main reasons have been attributed for the formation of lakes such as *constructive*, *obstructive* and *destructive.* The origin of floodplain lakes fall under the categories of the later two such as:

- *The origin of a typical ox-bow lake is a phenomenon of fluviatile activities of a river course wherein a portion of the river is being obstructed due to excess transportation and deposition of silt and ultimately the river channel diverted to some other route,leaving behind an isolated meander bend called as ox-bows. Meandering of river courses has been found more pronounced in floodplain where the intensity of flood used to be forceful and recurring in nature. Rivers ascending to the flat lands suddenly from higher gradient have been found to be more prone to produce meandering bend out of which some such meanders used to transform into ox-bow lakes due to obstruction in its hydrology. The ox-bow lakes available in the Gandak basin of Ganga river system in* *the State of Bihar represent this pattern of lake formation as most of the rivers after travelling at the higher gradient of foot-hills of lower Himalayas in Nepal suddenly debouch to the flat and tectonically depressed land of North Bihar with high current velocity and huge load of silt which gradually become instrumental in the formation of loop-like or serpentine ox-bow lakes.*

- The origin of tectonic lakes locally known as chaurs, pats, dhars, beels etc. is a function of geo-morphological changes brought about on the earth crust, leaving behind a trail of depressed land scape where monsoon run-off and flood waters accumulate and assume the states of lakes of varied shape, dimension and depths. The tectonic lakes are generally shallow and saucer shaped in extension. They may either be perennial or seasonal depending upon the depth of the depression. The North-Eastern portion of North Bihar and Assam have plenty of such lake area. These water bodies are known for their rich biodiversity reserves and beautiful refuge for migratory and resident avian fauna. The Kusheshwar sthan, Kabartal, Simri-Baktiarpur and Goga beel of North Bihar are the famous lake area (chaurs) of such type and are known to play very significant role in the over all ecological climate of the area besides performing a host of economic activities(Jha & Chandra, 1997).

The difference between the Ox- bow lakes and tectonic lakes (*chaurs*) has been presented in Table 1.

Classification of floodplain wetlands

Broadly the floodplain wetlands can be classified into two groups such as A) Ox-bow lakes and B) Tectonic lakes based on their origin. However, each lake type can further be classified as under.

A. Physically the ox-bow lakes can be of various types based on their riverine connection (Sinha & Jha,1997 b) :

I) lakes with riverine connection intact.
ii) lakes without or defunct connecting channels.
iii) lakes locked in between river and embankment and flood during monsoon.
iv) incomplete lakes between the embankments and rivers which get lost during monsoon.

The ox-bow lakes can also be classified, artificially, as :

I) *live* or *open* lakes with functional connecting channels with the parent river or its tributaries.
ii) *dead* or *closed* lakes without or defunct connecting channels.
iii) partially fluviatile lakes between the embankments and rivers.

B. Physically the tectonic lakes of Ganga and Brahamputra river systems can be classified in various ways, such as a) based on their seasonality b) based on major bio-production etc. (Sinha & Jha, 1997 a) :

a) based on duration of water retention or seasonality:

I) permanent or perennial chaurs.
ii) temprory or seasonal chaurs.

b) based on major bio-production:

I) chaurs where cultivation of makhana (*Ferox eurryale*), singhara (*Trapa spinosa*), etc. remains the major economic activities.
ii) chaurs where fish and fisheries remain the major activity.

Besides above said artificial or arbitrary classification more pragmatic approach for their classification can be adopted and accordingly the floodplain lakes need be classified on the basis of their trophocity or boidiversity for better management of their biological resources.

Ecological status of floodplain lakes in India
(Jha, 1989, 95, 97, Jha and Chandra 1997, Sinha and Jha1997 b, Sugunan, 1995b, Yadava,1989)

- Very high concentration of dissolved organic matter in the soil phase indicating constant in-put of vegetative matter.
- Wide fluctuations in dissolved oxygen values.As low as almost nil to as high as 18 mg/l or even more. The low values indicating stressed condition on account of waste discharge in the system whereas high values indicating super- saturated condition, typical of weed infested waters.
- Generally poor level of nutrients at water phase as they are locked in the macrophytic chain.
- Moderate to very high values of conductance subject to the nature of effluents in the system. Systems receiving sewage or other effluens indicate higher values as compared to lakes free from such ingress.
- Primary production values through phytoplanktonic chain have been found to be of poor to moderate ranges, depending upon the quantum and texture of phytoplankton abundance.
- The floodplain wetlands generally harbour poor density of plankton, a typical reflection of weed infested water body. Poor availability of plant nutrients, PO_4 & NO_3, owing to their locking in the hydrophytic chain.
-The nannoplanktonic assemblage has been found to be much larger as compared to net plankton and dominated by the high incidence of bacterioplankton. The phenomenon is a reflection of stressed aquatic regime, menifested by thick stand of macrophytes in such systems besides an indication of broken grazing chain for healthy propogation of carp fishery.
- The floodplain wetlands of Ganga and Brahamputra river systems have been found to pass through a phase of advanced eutrophication as reflected from high density of macrophytes to the tune of even 30 kg/m^2 at times.All kinds of macrophytes viz. Submerged, emergent, free-floating and marginal have been found to dominate the floodplain wetlands.
- The benthic niche of most of such lakes has been found to be worst affected as the solid-liquid interface is either blanketted by the over growth of submerged vegetation or covered under vegetational canopy of floting macrophytes creating a under water desert

and inhibit the growth of desired benth-ic organisms on one hand, while the oxidative-microzones responsible for the release of nutrients in the ambient water are being shielded on the other.

Transfer of energy and productivity potential

The floodplain wetlands due to their shallow nature and riverine connection are highly productive but fragile ecosystems.In recent years, however, the channelisation of energy has visciated from beneficial bio-production for human welfare to unwanted production due to a number of reasons, both man-induced and natural. In an aquatic ecosystem the resident biotic communities are known to linked each other for their survival and growth. This complex inter dependence in a food chain and the flow of energy in the community metabolism are the key of production functions.Proper undrstanding of trophic dynamics in a given aquatic ecosystem is essential to draw management packages. The transfer of energy in floodplain lakes and for that matter in all the quatic systems follows two established routes as under :

1) Energy fixed at
the level of producers-----to------- herbivores-----to-------predators (*normal grazing chain*)

2) Energy fixed at the level
of producers------to-----dead vegetative matters------to------ detritus feeders(*detritus chain*)

The normal grazing chain of floodplain wetlands has gone wary in the face of fast changing aquatic regime of such watwer bodies. Over colonisation of macrophytes in these systems has made the production functions topsy-Turvey. The focus has now shifted to the continuos pilation of detrital load at the bottom which remain largely unutilized in absence of efficient grazers. The present fish yield from the lakes is only a fraction of the total energy fixed at primary or producers level. The floodplain lakes being weed choked in characteristics exhibit very high detrital load, even to the tune of 400-500 gm^2 . The primary production and energy conversion of some such lakes have been presented in Table 2. The photosynthetic efficiency of these lakes has been found to be governed by two things viz., the level of management and the influx of waste materials in the system. It has been observed that the photosynthetic efficiency in case of floodplain lakes of Bihar ranged between 3.26 %(stressed lakes) and 4.86 %(partially managed nonstressed lakes).Based on the level of primary production the productivity potential of floodplain lakes available in the States of Assam, West Bengal & Bihar has been worked-out in the range of 1000 to 2000 kg ha^1 yr^1. Against this potential, however, the present level of yield ranges between 30 to 300 kg ha^1 yr^1 only and as such there exists enough scope for fisheries development. Primary production and conversion of energy of a group of floodplain lakes of Bihar wetlands have been presented in Table II & III.

Table 1. Difference between ox-bows and tectonic floodplain lakes (after Sinha & Jha.1997)

Ox-bow lakes	**Chaurs(tectonic**
1. The outer boundary of the lakes are generally fixed.	The boundary of the lakes are never fixed rather changes with the quantity of water ingress. Large scale swelling during monsoon and considerable shrinkage in lean months are the hall-mark of such lakes.
2.Ox-bow lakes are the obstructed bends of rivers as such generally serpentine in physical extension.	Chaurs are not the part of any river and they have no definite physical structure.The physical extension depends on the shape of the depression. However, most of them are generally saucer shaped.
3.The shore-line of ox-bows are invariably straight, being the cut-off portion of rivers.	The tectonic lakes generally represent very irregular and zig-zag shoreline.
4.Ox-bows are relatively deeper than chaurs.	Chaurs are always shallow in characteristics
5. The ingress of riverine water may or may not take place.If connecting channels exists and are functional river water would entre otherwise not.	The topographical distribution of chaurs in floodplains, where occurrence of flood is a regular phenomenon, are such that ingress of flood water is almost certain.
6. Less fluctuation in water spread area besides the ingress of waters, from rivers or catchment, used to have meagre or no current velocity which can uproot the prevailing plants in the system and, therefore, the ox-bow lakes provide relatively stable niche for the higher colonisation of aquatic vegetation.	Characteristically the chaurs exhibit very high fluctuation in water expansion.The excess of flood waters used to gush-in with greater force in such lakes as result the vegetations are being uprooted to a large extent, preventing greater colonisation of aquatic vegetations as compared to ox-bows.

Table II : Status and pattern of primary production n certain floodplain lakes of Gandak basin, Bihar (Jha & Chandra,1997)

lakes	primary production $MgCm^3 hr^1$	energy fixation $Cal\ m^3 d^1$	Available bottom energy $Cal\ m^2$
Larail	98.07-154.11	26136	$38.66x10^4$
Mahisath	75.08-110.0	19988	$39.13x10^4$
Dabadih	95.20-103.05	21411	$46.29x10^4$
Kamaldaha	41.09-190.06	24975	$51.26x10^4$

Table III : Transfer of energy in certain floodplain wetlands under Gandak basin Bihar (Sinha & Jha, 1997a)

lake	**Status**	**primary production to fish %**	**solar energy to fish %**
Muktapur	Free from external stress & partially managed for fishery	0.1622-0.2408	0.00335-0.01037
Kanti	Highly stressed by thermal ash slury. No fishery management	0.1209-0.1873	0.00241-0.009653
Manika	External stress factors negligible, partially managed	0.1831-0.3015	0.00463-0.018431

Motijheel	Highly stressed due to sugar factory and sewage effluents, partially managed	0.1462-0.2517	0.00251-0.010324
Tarkaulia	External stress factor almost absent, well managed	0.1843-0.3047	0.00546-0.01776

References

Jha, B. C.(1989) : Beel fisheries resources in Bihar and Uttar Pradesh. *CIFRI, Barrackpore Bulletin No. 63.*

Jha, B. C.(1995) :Fisheries of floodplain lakes of Gandak basin Bihar. In(ed.) Howes, J. R. Conservation and sustainable use of floodplain wetlands. *Asian Wetland Bureau, Kuala Lumpur. 123 pp.*

Jha, B. C.&
K. Chandra(1997) :Kusheshar sthan chaur (North Bihar)- Status and prospeects of fisheries development. *CIFRI Bulletin No. 70.*

Jha, B. C. (1998) : Salient ecological features of mauns and chaurs of North Bihar and their fisheries. In (ed.) Sugunan & Sinha. Fisheries enhancement of small reservoir and floodplain lakes in India. *CIFRI publ. Barrackpore*.

Sinha, M. &
B. C. Jha (1997a) : Uttar Bihar ke matsayakee jal sansadhan- vartaman awastha awem Bhavi sambhawanayen. *CIFRI, Barrackpore, Bulletin No. 69*

_______(1997 b) : Ecology and fisheries of ox-bow lakes(maun)- a threatened environment. *CIFRI, Barrackpore, Bulletin No. 74.*

Sugunan, V. V.(1995b) : Floodplain lakes-a fisheries prespective. In(ed.) Howes,J. R. Conservation and sustainable use floodplain wetlands. *Asian Wetlands Bureau. Kuala Lumpur. 123 pp.*

Yadava, Y. S. (1995) : Floodplain lakes- a conservation prespective. In (ed.) Howes, J. R. Conservation and sustainable use of floodplain wetlands. *Asian Wetlands Bureau. Kuala Lumpur. I13 pp.*

MANAGEMENT OF FLOODPLAIN WETLANDS FOR SUSTAINABLE FISHERY AND BIODIVERSITY CONSERVATION

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INTRODUCTION

Floodplains and their associated wetlands 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 river bed 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 flood water 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 can not 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 *beels*, *jheels*, *mauns*, *pats*, *boars*, *hoars*, *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
Total				**202,210**

The importance of floodplain wetlands emanates from a variety of factors such as:

- *Fishery,*
- *Irrigation,*
- *Agriculture and post harvest (jute retting etc)*
- *Retention and release of flood water,*
- *Source of water for drinking,*
- *Source of miscellaneous vegetation (Trapa fruits, lotus,makhana, reeds for mat- weaving, firewood, etc)*
- *Source of edible animals (molluscs, turtle, etc.),*
- *facility for duck rearing,*
- *Transport and communication routes,*
- *Effective organic waste recycling systems,* and
- *Rich biodiversity*

Floodplain wetlands - a fisheries perspective

Since the floodplain wetlands are rich in plant nutrients and are biologically diverse ecosystems, they generally possess high potential for *in situ* fish production. However, their fish production potential vary widely depending on ecological conditions, recruitment from the main river, management measures followed, *etc.* 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.

Capture fisheries of open floodplain lakes

The open floodplain lakes which retain their connection with the main rivers are characterized by habitat variables akin to lotic waters for most parts of the year. They have flowing water regime supporting low plankton and benthos biomass and high indices of community diversity. With slow eutrophication process and low level of macrophyte infestation rate, they provide a better environment for the ichthyo-denizens. Fish production in them is governed by inherent natural productivity and the extent of autostocking from the mainstream. The open lakes may be treated as a continuum of the main river and for developing a good capture fishery. They also serve as feeding and breeding grounds of commercially important riverine fishes and, therefore, are important for the fishery of the parent river as well.

Fishery management measures, followed in such lakes essentially centre round habitat conservation and fishing management. Some of these measures are:

i) Conservation of the habitat
ii) Ensuring proper recruitment by allowing free migration of brooders and juvenile fishes
iii) Regulation of fishing pressure based on fish stock assessment
iv) Devising and implementing regulations on mesh size, closed fishing seasons/grounds, and so on.

Culture-based fisheries of closed floodplain lakes:

The closed floodplain lakes are those which are totally cut off from the parent river or connected only for a very brief period during the flood season. They remain more akin to lentic ecosystems for most parts of the year. Since the volume of water exchange with the main river is low, they tend to accumulate silt and plant nutrients received from their catchment areas year after year. As a result, they are tend to be eutrophic with high biomass in respect of plankton, benthos, macrophyte, weed-associated fauna, *etc.* often associated with low index of community diversity. Many of them are heavily infested with macrophytes, with poor plankton production where most of the energy transformation takes place through the heterotrophic/detritus food chain. In the absence of recruitment from rivers and heavy macrophyte infestation, fish production in them is often much lower than their productive potential. Many weed-choked lakes are dominated by air-breathers and small-sized fishes resulting in low yields.

Many of the fishery management measures followed in open lakes for conservation and sustainable use of fish stocks are equally applicable to the closed ones where capture fishery norms are practiced. Besides, fish production rates in closed lakes can be further raised by practicing culture-based fisheries and various forms of enhancement. Culture-based fishery is based on stocking and recapture of fast-growing fish species similar to that followed in small reservoirs. Since floodplain lakes are usually shallower and richer in plant nutrients/fish food organisms than most reservoirs, they allow a higher stocking density to raise the fish yield. Chances of losing fish stock are low in closed floodplain lakes, unlike reservoirs where substantial stock loss takes place through irrigation canals/spillways. Stocking higher proportion of detritivores for effective utilization of energy accumulated at the detritus can give better results. Determining optimal stocking density, stocking size, minimum size at capture and selection of suitable candidate species are some of the crucial management options for achieving optimal fish production from culture-based fisheries.

Integration of culture and capture fisheries

Marginal areas of both open and closed floodplain lakes can be cordoned off for pen culture while leaving the remaining area for capture/culture-based fisheries. The pens can be managed more effectively by way of eradication of unwanted fishes, control of macrophytes, supplementary feeding, and so on. Since they are managed along culture fishery lines/norms, stocking density as well as fish production rates from them are quite high.

Conservation of biodiversity

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 judgement 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.

Biodiversity versus fishery development

Many developing countries are facing the challenge to feed their large human populations which 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.

CONCLUSION

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 can not 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.

REFERENCES

Leopold, L. B., M. B. Walman and J. P. Miller, 1964. Fluvial processes in geomorphology. *W. H. Freeman*, San Francisco, pp 522.

Maltby, E., 1991. Wetlands and their values. *In* Wetlands-facts on file. *Oxford,* New York, pp223.

Sugunan, V. V., 1997. Floodplain wetlands, small water bodies, culture-based fisheries and enhancement-conceptual framework and definitions. *In* (Eds) Sugunan, V. V. and M. Sinha, Fisheries enhancement in small reservoirs and floodplain lakes in India. *Bulletin* No. 75, Central Inland Capture Fisheries Research Institute, Barrackpore, pp 252.

Sugunan, V. V., 1995. Floodplain lakes- a fisheries perspective. *In* Howes J.R. (Ed.), 1995. Conservation ands sustainable use of floodplain wetlands, *Asian wetland Bureau, Kuala Lumpur, AWB Publication, No. 113*: 67-75.

Welcomme, R. L., 1979. Fisheries ecology of floodplain rivers. *Longman*. London and New York. pp 317.

HARVEST AND POST-HARVEST TECHNIQUES EMPLOYED FOR INLAND OPEN WATERS IN INDIA AND THEIR ECONOMIC CONSIDERATION

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India is bestowed with bountiful of inland open waters, in the form of rivers, reservoirs, floodplain wetlands and estuaries. Indian river systems comprised of 14 major, 44 medium and innumerable small rivers, desert streams and canals (Sinha, 1997). These have a length of over 0.17 m kms (Anonymous, 1996). Among the states, maximum riverine stretch is in Uttar Pradesh (31.2 thousand km) followed by Jammu and Kashmir (27.8 thousand km). After independence, several hydro-electric and irrigation projects or river valley projects have been commissioned, which resulted in large number of artificial impoundments, the reservoirs. These included 19134 small, 186 medium and 56 large reservoirs with total water spread of over 3 m ha (Sugunan, 1995). The maximum area under reservoirs is in the state of Maharastra followed by Orissa, Andhra Pradesh and Gujrat. The beels and oxbow and derelict waters are mainly in Orissa, Uttar Pradesh and Assam with an expanse of 0.79 m ha. The estuarine waters also form an important part of inland open waters with 2.6 m ha. area. For all the types of water bodies fish harvesting techniques used by the fishers are almost common, although, their extent of prevalence varied across them. For some waters and regions these techniques are modified according to requirements. Similar is the case with post-harvest techniques. The detailed description of these techniques for rivers, reservoirs, flood plain wetlands and estuaries is given in following paragraphs. Their economic consideration is discussed combinedly for all the water bodies.

Harvesting techniques

Rivers

Most of the Indian rivers have an open access for fishing, except some stretches where fishing rights have been transferred either to fishermen co-operatives and contractors in the form of lease for one to few years or to individual licensee fishermen. In rivers the fish harvesting included either harvesting of mature fish or fish seed in the form of spawn or juveniles. Although, the fishing of mature fishes is done all over the riverine stretches, but the spawn collection is location specific. The stretch of river Ganga in Bihar is excellent for collection of riverine fish spawn. It is the major source of raw material for production of stocking materials or fingerlings in West Bengal, which caters to the stocking requirements of the aquacultural and reservoir water bodies. During past three decades the riverine fisheries have followed declining trend and drastic change in catch composition, which resulted in diminishing returns for the fishing community. It witnessed massive shift in fishing practices to suit the present milieu. The most prevalent harvesting techniques in rivers with their period of operation (Saxena, 1989) are depicted in table 1.

Table 1 Major fish harvesting techniques for Indian Rivers

S.no	Type of net	common name	Period of operation
A.	**Drag net**		
1	Without pocket	Mahajal	November to July
		Darwari	Round the year
		Karta	November to July
		Chaundhi	Round the year except flood period
2	With pocket	Do-dandi	May to September
		Chhanta	July to March
B.	**Gill Net**	Phasla, current,	Round the year except flood period
		Gochail, Ranga	February to July
C.	**Purse net**	Bara Kamel	May to July
		Chota Kamel	October to January
D.	**Cast net**	Bhanwar jal	Round the year
E.	**Scoop net**	Jali	Round the year
F.	**Hook and Line**	Jor, Dori	Round the year except flood period
G.	**Traps**		Round the year
H.	**Roak fishing**		Round the year

Reservoirs

The main purpose of the reservoirs is irrigation or hydel power generation, so many of them are owned by state governments. To obtain fish harvesting rights the Department of Fisheries has to pay some fee or royalty. The fishing operations in these waters are considered as the subsidiary activity, and may or may not be given due emphasis during planning of the project. Consequently, the fisheries management practices are constrained by the main objective of the projects. Still, there exists vast untapped production potential for reservoirs in India, which may be explored through adoption of virgin waters or improving upon the existing management practices. The reservoirs in various states had different harvesting rights depending upon the prevailing conditions. These included departmental fishing, license fishing, free license fishing, share system and auction to private contractor or co-operatives. The most common harvesting rights for various states included lease to co-operatives for Andhra Pradesh, Karnataka, Maharastra, Orissa and Himachal Pradesh, lease to State Fisheries Development Corporation in Madhya Pradesh, Tamil Nadu, West Bengal and Gujrat; and open auction to contractors in the states of Bihar, Rajasthan and Uttar Pradesh. These harvesting rights influence the harvesting techniques. The fishing rights when rest with co-operatives/SFDC or the department of fisheries, mild fishing techniques were prevalent, i.e. gill nets, cast nets, traps, but in case of open access, license to fishermen and auction to contractors drag nets were also in use. The harvesting techniques adopted under different fishing rights are summarised in table 2.

Table 2 The fishing rights and practices for reservoirs in India

S.no.	Type of fishing right	Harvesting techniques
1	Lease to co-operatives/ state fisheries development corporation (SFDC)	Gill nets, cast nets, traps
2	Departmental fishing	Gill nets
3	Open access	Drag nets, gill nets, hook & lines
4	License to fishermen	Drag net, gill nets, cast nets, hook and lines
5	Auction to contractor	Drag nets, cast nets, gill nets, hook & lines

Floodplain wetlands

Most of the floodplain wetlands are either managed by fishery co-operatives or privately. The fish harvesting techniques for these waters are very traditional. Various kinds of locally made gears and indigenous methods are in use for exploitation of different fish species and prawns. The classification of these gears (Choudhury, 1992) are mentioned in table 3.

Table 3 The fishing techniques for floodplain wetlands of India

S.no.	Type of gear	Name of gear	Seasons of operation
A.	**Moving**		
1	*Drag net*	Mahari jal	Round the year
		Ber jal	Round the year
		Harhari jal	Winter
		Moi jal	Winter
		Panti jal	Winter
2	*Dip Net*	Jata jal	Monsoon
		Dharma jal	
		Ghoka jal	
3	*Cast net*	Khewali/Asra jal	Round the year
B.	**Stationary nets**		
1	*Gill net*	Fansi	Round the year
		Puthilangi/	Monsoon
		Koilangi and	
		Garoilangi	
		Hook and lines	Round the year
2	*Traps*	Polo,Sepa,	Round the year
		Jakoi, Jaluki,	
		Dingora, Darki,	
		Boldha	

Estuaries

The estuarine fisheries contributed significantly in Indian inland open water fish production. Open estuarine system included Hoogly-Matlah and Mahanadi estuarine systems. Godavari estuarine system is the main estuary of peninsular India, while Vasishta, Vainatheyam, Adyar, Kajuveli, Ponnaiyar, Godilam, Paravanan, Vellar, Killai and Coleroon are the small estuaries of this region. The main estuaries of North West coast are Narmada, Tapti and Mahi. These are also identified as excellent source of naturally occurring fish and prawn seed. Most of the estuaries are open for fishing activities. The most prevalent harvesting techniques in these waters are bag nets (stationary), drift gill nets, trawl nets, seine nets (large and small), purse nets, lift nets, cast nets, set barrier nets , hook and lines and traps (Mitra *et al.*, 1997). In case of Hoogly-Matlah estuary 74.7% of catch was of bag nets followed by drift gill net at 16.3%. The remaining nets had only 9% of catch.

Post-harvest techniques

The fish catch from inland open waters mostly feed the domestic demands and is marketed in raw form. The fish processing is very rare. Therefore, the post-harvest techniques mainly concentrate on fish marketing activities. Similar to harvesting techniques the post-harvest techniques are almost same for all the types of inland open waters, but slight difference exists due to nature of resources and harvesting personnel.

Rivers

Most of the rivers have an open access, so, the fishermen either dispose this catch at river site to local dealers or bring it to fish market for sale or auction. For leased out stretches, the fishermen hand over the catch to contractors or co-operatives. They further market it either themselves or pass over to the wholesalers cum commission agent, who auction it for local consumption or send to secondary or terminal markets.

Reservoirs

For most of the reservoirs fishing rights are with some organisation or contractor. So, fishermen hand over the catch to them. The fishermen's remuneration is in the form of royalty or prices at some fixed rate. These organisations are disposing off the catch through contractors or wholesalers and commission agents or directly to the consumers. The contractors or wholesaler cum commission agent may export it to bigger or terminal markets.

Floodplain wetlands

As indicated earlier, the floodplain wetlands are either managed by co-operatives or privately. The catch from these water bodies is mostly auctioned at the local landing centre. Local dealers take it to wholesale market or directly sell in retail market. In case of local commission agent fish passes to wholesaler cum commission agent to reach the retailer / secondary or terminal market.

Estuaries

Estuaries being the common property resource, individual fishermen hand over the catch to local dealers, who act as commission agent or retailer. The local dealer passes on the catch to the wholesaler/ wholesaler cum commission agent or sell directly to consumer.

Table 4 Most prevalent marketing channels for inland open water catches in India

Fisherman - Wholesaler cum commission agent - Retailer - Consumer
Fisherman - Retailer - Consumer
Fisherman - Local dealer/ Local dealer cum commission agent - Consumer
Fisherman - Local dealer - Wholesaler cum commission agent - Retailer - Consumer
Fisherman - Local dealer cum retailer - Consumer
Fisherman - Contractor/ Contractor cum wholesaler - Retailer - Consumer
Fisherman - Co-operative society - Contractor / Contractor cum wholesaler - Retailer - Consumer
Fisherman - Co-operative society - Wholesaler cum commission agent - Retailer - consumer
Fisherman - Co-operative society - Consumer
Fisherman - State Fisheries Department/ SFDC - Contractor - Wholesaler cum commission agent - Retailer - Consumer
Fisherman - Consumer

Economic consideration

Majority of inland open waters are the common property resources, so, highly vulnerable to irrational mode of exploitation and over concentration of fishing effort in terms of manpower and number of nets (Paul, 1992). For profitable fisheries on sustainable basis, it is emergent to manage harvest and post-harvest activities optimally. Due to very low socio-economic status and literacy level of the fishermen community , it is very difficult to gather the reliable information, particularly on economic parameters. The economic analysis is mainly concerned with the fishermen's investment on fixed and variable inputs and the outcome of fishing activity. The selection of harvesting techniques are generally based on physiography of water body, nature of fish stock and characteristics of raw material available. But above all, the most important factor for this selection is fishermen's financial capabilities, which force him either to purchase, hire or share the fisheries requisites. *Centris paribus*, following questions and options are involved in economic decision making.

1. Whether to purchase / hire / share the craft and gears?
2. If purchase, at what cost and of which material and dimensions?
3. If hire, at what rent and of which material and dimensions?
4. If hire, for how many months?
5. If share at what conditions?
6. When and where to fish ?
7. For whom to fish at what rate of royalty / price?
8. What should be the intensity and distribution of fishing effort over the year?
9. Whether the remunerations for the catch would cover the costs incurred?

Due to very low income levels, the fisherman is constrained by financial obligations, which restrict him to follow rational post-harvest techniques. Yet, for an economically optimum disposal of catch he has to decide :

1. How to sell ?
2. To whom to sell ? and
3. At what price to sell?

To examine the economic feasibility of harvest and post-harvest techniques, following cost and income analysis (Katiha, 1994) should be done for all the agencies involved in these activities. It would answer the questions posed above, exploring various options.

A. Cost analysis

1.	Cost A_1	Cash expenditure, license fee, boat rent, depreciation on fixed capital, interest on working capital;
2.	Cost A_2	Cost A_1 + fishing rent
3.	Cost B	Cost A_2 + imputed value of interest on fixed capital; and
4.	Cost C	Cost B + imputed value of family labour.

B. Income analysis

1.	Returns on Cost A_1	Gross income - Cost A_1
2.	Returns on Cost A_2	Gross income - Cost A_2
3.	Returns on Cost B	Gross income - Cost B
4.	Returns on Cost C	Gross income - Cost C

In short run, the fishermen can continue if returns on Cost A_2 are met, but for long run the Returns on Cost C must be positive.

References

Anonymous. 1996. *Handbook on fisheries statistics*. Fisheries Division, Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India, p. 128.

Choudhury, M. 1992. Fishing methods in floodplain lakes. *FAO sponsored training programme on floodplain fisheries management. Compendium. (Ed. Y.S.Yadava and V.V. Sugunan)* Vol. 2, pp In 163-166.

Katiha, P.K. 1994. Natural resource management : A case study of reservoir fisheries in Himachal Pradesh. Ph.D thesis. Unpublished. *Department of Agricultural Economics, Dr Y.S. Parmar University of Horticulture and Forestry, Solan (H..P)*, 125 p.

Mitra, P.M.; Karmakar, H.C.; Sinha, M.; Ghosh, A. and B.N. Saigal. 1997. Fisheries of the Hoogly-Matlah esturine system - An appraisal. *Bulletin no. 67, Central Inland Capture Fisheries Research Institute, Barrackpore*. p. 18

Paul, S. 1992. Pre-harvest and post-harvest management of floodplain fisheries. *In FAO sponsored training programme on floodplain fisheries management. Compendium. (Ed. Y.S.Yadava and V.V. Sugunan) Vol 2*, pp 141-143.

Saxena, R.K. 1989. Fishing methods in river systems. *In Conservation and management of inland capture fisheries resources of India (Ed. A.G. Jhingran and V.V. Sugunan), Inland Fisheries Society of India, Barrackpore*. pp. 61-68.

Sinha, M. 1997. Inland fisheries resources of India and their utilisation. *In Fisheries enhancement of small reservoirs and floodplain lakes in India. (Ed. V.V. Sugunan and M. Sinha), Bulletin 75, Central Inland Capture Fisheries Research Institute, Barrackpore*. pp. 1-11

Sugunan, V.V. 1995. Reservoir fisheries in India. *FAO Fisheries Technical Paper No. 345, Food and Agriculture Organisation, Rome*. 423 p.

Mass awareness and technology dissemination to achieve sustainable yield from open waters through participatory approach

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Introduction

The process of technological innovation, technical and scientific communication and technology transfer has been the subjects of considerable research in recent years. From a behavioural point of view, technological change and innovation occur as a result of complex sets of human interactions; information flows and transfers; individual and organisational creativity; individual and organisational risk taking and decision making capabilities. Each of these factors involve human beings with their motivations, perceptions, attitudes, beliefs, abilities, ambitions, personality and prior knowledge and experience.

Generally innovated technologies are sophisticated in nature and high input intensive. It is interdependent on so many inter-related practices each one of which have to be applied rationally in time and in the manner recommended by the scientists. A communicator concerned with open water fisheries, therefore, has to understand its characteristics in order to select appropriate methods and techniques for effective and rapid communication of appropriate technology to the clientele for their easy adoption. To achieve development from within a population, requires working with people in their existing situation, with their existing resources and skills.

Strategy for effective communication for mass awareness

The present open water fisheries management strategy in the country calls for rapid dissemination of information on open water fisheries and technical know-how to the clientele in mass scale in the direction and bringing the gap between research system and target groups in the field. The strategy for transfer of technologies on open water fisheries for the members of the resource poor target group is to be treated henceforth as one of the essential inputs to overall activity in the open water fishery develolpment programmes.

Types of information

Ideally any information system for sustainable fish production from open waters covers;

i) Information on natural resource and biodiversity
ii) Information on biology of fishes
iii) Information on seed availability
iv) Information pertaining to existing facilities and infrastructure
v) Information on the available technologies and package of practices

vi) Information related to environmental impact
vii) Information on crafts and gears
viii) Information related to conservation measures
ix) Information pertaining to Government policies and programmes.

It has been felt that negligible effort so far has been made in the country to provide such information to the target groups towards development of fisheries in open waters. Thus, a large gap has been created between awareness and adoption of measures on management of fisheries in open water systems.

Communication planning for mass awareness

The prime objectives of the programmes towards development of fisheries in open water bodies could not be achieved unless communication is taken as an important component and ingradient 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, preferences of individual and of social priorities. An essential ingradient 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 fisheries development in open waters. The case studies may be on achievements/activities of individual worker and experience of fishermen. The information can be compiled to give upto-date data.

Circulation

Information on management measures on open waters could be widely circulated in the form of circular letter, handout, leaflet, pamphlet, mimeograph etc.

Joint field visit

Joint field visits of researcher and extension worker will enable them to understand about success of the development programmes on open water fisheries 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

A.V. aids play important role in effective communication of information on open water fisheries management and resource conservation. The extension functionaries working in fisheries developmental programme must be equipped with audio-visual equipments. Radio and Television have a great potential as a medium of mass communication. The authorities concerned with Radio and TV may be coopted to ensure that they plan their programme to broadcast/telecast information on open water fisheires management and conservation regularly for mass awareness of the target group to strengthen open water fisheires development movement.

Extension system and holistic participatory approach

At every step of the management of fisheries in open water bodies people's participation in all the 4 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 fisheries need to be judged. It is equally important that the problems be approached holistically taking into account of the full range of human and community potentials.

Open water fisheries management 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 development activity seen in its broadest socio-political sense is :

- to enable people to critically understand their situations and problems;
- to identify their needs and to prioritize them;
- 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 fisheries management and should work, within a time frame, towards an ideal (even if it may not be wholly achievable) condition.

People participation - a desired phenomenon

Encouraging people's participation in the management of fishery 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 an 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 affected who really participate in such schemes
v) the representativeness and accountabiolity of the leader and the local organisations of the potentially - affected 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 an end to be achieved by the tool, suggests that, no matter how little the participation to begin with, it is a positive step towards not merely efficient and socially feasible action but towards development itself. Development, whelfare 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, nowadays, do something for the beneficiearies, whether this involves transferring technology or building infrastructure, or whatever other task, the effort is that of the agency.

Organisations in 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 and 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 develolper-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 in approach might even require in the research/extension agency to hold back on what it believes to be true, scientific and modern, and begin 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 indegenous learnings 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 it 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 self-sustaining and self-perpetuating, then the participating people's organisation has to have permanence and the ability to sustain the involvement of the community.

An important fact worth considering is that the existence of an organisation in a community does not ensure people's participation. Organizations frequently benefit only the wealthy and influential members of the community. There is also reality that several socio-cultural traditions tend to be authoritarian. In such communities, the leadership would oppose any form of organisation that promotes democratic and egalitarian norms. The research/extension agency would then have to consider whether it should use an existing traditional form of organisation in the community, a help it to from of organisation in the community or help it to form a new organisation. Governments and research/extension agencies in relevence to the development of the fisheries in open waters seem particularly attracted to the cooperative form of organisation. If it functions properly it can be an ideal organisation, ensuring democratic management and an egalitarian distribution of benefits. However, while there have been a few spectacular success, the experience in general with fishermen cooperative societies has not been always good.

In India, government perceives the cooperatives as a channel for development benefits to the community. It considers underdevelopment in fisheries as being due to the primitive nature of the traditional technology resulting in low productivity. So, its solution has been to enable fish farmers/fishermen to acquire assets that would help them to make better yield.

The role of the organisation in participatory management is, understandably, very, important and almost a necessary condition. However, it places a heavy burden on the Government/Research/Extension agency, which often has to strengthen the very organisation that not only will eventually have to hold it accountable. Government/Research/Extension agencies with their own objectives can not be depended upon to display such benevolence at all the times. Participation through organisation is, in this sense, therefore, much more difficult to plan and is unpredictable in nature. It suggests that there is need for the research/extension agency to commit itself first to participatory development and to the associated ideologies and attitudes, before it seeks strategies to foster organisation among fish farmers/fishermen.

Meaningful participatory approach

Participation grows out of meaningful relationships, that enable people to share and work together. There are several reasons why participation approaches succeed or fail. The reasons mentioned below could be considered as 'do's' and 'don'ts' for the developmental agencies. But it might be wiser to consider the suggestions more as guidance giving direction to the activity rather than deterrents to action.

Have a legitimate role : The management of open water fisheries is rather participatory project where a sort of negotiated activity in which people and the research/extension/developmental agencies to work together for commonly shared objectives. To be able to negotiate successfully fish farmers/fishermen, scientists, extension functionaries, developmental officials, have not only to respect each group but also it must also feel that there is a legitimate role to play for that group. The agencies and its members must really see a role in the organisational process be considered legitimate and successful participation will result.

Enable 'equalness' to facilitate negotiation : For negotiations to be conducted meaningfully, the fish farmers/fishermen, scientists, extension functionaries and developmental officials involved, must be reasonably equal. Unfortunately, agencies and the people may negotiate with, are often at different levels not only in terms of power but in terms of knowledge and ability as well. This could lead to the activity to be implemented being more agency oriented. So, the agencies has the key role and the responsibility of first creating 'equalness' through educational programmes that develop communication and negotiation skills as well as power of analysis.

Begin with the felt needs of the people : For participatory management to be successful, it is necessary for all the groups (mentioned earlier) involved to know what is they want. The agencies have their ownf mandate and the people have their own. Not only the content, but the priorities may also vary. But if successful participation is the aim, the begining has to be made with what the people consider, are their needs and which the agency agrees, are areas of concern.

Learn from and with people : Participation suggests that the people and the agency are agreed on to do something about the way things are to be moulded. But the agencies might not fully appreciate the circumstances and predicament of the people unless it is willing to learn from them. Only by learning from, and with, the people - their social dynamics and their needs and priorities, can the right agenda be mutually agreed upon and implemented with wholehearted participation of all in the community.

Build confidence as a prelude : People may be dissatisfied, but they must do something about that dissatisfaction. More important, they must have the confidence that they have the ability to do something about themselves. A whole range of cultural, social and historical factors, including past failures, can weaken this confidence. Thus, confidence-building is a task. The agencies may have to set itself before participation can be assured.

Help organisation to emerge : Some form of organisation *viz.*, Fishermen Cooperative Society, Fish Club etc. is necessary if participatory managtement is to succeed because there is a need to take decision, take responsibility for particular tasks, allocate tasks, all of which can be done better when a community or group is organised.

No autocratic behaviour : Scientists/extension functionaries/developmental officials often feel that they alone know what needs to be done which are not democratic in their own functioning and not participative in their decision making, will find extremely difficult to convince communities they work. In most cases, the agencies and its characteristic and behaviour can be the most important factors determining the success of participatory management.

Flexible approach : The agencies usually tend to specialise in order to be more efficient. Their managerial cultures also tend to make them more rigid and time conscious. In participatory management, where others are involved, these characteristic may work against the activity. The people's needs may not coincide with the agency's capabilities, the time taken to achieve something real in the field may not fit well with reporting and, budgeting schedules, mid course corrections may not be easy to bring in. Agencies need to have a far more flexible approach to their work if they wish to promote participation.

No place for unilateral decisions : The participatory approach grow out of the exchange of the agency's knowledge with people's blending in the process, the modern and the scientific with the traditional and the indegenous.

If the agencies really intend to become participative, the directions, objectives and priorities must evolve out negotiation and not out of unilateral decisions.

Need to realise limitations : If the agencies wish to work with a community and help to develop it, it really has only two choices :

- it can diversify its capabilities or bring in other agencies to be able to address the special needs of the people; or

- it can accept its limiations and negotiate for the use of its particular ability, of course keeping in mind that management in these circumstances would only be partial.

The agencies must be more realistic about the objectives that can be achieved, given their limited capabilities.

Getting the people do more : Agencies must do less and help people do more. Since, the goal is to get the people to do it at their own, the agencies should design tools how they can get others to do what agencies have the expertise to do. If the communities are to participate actively in the management process, the technology and techniques will have to be demystified, made simpler and more accessible. The agencies will have to release information freely to the people.

Coping with change : Working with communities, empowering them, enabling them to work with justice, democracy, the agencies will find the community going through basic structural changes. The agencies have to face those changes and its implications, the agencies will have to cope with it.

Conclusion

The experience with people's participation in fisheries related activities was initially limited. Significantly, it was the last sector to change from 'top-down' approach to a 'bottom-up' one. However, at present concerted effort must be prioritised towards participatory management approach for not only getting sustainable production of fishes from the open water bodies of the country but also for alleviating poverty in the rural areas.

Analytical methods for estimation of soil quality parameters

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Estimation of certain soil quality parameters are very important for evaluation of productivity of a water body. The relationship of fishes with their physical and chemical environment in soil must be known if higher yields per unit area are desired.

Soil samples should be collected from different locations in each water body by means of an Ekman dredge. The samples should be mixed thoroughly to make a representative sample. The samples should be air dried in shade, ground to fine powder by gentle pressing with a wooden hammer, strained through a 2mm and then a 80 mesh sieve and again air dried. The percentage of moisture in the soil may be determined by drying the soil in an oven at 103^0C. Analysis is done with the air dried samples and results are expressed on an oven dry basis.

METHODS OF ANALYSIS

1. pH

Soil pH is determined by electrometric method using a pH meter, the soil : water ratio being 1 : 2.5.

Procedure

Take 10 gm of soil in a 50 ml beaker and add 25 ml distilled water. The suspension is stirred for 20 minutes. Now calibrate the pH meter with buffer solutions of known pH and then immerse the electrode into the sample and determine the pH. For acidic soil sample use buffer solution having pH-4, while for neutral or alkaline soil adjust the instrument with a buffer solution having pH 7 or 9.

2. Organic Carbon

Organic carbon is estimated following Walkley and Black's Wet dijestion method.

Reagents

a) 1N Potassium dichromate solution : In an analytical balance, weigh 49.04 gm potassium dichromate AR/GR and dissolve it in one litre of distilled water.

b) 1N Ferrous solution : Dissolve 278.0 gm pure $FeSO_4$, $7H_2O$ or 392.13 gm of Mohr salt (Ferrous ammonium sulphate) in distilled water, add 15 ml of conc. H_2SO_4 and make up the volume to one litre. This should be standardised against N $K_2Cr_2O_7$ so that 1 ml of Ferrous solution = 1 ml N $K_2Cr_2O_7$.

c) Diphenylamine indicator : Dissolve 0.5 gm Diphenylamine in 100 ml conc. $H_2 SO_4$ and 20 ml distilled water.
d) Phosphoric acid (85%)
e) Conc. Sulphuric acid (sp. gr. 1.84)

Procedure

Place 1 gm soil sample in a 500 ml conical flask, add 10 ml of N $K_2Cr_2O_7$ and then add 20 ml of conc. H_2SO_4. Mix by gentle rotation for one minute and allow the mixture to stand for 30 minutes. Dilute with distilled water to 200 ml, add 5-10 ml of phosphoric acid and 1 ml of diphenylamine indicator. The mixture is titrated with 1N Ferrous solution until the colour change to sharp green from a bluish colour.

Calculation : (10 - No. of ml of N $FeSO_4$ solution required) X 0.3
= Organic Carbon (%)

3. Total Nitrogen

Total nitrogen is estimated by Kjeldahl's method.

Reagents

a) Conc. H_2SO_4.
b) Salicylic acid
c) Sodium thiosulphate
d) 12 N NaOH : Dissolve 480 gm Sodium hydroxide in one liter distilled water.
e) 0.1 N NaOH : Dissolve 4 gm NaOH Pellets in 1 liter distilled water. Standardise against 0.1 N H_2SO_4.
f) 0.1 N Na_2CO_3 : Accurately weigh 5.3 gm analytical grade Sodium carbonate in a chemical balance and dissolve it in one litre of distilled water.
g) 0.1 N H_2SO_4 : Take 3 ml of conc. H_2SO_4 and dilute it to 1080 ml with distilled water. Standardise against 0.1 N H_2SO_4.
h) Potassium Sulphate
i) Copper Sulphate
j) Methyl red indicator
k) Phenolpthalein indicator

Procedure

Take 5 ml of soil sample in a Kjeldahl flask, add 20 ml of conc. H_2SO_4, 0.5 gm Salicylic acid and Keep in cold for 10-20 minutes. Then add 2.5 gm Sodium thiosulphate, a pinch of copper sulphate and 5 gm of potassium sulphate and digest the mixture in a fume cupboard and for 1.5-2 hours until the contents are white and clean. Cool and add 50 ml water. Transfer the contents to a ammonia distillation flask. Make it alkaline with 80 ml of 12 N NaOH solution and distill off the ammonia collecting it in 10 ml of 0.1 N H_2SO_4 in a conical flask with a few drops of methyl red indicator. Collect about 150 ml of the distillate. Titrate the excess of 0.1 N H_2SO_4 with 0.1 N NaOH till the solution turns colourless.

Calculation : (10 - No. of ml of 1 N NaOH required) X 0.014 X 2
= Total Nitrogen(%)

4. Available Nitrogen

Available nitrogen is determined by alkaline permanganate distillation method as suggested by Subbiah and Asija.

Reagents

a) 0.02 N H_2SO_4 : Dilute 100 ml of N H_2SO_4 of standard stock solution to 500 ml with distilled water.
b) 0.02 N NaOH : Dilute 100 ml of 0.1 N NaOH of standard stock solution to 500 ml with distilled water.
c) Methyl red indicator : Dissolve 0.1 gm of methyl red powder in 25 ml of ethyl alcohol and make up the volume to 50 ml with distilled water.
d) 0.32 % K MnO_4 solution : Dissolve 3.2 gm of potassium permanganate in distilled water and make up the volume to 1 liter.
e) 2.5 percent NaOH solution : Dissolve 25 gm of Sodium hydroxide in distilled water and make up to one liter.

Procedure

Weigh 5 gm of the soil sample in a 500 ml Kjeldahl flask. Add 50 ml of 0.32 % $KMnO_4$ solution and 50 ml Of 2.5 % NaOH, 2 ml of liquid paraffin and 10-20 glass beads and distill the mixture. Collect the distillate in a conical flask containing 10 ml of 0.02 N H_2SO_4 and a few drops of methyl red indicator. Collect about 60-75 ml of the distillate. Titrate the excess of 0.02 N H_2SO_4 with 0.02 N NaOH to a colourless end point.

Calculation : (10 - No. of ml of 0.02 N NaOH required) X 2.8 X 2
= Available Nitrogen(mg/100 gm of soil)

5. Available phosphorus

There are a number of methods for determination of available phosphorus in soil which use different extractents. Of these Trough's method using 0.002 N H_2SO_4 as extractants is commonly used, since the method is very simple and it gives a good correlation with fish production.

Reagents

a) 0.002 N H_2SO_4: Dilute 20 ml of standard 0.1 N H_2SO_4 to one litre. Adjust the pH to 3.0 with Ammonium Sulphate
b) 50% H_2SO_4.
c) 10% Ammonium Molibdate solution
d) Acid ammonium Molibdate solution : This may be prepared fresh at the time of analysis. Add 15 ml of 50% H_2SO_4 to 5 ml of 10% ammonium molibdate solution.
e) Stannous Chloride solution : Dissolve 1 gm of stannous chloride A.R. in 100 ml of glycerin.

f) Standard phosphate solution (1 ml = 0.01 mg P) : Dissolve 4.388 gm of Potassium dihydrogen phosphate (K H_2PO_4) which has been dried over conc. H_2SO_4, in distilled water and make upto one litre. This stock solution contains 1 mg P per ml. Dilute 10 ml of this solution to one litre containing 0.01 mg P per ml. (= 10 ppm).

Procedure

Take 1 gm sample in a 250 ml bottle, add 200 ml of 0.002 N H_2SO_4 and shake the mixture for 30 minutes in a mechanical shaker, keep it for 10 minutes and filter. Filter 50 ml of the solution and determine its phosphate content as follows : To 50 ml of the solution in a Nessler Tube, add 2 ml of acid-ammonium molibdate reagent and 2 drops of Stannous chloride, mix gently, wait for 5-7 minutes and measure the blue colour concentration in a spectrophotometer at 690 mμ. Similarly, measure the colour photometrically for two or three standard phosphate solution with known phosphate concentrations and prepare a calibration curve, using a distilled water blank. From the calibration curve, estimate the phosphate content of the soil solution. Prepare at least one standard with each set of samples or once each day that tests are made. The calibration curve may deviate from a straight line at the upper concentrations of the 0.3 to 2.0 mg/l range.

Calculation : No. of ml of standard X 0.01 X 4 X 100 = mgP/100 gm soil or
Phosphate content in soil solution (mg/l) X 20
= mg P/100 gm of soil.

6. Calcium Carbonate

This method of determining HCl soluble calcium carbonate in a soil is useful for estimating the lime content of the soil.

Reagents

a) 0.5 N HCl solution : Dilute 40 cc conc. HCl to 960 cc with distilled water. Standardise against standard Na_2CO_3.
b) 0.5 N NaOH solution in one litre of distilled water.
c) 0.5 N Na_2CO_3 solution : Dissolve 26.5 gm pure sodium carbonate in one litre of distilled water.
d) Bromothymol Blue Indicator.

Procedure

Place 5 gm soil sample in a 250 ml bottle, add 100 ml of 0.5 N HCl and shake for one hour in a mechanical shaker. Allow to settle the suspension and pipette out 20 ml of clear liquid. Transfer to a conical flask, add 4-5 drops of bromothymol blue indicator. Titrate it with 0.5 N NaOH till it is just blue (from yellow). Note the reading and carry out a blank taking 20 ml of 0.5 N HCl in a flask and titrating in the same way.

Calculation : (Titrate for blank - Titre for soil solution) X 2.5
= % of $CaCO_3$ in the sample.

7. Mechanical analysis

Gravitational method

Reagents

a) Hydrogen peroxide (6%)
b) N HCl
c) N NaOH
d) 5% Silver nitrate solution
e) Ammonium hydroxide

Procedure

Take 20 gm soil sample in a 500 ml beaker, add 30 ml H_2O_2 and keep the beaker in a water bath. When oxidation of organic matter is complete, there will be no frothing after addition of more H_2O_2. Cool, add 50 ml N HCl and 100 ml distilled water to make the soil free from carbonates. Allow the content to stand for one hour with occasional shaking. Filter the soil and wash it with hot water to remove the acid, which may be tested by $AgNO_3$ solution. Transfer the soil to one litre beaker, add 8 ml of N NaOH and shake for an hour in a mechanical shaker. Transfer the content to a 1 litre tall cylinder, make up the volume and shake for one minute and allow to stand for 4 monutes (28^0C). Lower a 20 ml pipette, 10 cm deep and suck out 20 ml of the content, dry it in a 50 ml beaker to a constant weight to get the weight of silt and clay. After 6 hours repeat the operation to get the weight of clay alone.

Calculation : Wt. of Clay + Silt = x_1(wt. of sample after 4 minutes)
Wt. of clay = x_2 = wt. of sample after 6 hours.
From these readings percentage of clay, silt and sand can be found out as follows :
Silt (%) = $(x_1 - x_2)$ X 250 .... (A)
Clay (%) = x_2 X 250 - 1.6 .... (B)
Sand (%) = 100 - (Silt + Clay) = 100 - (A+B)

Cation exchange capacity of soil

Principle

Soil is a negatively charged colloid and around this negatively charged layer a positively charged layer is present. This positively charged layer consists mainly of exchangeable cations, namely Ca^{+2}, Mg^{+2}, K^{+1} etc. and H^+ to a small extent. Soil colloids have certain capacity for the exchange of these cations with other cations and a number of methods have been suggested to determine the CEC of soil.

In ammonium acetate method, when the soil is saturated with neutral ammonium acetate solution, a portion of NH_4^+ is absorbed by the soil and all the cations from the clay colloids are removed or exchanged through leaching by ammonium acetate solution due to mass action. Therefore the equivalent of NH_4^+ ions going to the clay colloids represent the exchangeable cations. Thus, the estimation of NH_4^+ in the soil will give as the CEC of the soil.

Reagents

a) Neutral ammonium acetate solution : Dissolve 77.0 gms of ammonium acetate in one litre distilled water. Adjust the pH to 7.0 by adding acetic acid or NH_4OH solution.
b) 40% ethyl alcohol.
c) Ammonium Chloride (pinch only) for completing the process of exchange.
d) N/10 H_2SO_4 or 4% Boric acid (using mixed indicator of methyl red and bromocresol green)
e) N/10 NaOH solution
f) 40% NaOH or 5 gms of anhydrous MgO.
g) Methyl red indicator

Procedure

1. Take 10 gm soil sample in a 250 ml beaker and add 50 cc of neutral ammonium acetate. Shake and heat at 70^0C for half an hour.
2. Cool the content and filter the soil on a Whatman No - 42 filter paper quantitatively. Wash the soil with neutral ammonium acetate solution several times. A pinch of ammonium chloride is added to the last washing.
3. The excess of NH_4^+ in the soil is washed with 40% alcohol until the filtrate is chloride free. (Test with $AgNO_3$ and HNO_3).
4. The soil and filter paper is transferred to 500 ml flask and distill with MgO, with some paraffin oil. Collect the distillate in a conical flask containing 25 ml of N/10 H_2SO_4 and 4 drops of methyl red. Collect about 200-250 ml of distillate.
5. The excess of N/10 H_2SO_4 isback titrated with N/10 NaOH.

Calculation : $$\text{CEC of soil} = \frac{(B-T) \times N \times 100}{W}$$

Where B = Blank titration in ml of standard alkali.
T = Actual titration in ml of standard alkali.
N = Normality of alkali (NaOH).
W = Weight of soil taken.

References

1. De, S.K. 1962. Methods of soil analysis. Narayan Publishing House, Allahabad. 204 p.

2. Jhingran, V.G., Natarajan, A.V., Banerjee, S.M. and David, A. 1988. Methodology on Reservoir Fisheries Investigations in India. Bulletin No. 12 CICFRI, Barrackpore. 102 p.

3. Piper, C.S. 1966. Soil and Plant Analysis. Hans Publishers, Bombay. 368 p.

Analytical Methods for Estimation of Water Quality Parameters

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Introduction

The purpose of the water Analysis is to know the exact composition of the sample at the particular point of time of sample collection After analysis is over, the results may be interpreted to suit a particular purpose of either surveillance of water quality, or of effluent quality or to assess the performance of wastewater treatment plant.

General Information

1. Collect the sample along with the suspended matter, shaking may be required. Calibrate all the glass-ware. Use A.R. grade reagent. Express the results as milligrams of parameters per litre of sample.

2. Statistical anlalysis of the data should be done before any conclusion is drawn.

3. In water samples the sum of anions (me/l) is equal to sum of cations (me/l) within reasonable limits if the ionic concentration is not excessive. This balance is not possible for polluted samples.

Sampling

A sample has to be representative and valid both in time and space. The parameters in the sample at the time of analysis should have the same values as those at the time and place of sampling. A sample will be representative depending upon the sampling techniques and preservation . A sample is valid if it represents the true picture water quality at the sampling point. Quality of water depends on frequency of sampling. Conditions at each sample source vary widely and sampling programme needs to the worked on the merits of the source.

Frequency of Sampling

Quality of water , flowing or stangnant , seldom remains the same in time. The larger the number of samples from which the mean is derived , the narrower will be the limits of the probable difference between the observed and true values of the mean. In order to double the realiability of a mean value , the number of samples must be increased four-fold, because confidence limits are proportional to the square of the number. Cost of sampling and analysis is directly related to the number of samples; hence a compromise between the increased reliability of data measured by confidence limits and the cost of its collection has to be reached.

Effluents or water quality changes depending on the mass inputs and changes in rate of water flow or on volume. Characteristics of water quality vary; 1) randomly, e.g. during storm, spillages in factory; 11) cyclically due to rainfall pattern. Also they vary with the production pattern in manufacture process, or depending upon the sourcees, e.g., a river or lake.

Sampling frequency at a source can be decided on the basis of the following stages :

1) Collection of information regarding factors causing changes in sample quality and previous analytical data.

2) Identifications of needs - highlighting the parameters of significance, depending on the source and requirement.

3) Preliminary study may be required to assess the existing water/ effluent quality variability nature in rerspect of concentrations of parameters. It is desirable to follow

Sampling pattern as follows :

a) Weekly samples for one year

b) Daily samples for 7 days consecutively
+
(4 times /year)

c) Round the hour sampling for 24 hours
+
(4 times/year)

d) 4-hourly samples for 7-days - and 4-times/ year.

The analytical data collected as per the above procedure will help to lay proper emphasis on parameters of relative importance, their ranges, interferences and frequencies of their occurrences. This is applicable to rivers, lakes, industrial effluent outfalls. concentration of a parameters is important, but is also equally important to correlate with the waste/ water flow to calculate the mass load.

Sampling procedures:

The determinations fall into three groups.:

a) Conservative, not changing with time.

b) Non-conservative , changes with time but can be stabilised for 24 hours by proper treatment.

c) Non-conservative, changes with time and cannot be preserved , e.g. tempertature, pH, D.O.

Composite Samples

It is a general practice to mix discrete samples to form a composite sample. Time based composite or weighted composite sample is one, when individual samples are mixed in equal proportion, or in portions according to the flow at the time of sampling. Analysis of a composite sample will be the average over the time of sampling. This will not give any indication of maxium or minimum values over the sampling period. Manual sampling is econimally reliable. composited samples are not possible for D.O., pH, temperature, CN, metals, & bacteria. These changes with time or due to chemical interactions.

Each sample should carry a tag or label as under:

1. Source
2. Date
3. Time
4. Preservative added
5.Collectors identity

SOME IMPORTANT PARAMETERS OF WATER ANALYSIS :

1. Dissolved Oxygen sampling : (1) DO (2) pH (3) Alkalinity (4) Chloride (5) Phosphate (6) Nitrate (7) Turbidity (8) Sp. Cond. (9) Hardness (10) Ca + Mg (11) BOD (12) COD (13) Primary Productivity (14) Free Co_2 (15) Silicate (16) Temperature

Sample must be collected without causing any change in the dissolved oxygen concentrations. Contact with air or agitation has to be avoided. Liquid can be siphoned through a glass rubber tube into the sample bottle. The tube reaching the bottom of the bottle and the liquid should be allowed to flow untill the contents of the bottles have been changed several times. Living organisms neeed oxygewn for their metabolic processes. Dissolved oxygen (DO) is also important in precipitation and dissolutiuon of inorganic substances in water. The solubility of oxygen in water depends upon its temperature.

1. It is necessary to know DO levels to asses quality of raw water and to keep a check on stream pollution.

2. Do test is the basis of BOD test which is an important parameters to evaluate pollution potential of the wastes.

3. DO is necessary for all aerobic biological wastewater treatment processes.

4. Oxygen is an important factor in corrision. Do test is used to control amount of oxygen in boiler feed waters either by chemical or physical methods.

Principles

Oxygen present in sample oxidizes the divalent manganeous to its higher valency which precipitates as a brown hydrated oxide after addition of NaOH and KI. Upon acidification, manganese reverts to divalent state and liberates iodine from KI equivalent to DO content in the sample. This liberated iodine is titrated against $Na_2S_2O_3$ (N/80) using starch as an indicator.

Interference

Ferrous ion, ferric ion, nitrite, microbial mass, and high suspended solids constitutes the main sources of interferences. Modifications in the estimation procedures to reduce these interferences are decribed in the sequel.

Apparatus

1. BOD bottles capacity 300 ml .
2. Sampling device for collection of samples.

Reagents

1. **Manganese sulphate**
2. **Alkali Iodide -azide reagent**
3. **H_2SO_4**
4. **Starch indicator**
5. **Stock sodium thiosulphate 0.1N**
6. **Standard sodium thiosulphate 0. 025 N**

Procedure

1. Collect sample in a BOD bottle using DO sampler.

2. Add 2 ml $MnSO_4$ followed by 2ml of NaOH + KI + NAN_3 . The tip of the pipet should be below the liquid level while adding these reagents. Stopper immediately.

3. Mix well by inverting the bottles 2-3 times and allow the precipate to settle leaving 150 ml clear supernatant .

4. Alt this stage , add 2 ml conc., H_2SO_4 . Mix well till precipitate goes into solution.

5. Take 203 ml in a conical flask and titrate against $Na_2S_2O_3$ using starch as indicator . When 2 ml $MnSO_4$ followed by 2ml NaOh + KI + NaN_3 is added to the sample as in (2) above 4.0 ml original sample is lost. Thus 203 ml taken for titration will correspond to 200ml of original sample.
200+ 300 / (300-4) = 203ml.

Calculation

1ml of 0.025N $Na_2S_2O_3$ = 0.2mg of O_2

$$\text{D.O. in mg/l} = \frac{(0.2+1000)\text{ml of thiosulphate}}{200}$$

2. BIOLOGICAL OXYGEN DEMAND (BOD)

APPARATUS

1. BOD bottles 300ml capacity
2. Incubator, to be controlled at 20^0 C$\pm$

REAGENTS

1. **Phosphate buffer**
2. **Magnesium sulphate**
3. **Calcium Chloride**
4. **Ferric Chloride**
5. **Sodium Sulphide Solution 0.025 N**

Procedure

(a) Preparation of dilution water

1. Aerated the required volume of distilled water in a container by bubbling compressed air for 1-2 days to attain DO saturation. Try to maintain the temperature near 20^0C .

2. Add 1 ml each of phosphatew buffer, magnesium sulphate, calcium chloride and ferric chloride solution for each litre of dilution water. Mix well.

3. In the case of the waste which are not expected to have sufficient bacterial population add seed to the dilution water. Generally , 2ml settled sewage. is considered sufficient for 1000 ml of dilution water.

(b) Dilution of sample.

1. Neutralise the sample to pH around 7.0 if it is highly alkaline or acidic.
2. The sample should be free from residual Chlorine. If it contains residual chlorine remove it by using $Na_2 SO_3$.

The following dilutions are suggested:

0.1% to 1%	For	Strong trade waste.
1% to 5%	For	Raw or Settled sewage
5% to 25%	For	Treated Effluent
25% to 100%	For	River Water

3. Siphon the dilution prepared as above in 4 labelled BOD bottles and stopper immediately.

4. Keep 1 bottle for determination of the initial DO and incubate 3 bottles at 20^0C for 5-days. See that the bottles have a water seal.

5. Prepare a blank in duplicate by siphoning plain dilution watere (without seed) to measure the O_2 consumption in dilution water.

6. Fix the bottles kept for immediate DO determination and blank by adding 2 ml $MnS0_4$ followed by 2ml NaOH + KI +NaN_3 as decribved in the estimation of DO.

7. Determine DO in the sample and in the blank on initial day and after 5 days.

8. Calculate BOD of the sample as follows :

Let D0 = DO inthe sample bottle on 0^{th} day.
D1 = DO " " " " " 5^{th} day
C0 = Do in the blank bottle on 0^{th} day
C1 = Do in " " " " 5^{th} day

C0--C1 =DO depletion in the dilution water alone
Do--D1= DO depletion in sample+dilution water.
(Do--D1) --(Co-C1) =DO depletion due to microbes
BOD mg/l = (DO--D1)--(Co--C1) mgX decimal fraction of sample used.
If the sample is seeded find out BOD of seed in the above manner and apply correction.

3. CHEMICAL OXYGEN DEMAND (COD)

Chemical Oxygen Demand (COD) test determines the Oxygen required for Chemical Oxidation of organic matter with the help of strong chemical oxidants. The test can be employed for the same purpose as the BOD test after taking into its limitations. The results in this can be obtained in 5hours as compared to 5days required for BOD test. Further the results gives reproducible results and is not affected by interferences as the BOD test.

PRINCIPLE :

The organic matter gets oxidised completely by $K_2Cr_2O_7$ in the presence of H_2SO_4 to produce $CO_2 + H_2O$. The excess $K_2Cr_2O_7$ remaining after the reaction is titrated with Fe $(NH_4)2$ $(SO_4)2$. The dichromates consumed gives the O_2 required for oxidation of the organic matter. Interference Fatty acids, Straight chain Fatty aliphatic compounds, chlorides, nitrites, and iron are thew main interfering radicals.

APPARATUS :

1. Reflux apparatus consisting of a flat bottom 250 to 500 ml capacity flask with ground glass joint and a condensor with 24/40 joints.
2. Burner or hot plate.

REAGENT :

1. **Standard potassium dichromate 0.25 N**
2. **Sulphuric acid reagent**
3. **Standard Ferriousammonium sulphate 0.1N**
4. **Ferroin indicator**
5. **$HgSO_4$: Analytical grade**

PROCEDURE :

1. Place 0.4 g $HgSO_4$ in a reflux flask
2. Add 20ml sample or an aliquot of sample diluted to 20ml with distilled water. . Mix well.
3. Add pumic acid or glass beads followed byt 10ml Std. $K_2Cr_2O_7$.
4. Add slowly 30ml H_2SO_4 containing $AgSO_4$ mixing throughly. This slow addition along with swirling prevents fatty acids to escape out due to high temperature.
5. Mix well. If the colour turns green either take fresh sample with lesser aliquot or add more dichromate and acid.

6. Connect the flask to condenser. Mix the contents before heating because improper mixing will result in bumping and sample may be blown out.
7. Reflux for a minimum of 2hrs. Cool and then wash down the condenser with distilled water.
8. Dilute top about 150 ml , cool and titrate excess $K_2Cr_2O_7$ with 0.1N $(NH4)_2 SO_4$ using ferroin indicator. Sharp colour change from blue green to wine red indicates end point or completion of the titration.
9. Reflux blank in the same manner using distilled water instead of sample.
10. Calculate COD from the following equation :

$$\text{COD mg/l} = \frac{(a - b) \times 8000}{\text{ml sample}}$$

Where a = ml Fe $(NH_4)_2$ $(SO_4)_2$ for blank
b = ml " '' " for sample
N = normality of Fe $(NH_4)_2$ $(SO_4)_2$

Note: For standarisation of ferrous ammonium sulphate , use 10.0 ml Std. $K_2Cr_2O_7$, acidify by adding 10.0 ml H_2SO_4 and titrate with Ferrous Am. Sulphate to be standardised using ferroin indicator. Calculate : N by $N_1 V_1 = N_2 V_2$.

4. Hardness

Hardness in water causes scale formation in boilers . It is also objectional from view point of water use for laundry and domestic purposes since it consumes a larger quantity of soap. Generally, salts of Ca and Mg contribute hardness to natural waters. Hardness may be classified either as (1) carbonates and non-carbonates or (2) calcium and magnesium hardness or temporary and permanent hardness.

Principle :

In alkaline condition EDTA reacts with Ca and Mg to form a soluble chealated complex. Ca and Mg ions develop wine red colour with erichrome black "T" under alkaline condition . When EDTA . is added as a titrant the Ca and Mg divalent ions get complexed resulting in sharp change from wine red to blue which indicates end point of the titration. The pH for this titration has to be maintained at 10 ± 0.1 . At a higher pH , ie. about 12.0 Mg ion precipitates and only Ca ion remains in solution . At this pH Murex indicator form a pink colour with Ca^{++}. when EDTA is added Ca^{++} gets complexed resulting in a change from pink to purple which indicates end point of the reaction. Metal ions do interfere but can be overcome by addition of inhibitors.

Reagents :

1. Buffer Solution
2. Inhibitor
3. Eriochrome black "T"

4. Murex indicator
5. Sodium hydroxide 2N
6. Standard EDTA solution 0.01M
7. Standard Calcium solution

PROCEDURE

A. Total Hardness

Take 25ml or 50 ml well mixed sample in porcelaine dish or conical flask. Add 1-2 ml buffer solution followed by 1ml inhibitor. Add a pinch of Eriochrome black "T" and titrate with standard EDTA (0.01M) till wine red colour changes to blue. Note down the Vol. of EDTA required (A). Run a reagent blank if buffer is not checked properly . Note the Volume of EDTA or Ca required by blank (B). Calculate Vol. of EDTA required by sample, C= (A$\pm$B) from volume of EDTA required in (A &B).

Calculate as follows:

$$\text{Total hardness mg/l as } CaCO_3 = \frac{C \times D \times 1000}{\text{ml of sample}}$$

Where C= Vol. of EDTA required by the sample

D= mg of $CaCO_3$-per 1.0ml EDTA0.01M used as titrant.

B. Calcium Hardness

Take 25ml or 30 ml sample in a porcelain dish. add 1ml NAOH to raise the pH to 12.0 and a pinch of indicator. titrate with EDTA till pink colour changes to purple. Note the Vol. of EDTA used (A').

Calculate as follows:

$$\text{Calcium hardness mg/l as } CaCO_3 = \frac{A' \times D \times 1000}{\text{ml sample}}$$

Where A' = Vol. of EDTA used by sample

D = mg $CaCO_3$ per 1.0 ml of EDTA used for titration

Magnesium hardness= Total hardness - Ca hardness

5. ALKALINITY

Hydroxides, Carbonates and bicarbonates contribute alakalinity to a liquid. Alkalinity values provide guidance in applying proper doses of chemicals in water and waste water treatment processes, particularly in coagulation , softening and operational control of anerobic digestion.

PRINCIPLES

Alkalinity can be obtained by neutralising OH, CO_3 and HCO_3 with standard H_2SO_4. Titration to pH 8.3 or de-colourization of Phenolpthalein indicator will show complete neutralization of OH and 1/2 of CO_3 while to pH 4.4 or sharp chang from yellow to pink of methyl orange indicator will indicate total alakalinity i.e., OH, CO_3, and HCO_3.

Interferences

Colour, turbidity, iron, aluminium, and residual chlorine are prime sources of interferences. Colour and turbidity can be avoided using potentiometeric titrations and residual chlorine can be removed by adding thiosulphate.

REAGENTS:

1. **Standard H_2SO_4 0.02N**
2. **Phenolpthalein indicator**
3. **Methyl Orange indicator**

PROCEDURE:

Take 25 or 50ml sample in a conical flask and add 2-3 drops of phenolpthaleian indicator. If pink colour develops titrate with 0.02N H_2SO_4 till it disappears or pH is about 8.3. Note the volume of H_2SO_4 required. (A) Add 2-3 drops of methyl orange to the same flask and continue titration till pH comes down to 4.4 or orange colour changes to pink. Note the vol. of H_2SO_4 added (B) In case pink colour does not appear after addition of phenolpthaleian continue as in 3 above. Calculate Total (T) , Phenolpthaleian (P) and methyl orange (MO) alkalinity as follows and express in mg/l as $CaCO_3$:
P-- alkalinity, mg/l as $CaCO_3$= Ax1000/ ml sample. Mo-- alakalinity , mg/l as $CaCO_3$ = B x 1000/ml sample. T-- alkalinity, mg/l as $CaCO_3$ = (A+B) x 1000/ ml sample.

6. CHLORIDE:

Chlorides occur widely in water and waste waters and are usually associated with Na ion. Although chlorides are not harmful, concentrations beyond 250mg/l impart a peculiar taste to water rendering in unacceptable from aesthetic point of view for drinking purpose. Presence of chlorides above the usual background concentration in a water source is also used as an indicator of pollution by domestic sewage.

PRINCIPLE:

Chloride ion is determined by titration with standard $AgNO_3$ in which AgCl precipitates out. The end point is indicated by formation of red silver chromate from excess $AgNO_3$ and potassium chromate used as an indicator in netural to slightly alkaline solution.

INTERFERENCE

Bromide, iodide, cyanide, sulfide, thiosulphate, sulfite, iron, phosphate are prime sources of interferences.

REAGENTS :

1. Potassium Chromate Indicator.
2. Silver Nitrate 0.0141N
3. Sodium Chloride 0.0141N
4. Special reagent to remove color and turbidity : Dissolve 125 g. $Alk(S0_4)_2$. 12 H20 or $AlNH_4$ (S04)2 .12 H20 and dilute to 100 ml . Warm to 60°C and add 55ml conc. NH_4OH slowly. Allow to stand for 1hr., Solution should be free from Chloride.

PROCEDURE:

Take 100ml sample and add 3ml special reagent . Mix well and allow to settle. Filter the supernatant for titration purpose. To the sample containing sulphite , add about 1ml H_2O_2 after neutralization. In case of sulphide or thiosulphate is present raise the pH of the sample to 8.3 or , more, add H_2O_2 1ml, and then again neutralize the sample. Adjust the pH of the sample between 7.0 and 8.0 Take 50 ml well mixed sample adjusting to pH 7.0- 8.0 and add 1.0ml K_2CrO_4 . Titrate with standard $AgNO_3$ solution till $AgCrO_4$ starts precipating . Standarise $AgNo_3$ against Std. NaCl. For better accuracy titrate distilled water (50) ml in the same way to establish reagent blank. Calculate as Follows :

$$\text{Cl mg/l} = \frac{(A-B)\,N \times 35450}{\text{ml. sample}}$$

where A = ml AgNo3 for sample
B= '' " Blank
N= Normality of $AgNO_3$ used.

7. TURBIDITY

Suspension of particles in water with passage of light is called turbidity. The method is based on a comparison of the intensity of light scattered by a sample and a standard reference under same conditions. Higher the intensity of scattered light higher the turbidity. Colour is the main sources of interferences in the measurement of turbidity.

APPARATUS :

1. Turbidification or Klett Summerson meter at 690 mu providing 1cm light path.
2. Nessleres tube , capacity 100ml.

REAGENTS

1. Strong Acid reagent
2. Sodium hydroxide 3N.
3. Phenolpthaleian indicator.
4. Ammonium molybdate
5. 1-Amino 2-napthol 4 - sulphonic acid (ANSA)
6. Stanous Chloride

PROCEDURE :

Prepare the caliberation curve in the range O - 400 unit by carrying out appropriate dilutions of solutions 3 and 4 above and taking readings on turbiditimeter. Take sample or suitably diluted aliquot and determine its turbidity either by visual comparison with the diluted standards or by reading on turbiditimeter. Read turbidity from the standard curves and apply correction due to dilution , if necessary. Report the readings in turbidity unit.

8. Orthophosphates:

Presence of phosphates in water analysis has a great significance . Phosphorous in small concentrations are used in water supplies to reduce scale formation. , to increase carrying capacity of mains, to avoid corrosion in water mains, to remove Fe anfd Mn in micro quantities and in coagulation especially in acid conditions . The presence of PO_4 in large quanties in fresh waters indicates pollution through sewage/ or industrial wastes. It promotes growth of nuisance causing microorganisms. Though PO_4 poses problems in surface waters, its presence is necessary for biological degradation of wastewater

PRINCIPLE:

Under the condition soluble PO_4 react with ammonium molybdate and produce molybdo phosphoric acid, which in turn, gets reduced to molybdenum blue after additions of a reducing agent such as NASA or Stanous Chloride. Colour developed is directly proportional to PO_4 concentration. Stanous chloride is more suitable for lower phosphate concentrations.

REAGENTS :

1. Sulphuric acid (50%)
2. Ammonium Molybdate (10%)
3. Acid molybdate reagent
4. Stanous Chloride solution
5. Standard phosphate solution

PROCEDURE :

Place 5. ml of the sample in a Nesslers tube, add 2 ml of acid am. molybdate reagent and mix by gentle stirring , add 2 drops of stanous chloride, mix gently, wait for five minutes and match the blue colour developed with standards prepared in phosphate free distilled water similarly as for nitrate .
No. of standard phosphate x 0.01 x 20 = ppm of P.

This can also be measured at 690 mu and 1 cm light path in a spectrophotometer.
Prepare standard graph using PO_4 solution in the range of 5--30 mg/l

9. NITROGEN :

Nitrogen estimation is of significance in sanitary engg. practices in many respects. Prior to introduction of bacteriological analysis procedures, determinations of various forms of nitrogen in waters was done to asses its quality. Presence of organic and ammonia nitrogen (also called total nitrogen) is accepted as a chemical evidence of recent organic pollution , particularly of animal origin. On the other hand , presence of the oxidised form , nitrites and nitrates , indicates remote pollution. Nitrifiucation of sewage nitrogen when it is treated in a sewage treatment plant may also be taken as an index of degree of treatment. Ammonia above a certain level is toxic to fish life in surface water. Nitrates in drinking water has been reported to be the cause of methemaglobinemia. Presence of nitrogen in appropriate amount in waste water is necessary for its treatment through biological processes. A knowledge of nitrogen in wastewater is important when it is used as irrigant.

Ammonia nitrogen

Ammonia produces a yellow colour compound when reacted with alkaline Nessler reagent , provided the sample is clarified properly. Colour , turbidity, Ca, Mg, salts and Fe inthe sample constitutes the prime sources of interferences.

APPARATUS

1. Spectrophometer having a range of 300-700 mu.
2. Nesslers tubes or 100 ml capacity volumetric flasks.

REAGENTS

1. Zinc Sulphate
2. Sodium Hydroxide (6N)
3. EDTA
4. Rochelle salt solution
5. Nesslers reagent
6. Standard am. solution.

Procedure

Take 100 ml of sample. Add 1ml $ZnSO_4$ solution. and 0.4 ml NaOH to obtain a pH of 10.5. Allow to settle and filter the supernatant through 42 No. Whatman filter paper. Take a suitable aliquot of sample and dilute to 50 ml. Add 3 drops of Rochelle salt solution or 1drop of EDTA , mix well. Add 2ml Nesslers reagent if EDTA is used or 1ml if Rochelle salt solution is used. Make up to 100ml Mix well and read % transmission after 10 min. at 410 mu or blue filter (42) , using a blank prepared in the same way using distilled water instead of sample. Prepare a calibration curveusing suitable aliquots of standard solution in the range of 5 to 120 ug/ 100ml for references following the same procedure as 1 to 5 but using the standard solution in place of sample.

NITRATES :

Principle : Nitrates reacts with phenol disulphonic acid and produces a nitro-deratives which in alkaline solution develops yellow color due to rearrangement of its structure. The color produced follows BEER's Law and its proportional to the concentration of NO3 present in the sample. Chlorides and nitrites are the two main sources of interferences. Pretreatment of sample is necessary when the interfering radicals are present.

APPARATUS

1. Colorimeter or Spectrophotometer having a range of 300-7O0 mu
2. Nesselers tube cap. 100 ml
3. Beakers - Cap 100 ml.

REAGENTS

1. **Phenol- disulphonic acid (PDA)**
2. **Sod. hydroxide 12 N**
3. **Stock Nitrate Solution**
4. **Standard Nitrate solution.(KNO_3)**
5. **0 Al. sulphate (10%)**

PROCEDURE

Evaporate to dryness 50 ml of the sample in a white porcelain basin on water bath. Cool and add 2ml of phenol disulphonic acid drop by drop and rub it throughly with a glass rod. Wait for about 5 minutes and add 2 ml of aluminium sulphate solution .Now add 12 N NAOH solution slowly with stirring until it is alkaline. If nitrate is present a yellow colour will appear. Remove aluminium hydroxide by filteration . Proceed similarly with standard nitrate solution as for ammonia determination.

NO. of ml of standard solution requires X 0.001 X 20= ppm Nitrate --N .

10. pH

pH is the negative logarithm of hydrogen activity more commonly, concentration, for dilute solution. For measurement of pH, a glass electrode is used along with a calomel reference electrode. Glass is an ion exchange material with preference for H- ions. Hydrogen ions are adsorbed on one surface and the possitive charge of these are transmitted through the glass by Na+ ion displacement. Hydrogen ions are desorbed on the other side. Therefore, a glass is a membrane specific for hydrogfen ions. The glass electrode consists of a glass bulb with dilute hydrochloric acid connected to the internal circuit through Ag-AgCl.

PRINCIPLE:

Nernst equation governing the effect of concentration of ions and formation of single electrode potential across the glass membrane is the basic concept of the pH measurement.

PROCEDURE:

Switch on the instrument and wait for few minutes till it warms up. Set the pointer of the meter to Zero by turning "set zero control". Take buffer solution of known pH in a clean beaker. Immerse the electrodes in the solution to a depth of one inch. Measure the temperature of solution by thermometer and adjust temperature. Put the selector switch to proper pH range and set the pointer to the known pH of the buffer by turning "Set buffer control". Now standardization is done. Put back the selector to zero and check once again with buffer. Wash the electrode by distilled water and wip with tissue paper.Take unknown solution in a clean beaker and immerse the electrode in the sample. Put the selector to expected pH range and read the pH Value indicated by the pointer. Put back selector to zero position. Remove electrodes , wash with distilled water and leave at zero set. Electrodes should be always immersed in distilled water. pH meter can be used for finding out end points of acidimetry, precipitation and titrations.

2) Colorimetric methods:

The principle of colorimetric estimations of pH is to develop color in the sample with an indicator dye and to compare this with colour of glass discs, color charts or coloured buffere solutions. The indicators used with range of pH are given below:

INDICATOR	**pH range**
Bromo-phenol blue	3.0 - 4.6
Bromo cresol green	3.8 - 5.4
Bromo cresol purple	5.2 - 6.8
Bromo thymol blue	6.0 - 7.6
Phenol red	6.8 - 8.4
Cresol red	7.2 - 8.8
Thymol blue	8.0 - 9.6

Place 10 ml of the sample in a small clear glass tube and add 0.5 ml of indicator. To know which of the above indicators is to be used a preparatory test with Universal indicator may be done which gives a very approximate value of the pH ; otherwise phenol red would be used first and then if necessary indicators of higher or lower ranges. For using these types of discs Lovibond pH comparator is required.

11. SPECIFIC CONDUCTIVITY

Specific conductivity offers a quick and convenient method for determination of the dissolved salts in water collectively ., the conductance of an electrolytes in solution being almost directly proportional to the ionic strength of that solution and the total conductance is equal to the sum of the several conductivities resulting from the various ionisable salts present.

PROCEDURE:

Specific conductivity is generally determined by a Conductivity meter. About 50 ml of the sample is taken in a beaker and the electrode is dipped into the sample. The switch to the reading mode will indicate conductivity of the sample in m-mhos/cm at a particular temperature.

12. SILICATE:

Silicate in water can be determined easily by colorometric methoids using artificial standards.

REAGENTS :

1. Standard picric acid solution
2. 10% Am. Molybdate solution
3. 25% sulphuric acid (by volume)

PROCEDURE:

Take 50ml of sample in a Nesslers tube add 2 ml Am. molybdate solution and 0.5 ml 25% H_2SO_4 . Stir and allow to stand for 10 minutes. Match the color of the sample and the standard following the usual procedures

NO. of ml of standard X 0.001 X 20 = mg Si per litre.

13. DISSOLVED FREE CARBON- Di-OXIDE :

As this is likely to escape easily from the sample , analysis should be done immediately after collecttion on the site.

REAGENT :

1. N/44 NaOH
2. Phenolpthelaine indicator

PROCEDURE :

Take 50 ml of the sample in a nesslers tube add two drops of Phenolpthalein indicator. If the water turns pink, there is no free carbon-di-oxide When the water remains colour less add N/44 NaOH drop wise from a 10 ml graduated pipette with a very gentle stirring with a glass rod till the color turns pink.

NO. of ml of N/44 NaOH required X 20 = ppm of free CO2.

14. CALCIUM AND MAGNESIUM:

The total alkalinity of water gives a fair idea of its Calcium and Magnesium contents but those can be determined accurately by Versenate method.

REAGENTS:

1. Standard Sodium Versenate
2. Indicator for Calcium and Magnesium (Erichrome Black 'T'+Na_2CO_3 + Iso-propyl alcohol
3. Indicator for calcium (solid) Am. purpurate+ NaCl
4. N --NaOH
5. Buffer solution
6. Standard Ca++ solution (Stock)

Procedure:

A standard end point is first prepared by diluting 10 ml of standard stock solution of Ca++ solution to 100 ml with distilled wateradding 2 ml N NaOH and 0.2 gm Calcium indicator to which 5 ml of Versenate solution is slowly added from a pippete so that the indicator assumes the end point color. 100ml of the unknown sample is now treated in the same way except that the addition of versenate is continued untill the tint of the unknown solution matches with that of thew standard prepared.

NO. of ml of versenate required = ppm of Ca++

2. Calcium + Magnesium :

100 ml of the water sample is slightly acidified with 0.01 N HCl equivalent to the alkalinity and boiled 0.5 ml of buffer solution is added and about 5 drops of Erichrome black "T" indicator. The sample is then titrated with standard versenate solution.

(NO. of ml of versenate required for Ca+ Mg-- No. of ml of versenate required for Ca) X 0.61 = ppm of Mg.

15. DETERMINATION OF PRIMARY PRODUCTIVITY :

1. By measuring carbon assimilation using radio isotope C^{14}

(a) selection of glass bottles of exactly same transparency.

One set of bottled made dark either by painting with black or preferably wrapping them completely with black tape or placing them inside small black plastic bags.

(b) Clamping of the glass stopper with a spring clip arrangement.

Care should be taken that under no circumstances , the content of the bottle radioactive material should be leak through loose stoppers.

(c) Construction of the float to suspend the bottles in water for ' in situ' experiments.

(d) Collection of water from different depths., treatments with $NaHCO_3$ -Na_2CO_3 solution containing C^{14} and replacement at the same depths.

In order that the whole of the eutrophic zone is covered , a predetermination of the light inttensities at different depths is necessary.

The water is placed in bottles , 3 light bottles and 2 dark bottles treated with diluted $NaHCO_3$ -Na_2CO_3 solution containing C^{14} are replaced at the same depths by tying them to the chords attached to the floats. The C^{14} ampoules generallly have a specific activity of about 4 μc which may be too strong. So a dilution to one tenth the strength is done just before treatment. For this it is necessary to have dilution water having the same carbon - content (determined by alkalinity estimation and adjusting to desired strength). Nine ml of this dilution is placed in a stoppered glass bottle, the C^{14} ampoule is broken and the content poured into it, taking all precautions that are necessary for handling radio active materials. It is mixed throughly and the desired quantity is taken out by an automatic pipette (In no case succking should be attempted). After treatment with C^{14} and replacement of the bottle to respective depths, they are incubated for five hours generally from 7.0 hrs to 12 hrs. The bottles are now taken out, immediately fixed with formaline and taken to laboratory for filterattion. Filteration should be should be started immediately as otherwise the plankton may disintigrate and pass through filters. Filtering is done with 'millipore' filters H.A. type with detachable tower type glass or perspex filters having suction arrangement. It is preferable to have the filteration done under a uniform suction of 0.3 atmosphere. Aftere washing with water of the same environment and finally with dilute hydrochloric acid , the filters with the residue are removed to desiccators and dried. The filters thus processesd to a Radio Tracer Laboratory for estimating the activity of C^{14} in them .

2. By measuring oxygen produced in photosynthesis using light and dark bottle technique

This method is followed side by side with C^{14} technique for comparing results and can be followed in places where facilities for more precise technique with C^{14} are not available. The experimental procedures are just the same as for C^{14} technique excepting that the treatment with C^{14} solution omitted . Initial concentration of the DO of the dark and light bottles may be determined for an understanding of the respiration effect though they may not figure in the final calculation.

The method consists of taking water samples, containing a neutral plankton population in glass bottles and exposing the bottles to light in the eutrophic zone . In a parellel experiment a portion of the initial sample is held in darkened bottle for the same length of time and at the same temperature as the illuminated sample. The initial O_2 content (IB) of the sample is determined by winklers method. The difference between this concentration and the concentration found from water in the illuminated bottle after a suitable period of exposure (LB) is a measure of net evolution of O_2 due to photosynthesis (LB-IB). This difference is not equal to the true net photosynthesis of the plants enclosed in the LB, as oxygen may have been consumed by both bacterial and animals in addition to the oxygen consumed by the respiration of the plant cells proper .It is more common to the Dark and Light Bottle technique to measure gross photosynthesis. This is done by finding the difference between the initial oxygen content (IB) of the water and the oxygen remaining in a dark bottle (IB--DB). Such a difference (a loss of O_2 due to respiration) is assumed to be equal to the total respiration occuring in the illuminated bottle over the same period of time and thus if added to the net value obtained from the LB-IB above gives a measure of the gross photosynthesis from the relationship.

Gross photosynthesis = net O_2 evolved + O_2 used for respiration
= gain in LB + loss in DB
= (LB-DB) + (IB-DB)
= LB-DB

$$\text{Gross production} = \frac{\text{LB-DB}}{\text{T (hrs)}} \times \frac{0.375}{\text{PQ (1.2)}} \times 1000 \text{ mgC/M3/hr}$$

$$\text{Net Production} = \frac{\text{LB-IB}}{\text{T (Hrs)}} \times \frac{0.375}{\text{PQ(1.2)}} \times 1000 \text{ mg C/ M3/ hr.}$$

$$\text{Respiration} = \frac{\text{IB-DB}}{\text{T (Hrs)}} \times 0.375 \times (1.0) \times 1000 \text{ mg/M3/ hr.}$$

PQ = Photosynthetic co-efficients

RQ = Respiration Coefficients