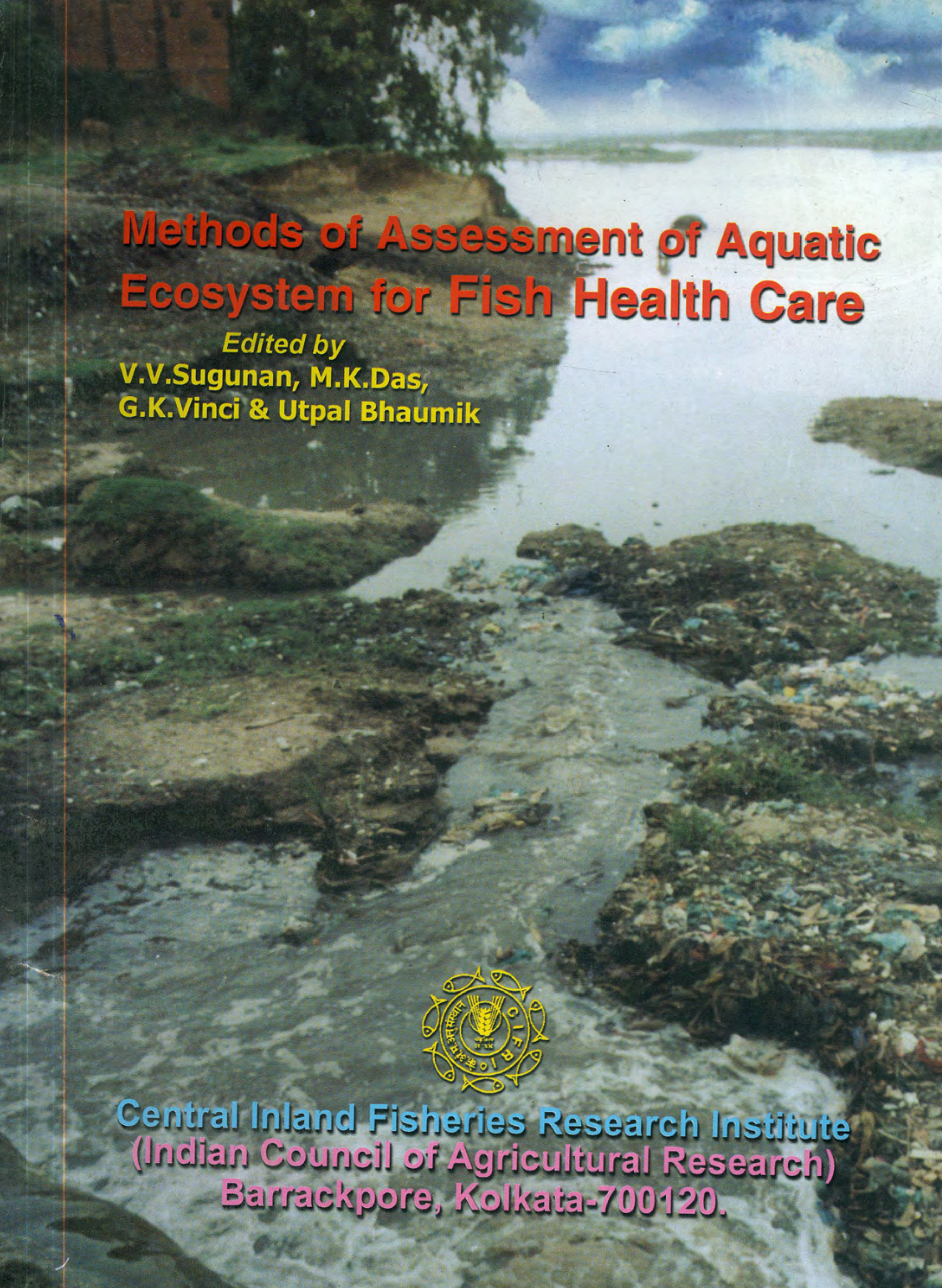

Methods of Assessment of Aquatic Ecosystem for Fish Health Care

Edited by
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INLAND AQUATIC RESOURCES OF INDIA AND THEIR RELEVANCE TO FISHERIES DEVELOPMENT

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INTRODUCTION

In India, fisheries have always been playing a pivotal role in the food and nutritional security of the people, especially in the rural areas. Unlike other types of animal food, fish comes in various price tags so that all segments of the society have access to it. Fish is not only the cheapest protein food within the reach of the poor, it is also one of the best health foods containing high-density lipoproteins. The country has made big strides in fish production during the last fifty years. From 0.75 million t in 1950-51, annual fish production has increased to 5.6 million t during 1999-00, registering an impressive eight-fold increase. Over the years, growth in the marine sub-sector has slowed down considerably due to dependence on the wild stocks of fish, which are obviously being over-exploited. Conversely, contribution of inland fisheries to the total fish production has increased from 24-29 % in the 1950s and the 60s, to nearly half during the 1990s (Table 1). The actual production of inland fish has increased 14-fold from 0.2 million to 2.8 million t during the last five decades. During this period, fish production systems in the inland waters have expanded, diversified, intensified and technologically advanced.

Table 1. Increase in fish production in India

Year	Marine	Inland	Total	Contribution of inland fisheries (%)
1950-51	0.5	0.2	0.8	29.0
1960-61	0.9	0.3	1.2	24.1
1970-71	1.1	0.7	1.8	38.2
1980-81	1.6	0.9	2.4	36.3
1990-91	2.3	1.5	3.8	40.0
1997-98	2.8	2.4	5.2	46.2
1998-99	2.9	2.5	5.4	46.3
1999-00	2.8	2.8	5.6	50.0

In spite of the phenomenal increase in fish production during the last five decades, the per capita availability of fish in India continues to be very low at 8 kg per head, against the world average of 12 kg. In order to fulfill the minimum nutritional requirement as stipulated by the WHO standards, a person needs 11 kg of fish $year^{-1}$. Assuming that 56% of the population include fish in their diet, the country currently needs, at least, 6.2 million t of fish. Thus, the current shortfall of fish production is about 0.6 million t. Since marine fishery is fast approaching a plateau in growth rate, most of the shortfall in future has to be met essentially from the inland fisheries. This paper deals with various inland fishery resources of India (other than the intensive aquaculture) and their role in increasing fish production in the country.

INLAND FISHERIES RESOURCES OF INDIA

Fish production systems in India can be classified into capture fisheries of the rivers and estuaries, aquaculture in ponds and various forms of enhancements (mainly culture-based fisheries being practiced in reservoirs, lakes and floodplain wetlands) as depicted in table 2.

Table 2. Open water fishery resources in India and their modes of fishery management

Resource	Resource size	Management mode
Rivers (km)	29,000	Capture fisheries
Mangroves (ha)	356,000	Subsistence
Estuaries (ha)	300,000	Capture fisheries
Estuarine wetlands (*bheries*) (ha)	39,600	Aquaculture
Backwaters/lagoons (ha)	190,500	Capture fisheries
Large and medium reservoirs (ha)	1,667,809	Enhancement (Stock and species)
Small reservoirs (ha)	1,485,557	Culture-based fisheries
Floodplain wetlands (ha)	202,213	Culture-based fisheries
Upland lakes (ha)	720,000	Not known

Capture fisheries, culture-based fisheries and enhancement

In a typical capture fishery, the wild untended stock of organisms is harvested with little human intervention on either habitat variables or the biotic communities. On the other hand, in culture fishery, the whole operation is based on captive stocks with a high degree of effective human control over the water quality and other habitat variables. Fishery management purely on capture fishery lines as in the case of marine fisheries, seldom operates in the inland waters of India, with the possible exception of rivers and estuaries. Intensive aquaculture is practiced in ponds. A range of management practices intermediate to culture and capture fisheries is collectively known as enhancement. FAO (1997) defines fisheries enhancements as *technical interventions in existing aquatic resource systems, which can substantially alter the environment, institutional and economic attributes of the system.* This is the process by which qualitative and quantitative improvement is achieved from water bodies through exercising specific management options. The common forms of enhancement which are relevant to inland water bodies of India are stock enhancement, species enhancement, environmental enhancement, management enhancement and enhancement through new culture systems. Culture-based fishery is the most common mode of enhancement being followed in inland water bodies in India. When the fish harvest in an open water system depends solely or substantially on artificial recruitment (stocking), it is generally referred to as culture-based fishery.

It has been estimated that 1.8 million t of fish is produced through inland aquaculture in India. The remaining 1.0 million t of inland fish is attributable to different types of inland open water systems. Although the breakup of catch from rivers, lakes, floodplain wetlands and reservoirs are not recorded, it is generally believed that the capture fisheries of rivers and estuaries contribute very little to their total inland catch. Bulk of the open water fish production emanates from reservoirs, small irrigation impoundments and floodplain wetlands. The main focus of management in these water bodies is culture-based fisheries and fisheries enhancement.

RIVERINE FISHERIES

The river systems of the country comprise 14 major rivers (catchment >20,000 km^2), 44 medium rivers (catchment 2,000 to 20,000 km^2) and innumerable small rivers and desert streams (drainage of less than 2,000 km^2). These river systems having a combined length of 29,000 km is one of the richest fish genetic resources in the world. The Gangetic system alone harbors not less than 265 species of fish. Similarly, 126 species belonging to 26 families have been recorded from Brahmaputra system. The peninsular rivers have been reported to bear at least 76 species fish species. The riverine scene, however, is a complex mix .of artisanal, subsistence and traditional fisheries with highly dispersed and unorganized marketing system, which frustrates all attempts to collect regular data on fish yield. A firm database on fish production trends of rivers is still elusive. Based on the information collected by CIFRI on selected stretches of the rivers Ganga, Brahmaputra, Narmada, Tapti, Godavari, and Krishna, fish yield from these rivers vary form 0.64 to 1.64 t per km.

The catch statistics indicate disturbing trends in the riverine fisheries of India. The biologically and economically desirable species have started giving way to the low-value species, exhibiting an alarming swing in the fish population structure of the Gangetic carps (Sinha *et al.,* 1998).Fish production in several stretches of the river sharply declined due to environmentasl changes that have taken place.A sharp decline in fish production from five stretches of the Ganga viz., Kanpur, Allahabad, Buxar, Patna and Bhagalpur is testimony to the deleterious effects of environmental changes on fish output. Average fish production from Ganga at Allahabad used to be around 205 t during the period between 1958-59 and 1965-66, which has declined to 59 t during 1996-97. More marked is the fall in the production rate of prized Indian major carps, which declined from 91.35 t in the 1950s to an abysmal 4.9 t in 1996-97. Thus, the percentage contribution of Indian major carps has declined from 44.5 to a mere 8% during the last four decades. A similar decline in qualitative and quantitative terms can be seen in Bhagalpur and Patna stretches of the river Ganga (Table 3). Another glaring feature of the catch structure is the increasing domination of lower age groups in respect of *Cirrhinus mrigala, Catla catla* and *Labeo rohita*. The once lucrative hilsa fishery above the Farakka barrage collapsed due to obstruction of the fish's migratory path.

Table 3. Qualitative and quantitative decline in fish catch (t) from Ganga

Allahabad

	1958-59 to 1965 -66	(%)	1973-74 to 1985 -86	(%)	1989-90 to 1994-95	(%)	1996-97	(%)
Major carps	91.35	44.5	40.44	28.7	11.04	11.5	4.94	8.3
Catfish	46.66	22.7	30.82	21.9	21.5	22.5	14.28	24.1
Hilsa	19.94	9.7	0.87	0.6	0.92	1.0	2.47	4.2
Misc.	47.48	23.1	68.79	48.8	62.1	65.0	37.61	63.4
Total	205.43		140.92		95.56		59.3	

Patna

	1986-89	1990-93	1996-97
Total	57.73	37.70	18.00

Bhagalpur

	1958-59 to 1965-66	(%)	1973-74 to 1983-84	(%)	1996-97	(%)
Major carps	16.62	18.2	10.06	10.8	7.31	20.4
Catfish	19.43	21.4	25.21	27.1	14.91	41.7
Hilsa	4.08	4.5	0.87	0.9	0.38	1.1
Misc.	50.82	55.9	56.96	61.2	13.20	36.8
Total	90.95		93.10		35.80	

The case of river Brahmaputra is no different from this as revealed in a recent survey in the state of Assam (CIFRI. 2000a). The fishery of major carps in several sectors of this river has declined with a corresponding increase in the catches of miscellaneous fishes. On the whole there was a 30% fall in the catch of major carps in Brahmaputra. The minor carps, hilsa and prawns declined by 50%, 81% and 58% respectively. Miscellaneous fishes filled the niches vacated by the carps and registered an increase of 141%. The survey also revealed large-scale destruction of brood fishes and juveniles. A similar survey conducted earlier in the Godavari also indicated depletion in fish yield. Mahseers, once plentiful in the upstream stretches of rivers, are already under the threat of extinction.

Table 4. Changes in fish yield and catch structure in Brahmaputra during the 1970s and 1990s

Groups	1973-79		1996-98		Change
	Average catch (kg day^{-1})	%	Average catch (kg day^{-1})	%	
Major carps	38.2	19.4	18.7	13.6	-30
Minor carps	27.8	14.1	9.6	7	-50
Catfishes	46.8	23.76	19.5	14.2	-40
Featherbacks	7.1	3.6	8.0	5.8	+61
Hilsa	22.1	11.2	2.9	2.1	-81
Prawn	9.8	5	2.9	2.1	-58
Misc. & Others	45.1	22.9	75.8	55.2	+141

Decline of fish populations in rivers is a universal phenomenon due to a variety of factors including destruction of habitat, effluent discharge and cascading effect of dams and other obstructions.

Factors responsible for decline in riverine fish yield

Besides water quality deterioration and socio-legal constraints, the decline of major carps in rivers has also been attributed to the flood control measures and large-scale water abstraction for irrigation purpose. Riverine fishes, by nature, are extremely sensitive to change in flood regime because of their dependence on seasonal floods, which inundate the grounds needed for feeding and reproduction. Thus, any change in the form and dimension of the flood curve in the rivers is bound to affect the community structure.

In the Ganga basin, 33.5 billion m^3 of water is presently held in storage reservoirs behind the weirs and barrages apart from 18 major canal networks diverting the water to irrigate 7 m ha of agricultural land. Indian carps are known to undertake short breeding migrations to the limpid shallow areas during monsoon. Water abstractions and impoundment of water behind weirs have destroyed a good amount of these breeding grounds resulting in recruitment failure. Floodplains are cut off from the river often converting them into virtual fish traps.

Collapse of hilsa fisheries in the Ganga above Farakka (Sinha *et al.,* 1998) is one of the classical examples of physiological strain and breeding failure that can be caused by dams and barrages to migratory fishes. Catadromous migrants like eels, freshwater prawns and the non-predatory catfish, *Pangasius pangasius* have also been affected by the barrage. Heavy siltation from catchment areas cuts off floodplain oxbow lakes and deep pools during summer. Major carps are known to retreat to these areas during dry season and get killed either due to drying of the area or due to indiscriminate exploitation.

ESTUARINE FISHERIES

Various estuarine systems, spreading over 300,000 ha, form an important component of the fisheries resources of India (Table 5). River course modifications have a negative impact on the estuarine fish populations. A glaring example is the overall decline in salinity of Hooghly-Matlah estuarine system, the largest in India, after commissioning of the Farakka Barrage with gradient and marine zones being pushed down towards the sea. This has brought about drastic changes in the species composition of fishes caught with freshwater species making their appearance in tidal zones at the cost of some neritic species (Sinha, 1999),besides problems caused by urbanisation, pollution, land development, dams, degradation and over-exploitation in some areas. Further, fishing by very small meshed nets may affect the concerned stocks. This situation may lead to depletion of stocks.

Table 5. Major estuaries and associated inland water bodies in India and their fish production levels (From Jhingran, 1988, Sinha *et al.*, 1999)

Estuary	Area (ha)	Annual fish production (t)	Major fisheries
Hooghly-Matlah	234,000	20,000 – 26,000	*Tenualosa ilisha, Harpodon nehereus, Setipinna phasa, Trichiurus* sp. *Lates calcarifer*, prawns
Godavari estuary	18,000	5,000	Mullets, prawns
Mahanadi estuary	30,000	550	Mullets, *Lates calcarifer*, Sciaenids, prawns
Narmada estuary	-	4,000	Hilsa, mullets, prawns
Peninsular estuaries	-	2,000	Mullets, prawns, clupeids, crabs
Chilka lagoon	103,600	4,000	Prawns, mullets, catfishes, clupeids, perches, threadfins, sciaenids
Pulicat lake	36,900	760-1370	Prawns, mullets, perches, crabs, clupeids
Vembanad lake and other backwaters of Kerala	50,000	14,000-17,000	Prawns, mullets, *Lates calcarifer, Etroplus suratensis, Chanos chanos*
Estuarine wetlands (bheries)	42,600	37,500	Prawns, mullets, tilapia, *Lates calcarifer*
Mangroves	356,500	-	

Poor tidal oscillations and flood discharge due to sand bar formation in Mahanadi estuary has already affected fish yield. The fisheries of Godavari estuary too have been seriously affected by sand bar formation. Fisheries potential of Tapti estuary drastically declined after commissioning of the Ukai dam. Mushrooming industries on the bank of Mahi pose serious pollution problems in the estuary.

Lagoons and backwaters

Lagoons and backwaters associated with estuaries constitute an important inland fishery resource. Chilka and Pulicat Lake in the east coast and the Vembanad lagoon in the west coast are the major brackish water lakes in India. Regulated discharge through incoming rivers, siltation and anthropogenic pressure have made considerable negative impact on the fishery of Chilka Lake. Siltation shrunk the lake area from 906 km^2 in 1965 to 620 km^2 in 1995. Weed infestation is @ 950-60 kg m^{-2}. Total fin fish landing has decreased from 4,243 t in 1990 to 1270 t in 1995 and prawns reduced from 28% to 14% due to over-fishing and wanton destruction of stocks, barricading the outer channel with fixed small meshed gill nets, construction of pens with fine mesh nylon mosquito netting, increased number of operators

Fish catch from Pulicat lagoon is dependent on the ingress of fish and prawn seed from the sea. However, the sand bar formed at the mouth adversely affects recruitment. The production dropped from 2,600 t during 1945-46 to less than 1,000 t..

Prawn catches, both from impoundment and open waters of *Vembanad Backwaters* has declined, mainly due to human intervention, pollution and over fishing (Menon *et al.*, 2000).

Mangroves and estuarine impoundments (*bheries*)

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 its own fishery (Kathiresan, 2000). Nearly 85% of the Indian mangroves are situated in the Sundarbans in West Bengal and Bay of Bengal islands. The Indian share of Sundarbans once covered an area of 4,262 km^2, which has now shrunken to 3,560 km^2. Even this is under pressure from various human activities. Mangroves are declared as protected areas where fishing is prohibited. Several creeks are known to be the sites for fish and prawn seed collection. Although against the norms of conservation, these seed collection activities sustain the aquaculture in the region, providing livelihood to thousands of fishers. The Sundarbans fishery consists of 18 species of prawn, 34 species of crabs and 120 species of fish besides 4 species of turtles. The estuarine wetlands around Calcutta, which form a very important source of meeting the city and suburban demand for fish, are fast depleting due to urban expansion programmes and pressure on the land.

RESERVOIRS

Reservoirs are defined as 'man-made impoundments created by erecting a dam of any description on a river, stream or any water course to obstruct the surface flow' (Sugunan, 1997). However, water bodies less than 10 ha in area have been excluded from this definition. The Ministry of Agriculture, Government of India classifies reservoirs as small (<1000 ha), medium (1,000 to 5,000 ha) and large (>5000 ha) for the purpose of fishery management, which constitute the single largest inland fisheries resource in terms of resource size and production potential. It has been estimated that India has 19,134 small reservoirs with a total water surface area of 1,485,557 ha. Similarly, 180 medium and 56 large reservoirs have an area of 527,541 and 1,140,268 ha respectively. Thus, the country has 19,370 reservoirs covering 3,153,366 ha (Sugunan, 1995).

Fishery management of reservoirs

In broad terms, management of medium and large reservoirs in India can be considered as more akin to *enhanced capture fisheries.* Although many of them are stocked, their fisheries continue to depend, to a large extent, on the wild or naturalised fish stock. Conversely, small reservoirs are managed as *culture-based fisheries,* where the fish catch depends on stocking.

Management of medium and large reservoirs

Since large and medium reservoirs are to be developed on the principles of enhancement of capture fisheries; the main accent of which is on conservation of habitat in order to allow the natural recruitment and growth of the target species. Stock monitoring is achieved through the manoeuvering of fishing effort and following mesh size regulations. Introduction is resorted to for correcting imbalances in species spectrum and stocking is done as a temporary measure to compensate for recruitment failure.

Stock enhancement: Stocking attempts in medium and large reservoirs are successful only when the stocked fishes breed and propagate themselves in that system. Catla stocked in Sathanur, Gandhisagar and Ukai also led to increase in yield, primarily because of its breeding success (Sreenivasan, 1984). In sharp contrast, in a number of reservoirs like Nagarjunasagar, Bhavanisagar, Krishnagiri, Malampuzha and Peechi, the fish did not make any impact because of its failure to breed.

Species enhancement: This aims at augmenting the species range by adding fish species from outside with a view to colonize all the diverse niches of the biotope for harvesting maximum sustainable crop. The tilapia, *Oreochromis mossambicus* was stocked in reservoirs of south India during the 1960s. Jhingran (1991) reported a gradual decline in size of tilapia in reservoirs of Tamil Nadu and Kerala over the years. Moreover, it has a low consumer preference except in the state of Kerala. Today, fishery managers in India do not prefer *O. mossambicus* as a candidate for stocking (Sugunan, 1995). A spectacular performance of silver carp is recorded from Gobindsagar reservoir (Himachal Pradesh) where after an accidental introduction, the fish formed a breeding population and brought about a phenomenal increase in fish yield. Silver carp was instrumental in enhancing production of Gobindsagar from 160 t in 1970-71 to more than 1,000 t at present.

The Indian policy on stocking reservoirs disallows the introduction of exotic species into the reservoirs. However, presence of tilapia, common carp and silver carp in reservoirs is a *fait accompli*. Common carp is very popular in reservoirs of the northeast where it enjoys a favourable microclimate and a good market. Silver carp and grass carps are not widely encouraged to be stocked in Indian reservoirs, except in a few small reservoirs of Tamil Nadu and the northeast. The three exotic species *Aristichthys nobilis, O. niloticus* and *Clarias gariepinus* brought in clandestinely by the fish farmers, have not gained entry into the reservoir ecosystems so far and they remain restricted to the culture systems.

Management of small reservoirs

More than 70% of the small reservoirs in India are impoundments created to store stream water for irrigation. They either dry up completely or retain very little water during summer (Haniffa & Pandian, 1978), thus ruling out any possibility of retaining broodstock for recruitment. Thus, culture-based fishery is the most appropriate management option for the small reservoirs in India. The key management parameters of culture-based fishery are *species selection, stocking,* and *environmental enhancement* (enriching the water quality through artificial eutrophication).

Species selection: The culture-based fisheries of small reservoirs in India largely centre round the three species of Indian major carps *viz., Catla catla, Cirrhinus mrigala, and Labeo rohita.* The Indian major carps have an impressive growth rate and their feeding habits are suitable for utilisation of various food niches. Instances where stocking of Indian major carps became ineffective in small reservoirs are very rare.

Stocking: Augmenting the stock of fish has been the most crucial management input in the reservoir fisheries. Augmentation of stock is also necessary to prevent the unwanted fishes from utilising the available food niches and flourishing at the cost of economically important species as most of the food niches are shared between Indian major carps and uneconomic species.

Stocking rate: Stocking densities need to be specified for individual water bodies or a group of them sharing common characteristics such as size, presence of natural fish populations, predation pressure, fishing effort, minimum marketable size, amenability to fertilisation and multiplicity of water use. The main considerations in determining the stocking rate are growth rate of individual species stocked, the mortality rate, size at stocking and the growing time. Recently, based on the National Consultation on Reservoir Fisheries (Sugunan, 1997), the Government of India has adopted Welcomme's (1976) to calculate the stocking rate for small reservoirs.

Environmental enhancement : By improving the nutrient status through selective input of fertilisers in small reservoirs, stocks can be maintained at levels higher than the natural carrying capacity of the ecosystem. However, careful consideration of the possible impact on the environment is needed before this option is resorted to. Scientific knowledge to guide the safe application of this type of enhancement and the methods to reverse environmental degradation, if any, is still inadequate. Sreenivasan and Pillai (1979) Sreenivasan (1971), (Sugunan and Yadava, 1991 a, b) have tried this method with encouraging results. Environmental considerations and the possible conflicts of interest among various water users are the main factors that prevent the use of this option.

Fish production trends

In spite of a conducive limno-chemical regime, good standing crop of plankton and high rate of primary productivity, the fish yield from the reservoirs on a national level is very poor. It varies from 0.05 kg ha^{-1} in Bihar to 35.5 kg ha^{-1} Himachal Pradesh with a national average of 20 kg ha^{-1} (Table 6). The average national yield from small reservoirs in India is nearly 50 kg/ha^{-1}, which is low (Sugunan, 1997), compared to other countries in Asia and Latin America such as China (743 kg ha^{-1}), Sri Lanka (300 kg ha^{-1}) and Cuba (100 kg ha^{-1}). There is an urgent need to prioritize the culture-based fisheries of reservoirs as a major means to increase inland fish production in India. This mode of fishery development is environment-friendly, cost effective and socially relevant. Welcomme (1996) considers this one of the fastest expanding sectors of fisheries.

Table 6. Fish yield from reservoirs of India (kg ha^{-1})

States	Small	Medium	Large	Pooled
Tamil Nadu	48.50	13.74	12.66	22.63
Uttar Pradesh	14.60	7.17	1.07	4.68
Andhra Pradesh	188.00	22.00	16.80	36.48
Maharashtra	21.09	11.83	9.28	10.21
Rajasthan	46.43	24.47	5.30	24.89
Kerala	53.50	4.80	-	23.37
Bihar	3.91	1.90	0.11	0.05
Madhya Pradesh	47.26	12.02	14.53	13.68
Himachal Pradesh	-	-	35.55	35.55
Orissa	25.85	12.76	7.62	9.72
Average	49.50	12.30	11.43	20.13

Reasons for low yield

Technological input like scientific management practices either received low priority or was overlooked altogether in reservoir fisheries development in India. This resulted in arbitrary stocking and non-adherence to sound stock management norms leading to low productivity. Fish yield of small reservoirs, where the management is on the basis of culture-based fisheries is dependent on a number of parameters, such as growth rate, natural mortality and fishing mortality. Therefore, stocking density, size at stocking, size at harvesting, rate of fishing mortality, and harvesting schedule hold the key for obtaining the optimum yield. A close scrutiny of the fishery management followed in the small water bodies indicates that these vital aspects of management have not received adequate attention.

There is no clear-cut policy and guidelines on stocking and other management measures, without which, the measures taken by various state governments become arbitrary. Strict monitoring of the size at stocking, and size at harvesting is often not done leading to poor production. Overstocking, under stocking, stocking at small size, catching fish at small size and lack of maintenance of stocking and harvesting schedule are the most common drawbacks noticed. Today, the 900 hatcheries across the country produce more than 18000 million fry of Indian major carps annually. But, they are seldom reared to fingerling size for stocking in reservoirs. Most of the fry produced in the hatcheries go to the aquaculture segment, managed by the private sector. The government and co-operative societies, which manage the reservoir fisheries, do not have enough infrastructures to raise the required number of fingerlings.

FLOODPLAIN WETLANDS

The *beels*, or floodplain wetlands usually represent the lentic component of floodplains *viz.,* ox-bow lakes, sloughs, meander scroll depressions, residual channels and the back swamps and excluding the lotic component (the main river channels, the levee region and the flats). In addition, tectonic depressions located in river basins are also included under *beels*. Thus, all the wetland formations located at the floodplains can be termed as floodplain wetlands (*beels*). They are either shallow depressions or dead riverbeds generally connected to the principal rivers and/or receive backflow water from the rivers during floods or from the huge catchment area following monsoon rains. Floodplain wetlands form an important fishery resource in Assam, West Bengal and Bihar where thousands of poor fishermen are dependent on these water bodies for their livelihood. The magnitude of their distribution and potential as a fishery resource in different states can be seen from Table 7.

Table 7. Distribution of floodplain wetlands in India.

State	Distribution (by district)	River basin	Local name	Area (ha)
Arunachal Pradesh	East Kameng, Lower Subansiri, East Siang, Dobang valley, Lohit, Changlang & Tirap	Kameng, Subansiri, Dibang, Lohit Dihing & Tirap	*Beel*	2,500
Assam	Brahmaputra & Barak valley districts	Brahmaputra & Barak	*Beel*	10,000
Bihar	Saran, Champaran, Saharsa, Muzaffarpur, Darbhanga, Monghyr & Turnea	Gandak & Kosi	Maun, Chaur & Dhar	40,000
Manipur	Imphal, Thoubal & Bishnupur	Iral, Imphal & Thoubal	Pat	16,500
Meghalaya	West Khasi hills and West Garo hills	Someshwari & Jinjiram	*Beel*	213
Tripua	North, South & West Tripura districts	Gumti	*Beel*	500
West Bengal	24-Parganas North & South, Hooghly Nadia, Murshidabad, Maldah,, Cooch Behar, Burdwan, North & South Dinajpore and Midnapore	Hooghly, Ichhamati, Bhagirathi, Churni, Kalindi, Dharub, Dharala, Pagla, Jalangi, Behula, Torsa and Mahananda	*Beel* Charha & Baor	42,500
Total				**202,213**

Biological importance of *beels*

The *beels* are considered as biologically sensitive habitats as they play a vital role in the recruitment of fish populations in the riverine ecosystems and provide nursery grounds for commercially important fishes. They form an important fishery resource in the northern and northeastern states of the country. If managed along scientific lines, fish production in *beels* can be increased significantly. For example, scientific management techniques developed over the past fifteen years have shown that the fish yields from West Bengal *beels* can be raised to 1,000-1500 kg ha^{-1} yr^{-1} from its present level of only 100-150 kg ha^{-1} (CIFRI, 2000 b).

Water residence and renewal time as well as the extent of macrophyte infestation are the two most important factors affecting the ecology and fisheries of *beels*. Thus, the classification using these two characteristics (closed and open *beels*) is much more relevant from the ecological and fisheries point of view than the previously discussed ones. Ecology and production functions of the floodplain wetlands of Assam and West Bangal have been investigated by CIFRI, the highlights of which are detailed below.

Criteria for ecosystem-oriented management of floodplain wetlands in India

The efficiency to transfer solar energy from one trophic level to the other is the primary considerations in selecting management option. This is dependent on the water renewal cycle and the species spectrum of the parent rivers and the *beels*. Ecosystem-oriented management implies increasing productivity by utilizing the natural ecosystem processes to the maximum extent. In an ecosystem, the biological output or the production of harvestable organisms can be at various trophic levels. Under a grazing chain *phytoplankton* → *zooplankton* → *minnows* → *catfishes* system or a *phytoplankton* → *zooplankton* → *fish* system prevails. Since no grazing chain of *macrophytes* → fish exists in *beels*, macrophytes are invariably channeled through detritus chain. There are different detritus chains such as *macrophytes* → *detritus* → *detritivore* system, *phytoplankton* → *detritus* → *benthos* → *bottom feeders* system and *macrophytes* → *associated fauna* → *air breathing* fish system.

Fisheries of the open beels

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

Culture-based fisheries of the closed *beels*

Management of completely closed *beels* or those with a very brief period of connection with the river is more like small reservoirs. The basic strategy here ought to be stocking and recapture of fish. In a culture-based fishery, the growth is dependent on stocking density and survival is dependent on size of the stocked fish. The right species stocked in right number, in right size and their recapture at right size are the determining factors. These have to be decided as a part of ecosystem-oriented management. The management parameters are size at stocking, stocking density, fishing effort, size at capture, species management, selection of species and selection of fishing gear.

Culture and capture systems

There are systems, which combine the norms of capture and culture fisheries. The marginal areas of *beels* are cordoned off for culture systems either as ponds or as pens and the central portion is left for capture fisheries .This has been tried in many places of the country with certain degree of success. *Beels* also can be part of an integrated system including navigation, bird sanctuary, post harvest, aquaculture and open water fisheries. A proposed scheme of closed *beel* has been shown as an example. This plan is a part of holistic development of the wetland, which can benefit the local people and help retaining the biodiversity of the *beel* and its environment

Pen culture in *beels*

Pens are barricades erected on the periphery of *beels* to cordon off a portion of the water body to keep captive stock of fish and prawn. Pen culture offers scope for utilizing all available water resources, optimal utilization of the fish food organisms for growth and complete harvest of the stock. Pens can be of any shape and size and they can be constructed by using a variety of locally available material. The Central Inland Capture Fisheries Research Institute has standardized methods for culture of freshwater prawn, *Macrobrachium rosenbergii* in pens.

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

UPLAND LAKES

Natural lakes situated in the colder upland regions of India are estimated to cover an area of 720,000 ha (Jhingran, 1988). But, these lakes have not been studied for their fishery potential. On account of their limnological characteristics, they are suitable for developing cold-water fisheries. These lakes support a lucrative indigenous and exotic fish fauna comprising schizothoracids, mahseers, trouts, tench, crucian carps and the mirror carp. Annual fish yield in Deccan upland lakes range between 1.8 and 9.3 kg ha^{-1} in Kodaikanal, 16.7 and 49.5 kg ha^{-1} in Yercaud, and 33.0 and 111.0 kg ha^{-1} in Ooty (Vass, 1988). The yield rates from Himalayan lakes range from 8.0-22.5 kg ha^{-1} in Dal lake, 10.0-28.5 kg ha^{-1} in Anchar, 15-45.0 kg ha^{-1} in Wular, 2.0 to 6.0 kg ha^{-1} in Manasbal and 5.0 - 15.0 kg ha^{-1} in Sivalik lakes. The catches in most of these lakes are dominated by *C. carpio* with sizeable contribution from schizothoracids and mahseers in northern lakes and *Oreochromis mossambicus* in Deccan lakes.

Management norms for these upland lakes are virtually non-existent and limnological information is available only from a few of these lakes. Some of these lakes in Kashmir Himalayas are experiencing a disturbing trend – the schizothoracids giving way to the common carp. The common carp introduced into the Kashmir valley now contributes 65-78% of the total fish landings of the region. The catch structure and composition have significantly altered in recent years. A parallel situation has been observed in case of mahseers in Kumaon and Sivalik lakes. In Bhimtal Lake, the common carp constitutes 21-67% of the catches leading to a decline by 27-45% of the *Tor putitora* population.

Very little is known about the fishery potential of upland lakes. On account of their remoteness and the low temperature regime, drastic increase in yield and production are not expected from these water bodies.

CONCLUSION

Rivers, estuaries and the lagoons, being under the threat of environmental degradation, are not expected to play a significant role in meeting the additional requirements of inland fish production in India. Unchecked growth of intensive aquaculture may open up many new environmental, social and legal issues. Thus, the eco-friendly option of developing culture-based fishery in small reservoirs and floodplain lakes, coupled with the stock and species enhancement in large reservoirs, hold the key to future inland fisheries development in India.

A policy for development of inland fisheries in the country needs to be developed for fish yield optimisation from different types of water bodies. The rivers and estuaries offer little scope for increase in yield and production due to environmental considerations. Nevertheless, these water bodies are the source of a very rich and varied fish germplasm needing conservation. The main emphasis here should be to conserve the natural habitat and protect the germplasm diversity. Even maintaining the present level of production by arresting the loss of habitat will be a great achievement. Any substantial increase in inland fish production should come from development of culture-based fisheries in small reservoirs and various kinds of enhancement in medium and large reservoirs. These are recognized as eco-friendly and socially relevant means of fishery development all over the world. In India, by virtue of the enormous resource size, reservoirs and floodplain wetlands can ensure substantial production hike, even at a modest increase in yield rate through adopting culture-based fisheries.

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ENVIRONMENTAL STATUS OF RIVERS IN INDIA AS SUITABLE FISH HABITAT

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INTRODUCTION

The ecology of the Indian rivers has not yet been fully understood, although individual workers, research Institutes and universities have done some sporadic work in isolation on various rivers (Natarajan, 1989, Jhingran, 1990, Khan *et al.*1996, Sinha *et al.* 1998, Ramakrishnaiah, *et al.*, 1999, Pathak, 1999, Chakraborty, 1999, Singh, 1999, Sinha & Khan, 2001). There is hardly any data available on time series of any river except the Ganga, making it very difficult to understand the mechanism of production at various levels.

ENVIRONMENTAL STATUS OF INDIAN RIVERS AND SUITABILITY OF FISH PRODUCTION

Certain core abiotic parameters responsible for fish production pertaining to some important Indian rivers are shown in Table 1. A brief description of most important parameters is given below:

The water temperature of Indian river is in the optimum range and suitable for the growth of fishes and other aquatic organisms. In Indian rivers, the level of oxygen values are in optimum range except at hot spots of pollution where values fluctuate around 1 mg l^{-1}, thus not suitable for fish growth.

Natural levels of dissolved phosphorus are very low, around 0.01 mgl^{-1} for PO_4^{3-} and 0.025 mgl^{-1} for total dissolved phosphate, which include the organic form. Natural levels of dissolved inorganic nitrogen are also low (0.12 mgl^{-1}). In Indian rivers concentrations of phosphates and nitrates are moderate except in the Ganga and its tributaries and at the outfalls of rivers where discharge of pollutants is high.The pH, alkalinity and hardness in Indian rivers are suitable for fish habitat.

BIOTIC COMMUNITIES

Plankton

The plankton of Indian rivers is quantitatively and qualitatively rich and diverse. In the Ganga, Godavari & Mahanadi it ranges from 29-7885 ul^{-1}, 9 - 6848 ul^{-1} and 57-321 ul^{-1}respectively. Bacillariophyceae followed by Chlorophyceae and Myxophyceae generally dominate the plankton flora. Dinophyceae and Desmidaceae are found in meagre quantities. The quantitative and qualitative composition of plankton vary between stretches, as also with the season and nutrient concentration / eutrophication.

In the Ganga and Mahanadi 51 and 31 species respectively of common microalgae have been reported. The main micro - algal flora recorded are: *Navicula* spp. *Fragilaria* spp. *Synedra* spp., *Gyrosigma* spp., *Diatoma* spp., *Nitzschia* spp. *Cymbella* spp., *Tabellaria* spp., *Pinnularia* spp., *Staroneis* sp., *Melosira* spp. *Surirella* sp., *Asterionella* sp., *Pleurosigma sp., Coscino*discus sp. (**Bacillariophyceae**) *Microspora* spp., *Tribonema* sp., *Oedogonium* spp., *Protococcus* sp., *Ulothrix* spp., *Kircheneriella* sp., *Chaetophora* sp., *Zygnema* sp., *Hormidium* sp., *Coelastrum* sp., *Pediastrum* spp., *Ankistrodesmus* sp., *Selenastrum sp., Scenedesmus* spp.(**Chlorophyceae**), *Cosmarium* spp., *Desmidium* spp. *Gonatozygon* spp., *Penium* sp., *Closterium* spp (**Desmidaceae**),*Oscillatoria* spp., *Anabaena* spp., *Phormidium* sp., *Lyngbya* sp., *Spirulina* sp., *Microsystis* sp., *Merismopedia* sp. (**Myxophyceae**) and *Ceratium* sp. (**Dinophyceae**).

Among zooplankton rotifers, crustaceans and protozoa are observed in adequate numbers. The dominant fauna recorded are: *Brachionus* spp., *Keratella* spp., *Filnia* spp, *Polyarthra* sp, *Lecane* sp., *Filinia* spp, *Rotitoria* sp. (Rotifera); *Cyclops* spp., *Diaptomus* spp. (Copepoda); *Daphnia* spp., *Bosmina* spp., *Sida* sp., *Macrothrix* sp., *Diaphanosoma* spp. (Cladocera), *Difflugia* sp., *Vorticella* sp., *Actinosphaerium* sp. and *Actinophrys* sp. (Protozoa).

Macrozoobenthic community

Similar to plankton, the macrozoobenthos fauna of Indian rivers is very rich and diverse. It is dominated by Mollusca and followed by Insecta and Annelida. It ranges from29-7685 um^2, 26-782 um^2 and 73-1170 um^2 in Ganga, Godavari and Mahanadi respectively. The main macrozoobenthos fauna recorded are: *Bellamya bengalensis, Thiara tuberculata, Brotia costula, Pila globosa, Lymnaea spp., Lamellidens spp., Pisidium sp., Sphaerium sp., Corbicula* spp., *Perreysia* spp.(*Mollusca*), chironimid larvae, dragon fly larvae, stonefly larvae, mayfly larvae, *Phylopotamus* sp. , Hydropsyche, *Chaoborus* spp., beetle larvae (Insecta); *Tubifex tubifex, Deris* sp., *Nepthys* spp. and water Leeches(Annelida).

Aquatic weeds

Aquatic weeds are observed where water current is slow and substratum is soft. The weeds provide shelter, food and breeding substrate to various type of biota. Weeds also absorb heavy metals. The common weeds from Indian rivers are: *Hydrilla* spp., *Vallisneria* sp., *Ceratophyllum* spp., *Naja* sp., *Potamogeton* spp., *Chara* spp., *Nitella* sp., *Salvinia* sp., *Eichhornia* sp., *Ipomoea sp., Marsilia* sp. *Cypreus* sp. and *Polygonum* sp.

RIVERINE RESOURCE OF INDIA

The total length of Indian rivers is about 45000 Km which includes 14 major rivers, each draining a catchment area of above 20,000 Km^2 ,44 medium rivers with catchment area between 2000-20,000 Km^2 and the innumerable small rivers and desert streams that have a drainage of less than 2000 Km^2. The major river systems of India on the basis of drainage, can be divided broadly into two: (i) Himalayan river system (Ganga, Indus and Brahamputra) and (ii) Peninsular river system (East Coast and West Coast river system). The details of the area and potential fish yield of the major rivers are furnished in Table 2.

Ganga river system

It is one of the largest river systems of the world, having a combined length (including tributaries) of 12500 km. After originating from Himalayan, it drains into the Bay of Bengal, after traversing a distance of 2225 km. The Ganga River system harbours about 265 fish species, out of these 34 species are of commercial value including the prized Gangetic carps, large catfishes, feather backs and murrels.

In mountainous region, from source to Haradwar, *Schizothorax* spp., catfishes, Mahseers and *Labeo* spp. dominate the fisheries. The commercial fisheries in this zone are non-existing due to sparse population, inaccessible terrain and poor communication between fishing grounds and landing centres. However, commercial fisheries assume importance in 1005-km middle stretch of the river (Kanpur to Farakka). The important landing centres are Kanpur, Allahabad, Patna, Buxar and Bhagalpur. The mainstay of fishery is the species belonging to cyprindae (176 species) and siluridae (catfishes). The important species are Gangetic major carps, catfishes, murrels, clupeids and featherbacks besides migratory hilsa. On an average fish yield has fluctuated in the stretch between a high of 230 t and a low of 12.74 t during 1958 to 1995 and yield of major carps on Kg $ha^{-1}yr^{-1}$ basis from 83.5 to 2.55 during the above period. The fish yield has come down at Allahabad and Patna landing centres from 950 kg km^{-1} yr^{-1} and 1811.2 kg km^{-1} yr^{-1} in 1960s to 311.6 kg km^{-1} yr^{-1} and 629.8 kg km^{-1} yr^{-1} in 1990s respectively.

Decline in Hilsa Fishery

The commissioning of Farakka barrage in 1975 caused an adverse effect on hilsa fishery, being migratory in nature. In pre-Farakka period (1958-72), the yield of hilsa at Allahabad varied from 7.87 to 40.16 t, at Buxar from 7.38 to 113.36 t and at Bhagalpur, 1.47 to 9.79 t. The scenario has adversely changed in post-Farakka period and hilsa yield has come down to 0.13 to 2.04 t, 0.07 to 2.60 t and 0.01 to 2.178 t respectively at the above centres. This is a classical example of adverse effect of construction of dams/barrages on the yield of migratory fishes. Similar problem is observed in migration of mahseers in upland rivers due to construction of barrages. This has resulted in dwindling of their population.

Potential fish yield

Actual fish production from the river at Allahabad was 21.33 kg ha^{-1} during 1972-79, 28.69 kg ha^{-1} during 1980-86 and 15.19 kg ha^{-1} during 1989-93. It showed that only 13.29-13.74% of the potential is being harvested. At Patna and Bhagalpur, 25.19% to 26.30% of the potential is harvested. The overall utilization of fish yield potential in the upper and middle Ganga comes to only 22.80%. In the lower Ganga, against a potential yield of 198.28 Kg ha^{-1}, only 30.03 Kg ha^{-1} is currently harvested Thus, in general the fish yield potential is inadequately utilized in all the sectors leaving scope for further improvement through efficient management.

Brahamputra River System

The Brahamputra river originates from a glacier (Kubiangiri) in Tibet and has a combined length of 4025 km including its tributaries. The geologically nascent state of Himalayas from where this river originates has substantially contributed to the high silt in the main channel. On account of this, the Brahamputra riverbed has risen during 1937-97 by c 4.5 m due to deposition of silt. Like Ganga basin, the Brahamputra valley is also dotted with abandoned beds called beels, which support rich fishery. The major portion of the river lies in Tibet and in Indian territory the river flows a stretch of about 700 km only. The Ganga joins it in Bangladesh, forming the largest delta in the world.

Fish stock composition

The upper sector of the river does not support commercial fishery of any significance. This segment harbours cold water fishes such as *Tor tor, T. putitora, T. mosal, T. progeneius, Acrossocheilus hexagonolepis* and a large catfish, *Bagarius bagarius*. A total of 126 fish species belonging to 26 families out of which 41 being of commercial importance have been reported. The fish fauna is a mixture of torrential fauna, specific to northern bank and of a mixed type in the southern bank. The major constituents of potamic stretch fisheries are: Gangetic major carps, medium carps, minor carps, catfishes (*W. attu, M. seenghala, M. aor, M. vitattus, B. bagarius, S. silondia, C. garua, P. pangasius, Rita rita, H. fossilis, O. bimaculatus, A. coila*) and *Hilsa ilisha*. Miscellaneous fishes such as *S. Phasa, G. chapra, M. armatus, M. aculeatus, G. giuris, Pama pama. Ambassis* spp. and feather-backs (*Notopterus notopterus, N. chitala*) also form substantial fisheries of the potomon region.

The average catches at four important landing centres were estimated at 847 t in 1970s. Catfishes dominate the fisheries in the upper, middle and lower stretches of the river. In the upper middle stretch miscellaneous fishes dominate (54.14%), followed by catfishes (28.40%) and major carps (17.46%). While in middle stretch catfishes (28%) have replaced the miscellaneous fishes followed by major carps (26%) and hilsa (18%), while fisheries of lower mid-stretch is again dominated by a miscellaneous group (34%) followed by catfishes (24%), minor carps (20%), major carps (11%) and hilsa (7%). Contribution of prawn in the total landing of the mid-stretch is restricted to only 4 - 7%.

In another survey conducted by CIFRI, during 1973-79 at the fish landing centres of Guwahati revealed that the fish landing has decreased to about 6-folds from 233.44 t in 1973 to a low of 39.02 t in 1979. The major carps yield has drastically declined by 5.6 folds (47.61 to 8.5 t). Similarly catfishes declined by 8 folds (58.7 to 7.3 t), and hilsa by 2.7from 2.3 to 0.4 t during the above period. The decline in major carps yield may be attributed to heavy exploitation of brooders (Ujaimara activity) as well as of juveniles.

Peninsular river system

This system may be broadly categorized into two (1) East coast river system and (2) West coast river system.

East coast river system

The combined length of the four rivers which constitutes this system *viz*., the Godavari, the Mahanadi, the Krishna and the Cauvery is about 6437 km with a total catchment area of 1231 mha.

The Godavari

The headwater harbours a variety of game fishes but does not support commercial fishery. According to a survey conducted by CIFRI (1963-69) on a riverine stretch of 189 km (between Dowlaiswarum and Pumnagudum Anicut), a fish yield between 218 and 330 t was estimated. The fish yield in kg/ha ranged between 6.14 (1969) to 9.36 (1963), indicating a declining trend. It has been observed that at present (1990s) the river is maintaining a fish production of 1 ton/km/annum against a fish production of 1.392 t Km^{-1} yr^{-1} in 1960s.

West Coast River System

The main westward flowing rivers are Narmada and Tapti.

Composition of fish stock

Narmada river harbours eighty-four fish species belonging to 23 genera. The contribution of carps in commercial fishery is of the order of 57.47 to 62.40% (Mahseer, 23.7 to 27%, *Labeo fimbriatus*, 18.20 to 19.20%, *L. calbasu*, 52-6.40%) followed by catfishes, 34 to 38% (*Rita* spp. 12.0 to 14%, *M. seenghala*, 7.80-9.90%, *M. aor* 4.7 to 5.0%, *W. attu*, 7.40 to 8.20%, *M. cavasius* 0.5 to 0.8%) and miscellaneous fishes 4 to 5% (*Channa* spp., *Mastacembalus* spp., *N. notopterus* and minnows). According to an estimate from a 48-km stretch (Hoshangabad to Shahganj) of the river, a monthly yield of 32.8 to 52.7 tons was reported in 1967. Since then, no perceptible change either in fish catch or in fish composition has been observed. However, now the river ecology might undergo a sea change with the proposed irrigation projects which will transform the river into a chain of reservoirs (major 450, medium and minor 350) almost obliterating the riverine habitat.

FACTORS INFLUENCING FISH YIELD FROM RIVERS

Biological and ecological studies have revealed that the fish communities are very sensitive to flood regime because of their dependence on the seasonal floods to inundate the ground needed for feeding and breeding. Any change in the pattern and form of flood curves result in the alteration of fish community structure. A characteristic feature of a river system is the nature of the input governing the productivity pattern. In the upper stretch of the rivers, such inputs are mainly allochthonous but in the potomon region encompassing the flood plains, the major inputs are silt and dissolved nutrients. There is a gap of knowledge on the relationship between these inputs and energy flow and productivity trends in these systems.

The intensity of fishing, nature of exploitation and species orientation are the characteristic of the artisanal riverine fisheries and are governed by (1) seasonality of riverine fishing activity; (ii) unstable catch composition; (iii) conflicting multiple use of river water, (iv) cultural stresses leading to nutrient loading and pollution; (v) lack of understanding of the fluvial system and infirm data base; (vi) fragmentary and out-moded conservation measures lacking enforcement of machinery; (vii) inadequacy of infrastructure and support services (viii) affordability and palatability and (ix) socio -economic and socio-cultural determinants.

An intelligent management strategy has to take cognizance of key parameters such as hydrology, fish stocks and dynamics of their population together with regulatory measures for fishing. Observance of closed seasons and setting up of fish sanctuaries have proved their efficacy in fostering recovery of impaired fisheries. Experience has indicated that gear control measures are liable to fail in yielding results until the artisanal level of fisheries exploitation is significantly changed.

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Table 1. Physico – chemical characteristics of certain important Indian rivers

Nature of the river	Physico-chemical characteristics							
	Temperature (^{0}C)	Transparency (cm)	pH (mgl^{-1})	D.O. (mgl^{-1})	Alkalinity (mgl^{-1})	Nitrate (mgl^{-1})	Phosphate (mgl^{-1})	Gross primary Productivity (mg $Cm^{3-1}h^{-1}$)
Ganga	11.5-33	11-150	7.6-8.8	3.73-10.8	97-296	Tr.-12.49	Tr.-0.73	87-593
Damodar	22.5-37	90-1050 (ppm)	6.5-8.4	1.7-9.1	34-204	0.21-6.06	0.02-0.60	--
Mahanadi	19-36	0-250	6.52-8.98	1.10-10.0	44.5-112.5	Tr.-0.40	Tr.-0.0043	312-824
Narmada	18-32	3-140	7.2-10.0	0.9-11.2	86-856	0.02-1.2	0.02-0.65	16.7-312.5
Godavari	23-32	6-200	7.4-8.20	6.6-8.90	96-191	0.021-0.054	0.006-0.18	17-208
Brahamputra	17.8-21.2	35.4-87.2	3.0-7.9	7.32-8.45	56.9-71.2	0.019-0.038	0.004-0.016	212-35mg C/m^2/day
Jhelum	5-23	20-90	7.5-8.45	4.2-12.10	112-237	0.08-0.45	0.10-1.18	--

Table 2. Showing the potential fish yield from Indian rivers based on their length and basin area. (After Khan and Tyagi, 1996)

River	**Length (km)**	**Basin area (million km²)**	**Fish yield (tonnes)**	
			Area based	*Stream length based*
Himalayan river				
Ganga	2525	0.88	17443	17142
Yamuna	1376	0.37	5243	8588
Brahamaputra	800	0.19	1782	3958
East Coast rivers				
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

ESTUARIES IN INDIA - THEIR PRESENT ECOLOGICAL STATUS IN RELATION TO FISH HEALTH

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INTRODUCTION

Estuary is defined as a semi enclosed coastal body of water having free connection with open sea, where sea water is measurably diluted with freshwater derived from land drainage. It may include the mouth of the river, the backwater lakes and tidal creeks. Varying quantum of freshwater discharge from rivers in different seasons and tidal changes during a year may cause considerable fluctuations in salinity and other physico-chemical conditions resulting in significant changes in the estuarine ecosystem. The estuaries are amongst the most productive natural ecosystems because of regular active interaction between freshwater discharge and the tides from the sea. The estuaries of rivers and connected mangroves, backwaters and brackish water lagoons constitute important fisheries resources of the country. They are highly productive because of their nutrient rich water and deltaic soil and contribute significantly to the total inland production of prized prawns, mullets, hilsa, milk fish and *lates*. The yield from estuaries ranged between 45 and 75 kg ha^{-1} yr^{-1}.

ESTUARIES IN INDIA

India has vast water area of 2.0 million ha under estuarine fisheries comprising Hooghly-Matla, Mahanadi, Godavary, Narmada, peninsular estuaries, lagoons (Chilka, Pulicat, Vambanad lakes), backwaters of Kerala, mangroves and estuarine impounds in Sundarbans. Details of estuarine fisheries resources of India are depicted in Table-1. They can be classified into estuaries of east, peninsular and west coast of India.

Estuaries of eastern India

Hooghly Matla estuarine system

The Hooghly Matlah estuarine system located in West Bengal is the largest among the estuaries on the Indian coast covering the Gangetic delta called Sundarbans. Sundarban is the World's largest delta endowed with largest mangrove vegetation. The entire lower portion of the estuarine system is criss crossed by many major and minor estuaries and supports many important biotic communities. The total area of the estuarine system is about 8029 km^2. The principal components of the estuarine system are the main Hooghly channel, its five tributaries *viz.,* Jalangi, Chunni, Damodar, Rupnarayan and Haldi, and adjacent estuaries *viz.,* Saptamukhi, Thakuran, Matlah, Gosaba, Harinbhanga, Ichamati, Raimangal, Bidya and Kulti situated in the lower marine zone. The Hooghly estuary is a positive mixohaline type of estuary, exhibiting semi-diurnal type of tide. The active tidal regime is felt up to 200 km and it used to be felt up to 300 km upstream during pre-Farakka barrage period.

After commissioning of Farakka barrage in 1975, the main Hooghlty estuary is fed directly by the Ganga through feeder canal and Bhagirathi. The additional discharge of freshwater into the system has significantly improved the ecology and productivity of the Hooghly estuary.

Physic-chemical features

Thermal stratification was not recorded in the estuarine system due to tidal action. The water temperature of the system ranged between 16.5 and 33.2 °C, the maximum being recorded during summer and minimum during winter. Mean water temperature in the Hooghly estuary ranged between 24.2 and 28.7°C which is considered optimum for fish production (Nath,1998).

The water transparency varied between 13 and 60 cm which was lower in the gradient zone compared to freshwater and marine zone. Transparency was maximum during winter and minimum during monsoon.

The water reaction was slightly alkaline (pH 7.4-8.3), which is congenial for aquatic habitat. The water had a high buffering capacity so that only marginal changes in pH had been noted.

Dissolved oxygen content was maximum in freshwater zone, followed by marine zone, while minimum was noted at the gradient zone. D.O. in the estuarine water ranged between 4.5 and 10.0 mgl^{-1}.

Total alkalinity content (64-184 mgl^{-1}) was conducive for aquatic habitat. The content was higher in freshwater and gradient zone than those in marine zone. Maximum content was recorded during summer and minimum during monsoon or post-monsoon.

After commissioning of Farakka Barrage, the salinity of Hooghly estuary dropped significantly in all regions (Bagchi *et al.*,1994). In Hooghly estuary salinity was minimum (0.039-0.066 gl^{-1}) in freshwater zone, which was slightly higher in transition zone (0.15-1.42 gl^{-1}) but maximum salinity 21.1-25.4 gl^{-1} was found in the marine zone (Nath,1998).

Phosphate content was higher (0.02 – 0.33 mgl^{-1}) in freshwater zone, followed by transition zone (0.02-0.27 mgl^{-1}) while lower content was noted in the marine zone (0.01-0.15 mgl^{-1}).

Similarly, nitrate and silicate contents were maximum in freshwater zone and minimum in the marine zone.

Calcium and magnesium contents were lower in freshwater and gradient zones, while they were very high in marine zone. In freshwater region calcium content was higher than that of magnesium, but in marine zone magnesium content was higher than that of calcium.

Primary production was higher in the marine zone, followed by freshwater zone, while lower production was found in the gradient zone, presumably due to higher turbidity and turbulance in that zone. The minimum primary production was recorded at Nawabganj centre of the freshwater zone presumably doe to adverse environmental condition caused by the discharge of industrial effluents. Since the Matla estuary was free from industrial pollution, maximum photosynthetic production was observed there. During monsoon season, due to cloudy and rainy weather conditions, the net primary production was in very low to trace levels. However, during sunny weather and calm river, the photo-synthetic productivity was high. Peak primary production was recorded during winter.

In Hooghly estuary the freshwater zone had slightly higher dissolved oxygen, total alkalinity, phosphate, nitrate and silicate contents compared to those in gradient and marine zones indicating that those nutrients were allochthonous. The marine zone had higher contents of free CO_2, hardness, sulphate salinity, sp. conductivity, sodium, potassium, calcium and magnesium. In bottom soil the marine zone had higher contents of important nutrients such as available and total nitrogen, available phosphorus, organic carbon and sp. conductivity. Gross and net primary production were higher in the marine zone indicating that this zone is nutrient rich and more productive.

Although large number of industries and municipalities discharge their effluents to Hooghly estuary, the water and soil qualities of the estuary were more or less congenial for aquatic production. Though the industrial effluents and heavy metals are highly toxic to aquatic organisms, the toxicity is presumably nullified in the main channel of the estuary due to huge dilution by the river water. Moreover, bore tide in Hooghly estuary not only enhances nutrient contents and primary production, but it helps to remove unwanted pollutants and toxic metabolites from the estuary making the system more congenial for aquatic habitat (Nath and De,1996; 1998).

Plankton

Investigation revealed that plankton production in Hooghly estuary has increased during post Farakka barrage period. Members of Bacillariophyceae dominated the plankton. Plankton production was higher in lower estuary compared to freshwater and gradient zones. Representation of Cladocerans was poor in the zoo-plankton.

Benthos

Gastropods dominated in the zoo-benthos in the Hooghly estuary. Freshwater and gradient zone had higher concentration than marine zone.

Matlah estuary

Besides Hooghly main channel, Ichamati and Moriganga other Sundarban estuaries do not receive freshwater discharge directly from headwater source. All these estuaries including Matlah are considered as estuarine inlets carrying tidal brackish-water. During high tide nutrient rich diluted water from the mouth of Hooghly estuarine complex enter into estuarine inlets. During monsoon, these inlets receive some run off-water from the catchment areas. The water and soil characteristics of Matla estuary have been found conducive for larval rearing. Optimum physicochemical condition, lesser predation, ample food supply from Sundarban mangrove vegetation, minimum salinity fluctuation, absence of aquatic pollution and tidal effects were some of the important attributes for high availability of *P.monodon* seed in the Matla estuary (Nath and Sinha,1996).

Kulti Estuary

Kulti estuary receives Calcutta municipal effluents containing both industrial and domestic matters. The fouling black effluent is discharged into the estuary at Kulti lock gate during low tide. The Kulti estuary at lock gate had very low D.O., pH, and high CO_2 and free ammonia and was highly polluted. Total alkalinity, nitrate, phosphate and silicate contents at lock gate were high. Condition of the estuary is gradually improved towards downstream at Dhamakhali, where it received sufficient water during high tide.

Mahanadi estuary

Mahanadi estuary is situated in Cuttack and Puri districts of Orissa. It is charracterised by poor oscillations and flood discharges because of formation of sand bars at the estuarine mouth which restrict the influences of flood tide up to 30-35 km upstream only. This estuary is poorly productive.

Estuaries of West Coast

Narmada, Tapti and Mahi are the three main estuaries of West coast.

Tapti was a moderately productive estuary, but after construction of Ukai dam in the upper freshwater region of the river, it has gradually lost its productivity.

Mahi estuary in Gujarat is facing the problem of acute industrial pollution due to large number of industries situated on its banks.

Narmada estuary stretches from Rajpipla down to Broach over a distance of 135 km. The physico-chemical parameters of water and soil were, in general, very conducive for aquatic productivity. High water temperature (17.5-31°C), alkalinine pH (7.4-8.7), rich oxygen, high alkalinity (70-190 mgl^{-1}), phosphate and silicate contents all reflect good productive character of the estuary (Nath,2001). In this estuary Bacillariophyceae dominated over other groups of plankton. Zooplankton was poor. Macro-benthos fluctuated between 259 and 7685 no/m^2. At Baijalpur and Sakkarpura points which received sewage and industrial effluents respectively, aquatic pollution was found. This affects in organic enrichment, low D.O., low transparency, high free CO_2 and high TDS in areas around the outfall. Higher abundance of annelids was recorded.

However, after commissioning of the Sardar Sarobar dam on river Narmada, the ecology of the Narmada estuary may be affected adversely leading to drastic fall in aquatic productivity due to poor freshwater discharge. Hilsa, mullets and prawns are the major fisheries of Narmada estuary.

Estuaries of peninsular India

Godavari estuary in Andhra Pradesh is the major estuary of peninsular India. The tidal effect extends up to 40-50 km upstream from the sea mouth in this estuary. Formation of sand bars in estuary mouth restricts the entrance of tidal water. About 185 species of fishes are available in this estuary.

Adyar, Karuveli, Poniyar, Godilam, Paravan, Vellor, Killari and Coleroon are other estuaries of peninsular India. In all these estuaries tidal effect is felt up to 6-25 km and mullet, prawns, crabs and clupieds are major fisheries.

ECOLOGICAL DEGRADATION AND THEIR EFFECT ON FISH HEALTH

Various sources of ecological degradation have been recorded by National Oceanic and Atomospheric Administration of U.S.A. The four major categories are sewage, industrial effluents, land erosion and agricultural drainage.

Hooghly estuary may suffer from ecological degradation of all possible types. It is estimated to receive1280 million litres of liquid waste per day within a stretch of 92 km between Dumurdaha and Birlapore. Of these 430 million litres is contributed by 96 industries and 850 million litres by domestic and municipal effluents (Sinha, 1994). This liquid wastes contribute 106.1 t of BOD load, 2318.34 t total solids, 1057.3 t of suspended solid and 1261.1 t of dissolved solids. As a result of this pollution load, plankton, bottom biota, and primary productivity of the estuary may be affected at the outfall region which may influence the fish health. Fishes may also be directly affected due to these effluents particularly to the outfall regions. Continuous presence of heavy metals (lead, cadmium, chromium, manganese) in the areas around outfall is detrimental to fish health resulting in diseased and contaminated fish.

Pesticide (DDT) residues have been reported in sediment, fish and molluscs in the industrial stretch around Calcutta, which may produce contaminated and diseased fish and shell fish. Bio-accumulation and bio-magnification of heavy metals in fishes, shrimps, molluscs and crabs have been reported (Sinha,1994).

About 100 industries situated between Bombay city and Kalyan discharge their untreated waste into creeks or streams which ultimately enter into Kalu river estuary making it highly polluted. Acidic condition (pH 1.2) has been found in this estuary converting it into a death trap for fishes. Mirgratory Hilsa, which once formed a good fishery, no longer enter into this river. Bombay Bay also is getting polluted due to the waste from Atomic energy establishments and city sewage so that fish catch around Bombay has declined and so have the oysters that breed in the area.

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Summer School on *Methods of assessment of aquatic ecosystem for fish health care*
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HABITAT STATUS OF RESERVOIRS IN INDIA IN RELATION TO FISH HEALTH

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INTRODUCTION

Reservoirs form the second biggest source next to ponds and tanks, accounting 30% of the inland water resources of India. Water is actually not a constraint for fish productivity in Indian reservoirs.

LIMNO-CHEMISTRY OF WATER IN RELATION TO FISH HEALTH

In tropical Indian reservoirs, temperature is not a limiting factor and diurnal variation of water temperature ranging from 2-4°C and 10-12°C during post-monsoon and pre-monsoon seasons respectively exerts influence on plankton dynamics and availability of nutrients from soil to water phase. A stable thermal stratification with distinctly stratified hypolimnion in temperate, subtropical and some of the tropical reservoirs in India is responsible for higher productivity, as compared to homothermal reservoirs.

Normally, DO is more during pre- and post-monsoon seasons than monsoon in Indian reservoirs due to downpour. DO during March-April in day time is more in some tropical and peninsular reservoirs due to *Microcystis* bloom as observed in Musi reservoir, A.P. There was a mass mortality of *Catla catla* in the 'V' shaped, gorgy Manchanbele reservoir, near Bangalore in June, 2002 due to sudden decline in surface DO concentration below 1.0 mgl^{-1} owing to prolonged anoxic condition at the both meta- and hypolimnion.

As most of the reservoirs studied in A.P were free from macrophytic vegetation being confined to limited littoral zone only (Das, 2000), free CO_2 was in trace or absent at surface waters. In contrast. substantial amount of free CO_2 was found at surface water in the major reservoirs of M.P. The values from 2.0 to 42.0 mgl^{-1} in Bergi, Tawa and Haldi (Unni, 1993) and 16.0 to 30.0 mgl^{-1} in Rihand (Singh, *et al.*, 1980). In reservoirs having shallow depth and large phytoplankton population, the concentration of dissolved CO_2 tend to increase due to planktonic respiration at night as well as death of plankton bloom along with heavy organic load at the bottom as observed in Musi reservoir. In general, most of the Indian reservoirs are free from CO_2 toxicity as sub-lethal effects in fish get prominant when CO_2 concentration ranges from 15-50 mgl^{-1}.

Due to natural buffering capacity of water, Indian reservoirs seldom show acidic reaction. In general, water pH is low during monsoon due to dilution of alkaline substances or dissolution of atmospheric CO_2 with the resultant increase in the subsequent post-monsoon and pre-monsoon periods. Reservoirs under Krishna (8.35-8.87) Godavari (8.61-8.80) and Penna (8.37-8.48) basins generally record higher pH than those in the Cauvery basin (7.47-8.06) due to acidic soil reaction in the later. Reservoirs of M.P. have shown neutral to moderately alkaline water reaction.

Specific conductivity is an index of the amount of water soluble salts present in water. Studies indicate the total concentration of dissolved ions often has wide bearing on the productivity. Specific conductivity value for fresh waters often ranges from 25 to 500 μS cm^{-1}. Except Musi, the other reservoirs of A.P. showed sp. conductance (μS cm^{-1}) in the range 316 to 610 on an average; while maintaining a good productive trend. The major Central Indian reservoirs have lower values of sp. conductivity as compared to A.P. reservoirs *viz*., Gandhisagar (229-285), Bergi (192-221), Sampna (140-150) and Tawa (101-495) with a seasonal maxima of 495 μS cm^{-1} (Unni *et al*., 1998). In Karnataka, the range was 57 (Linganamakki) to 457 (Narayanpur) with the highest value noticed in V.V.Sagar (647 μS cm^{-1}).

Waters with low alkalinity (< 20 mgl^{-1}) have a very low buffering capacity and consequently are very vulnerable to rapid fluctuations in pH especially during rainfall along with phytoplankton blooms which is directly harmful to fish populations. Reservoirs under Cauvery basin show lower values of TA (mg l^{-1}) (25 to 48) as compared Krishna (107-206), Godavari (127-150) and Penna basins (95-125). The low values of TA in CB reservoirs are due to the acidic basin soil of red and lateritic type originating from mountains and forest areas. Dominance of carbonate is least pronounced in CB reservoirs compared to reservoirs under other river basins.

Hardness going below 20 mg l^{-1} develops stress in fishes. Again, very high alkalinity 200-250 mg l^{-1} coupled with low hardness (< 20 mg l^{-1}) results in the rise in pH during afternoon beyond 11.0 and causes death to fish. Cauvery basin reservoirs are said to be of soft water reservoirs (23-68 mg l^{-1} TH) as compared to Godavari (102-124 mg l^{-1} TH) Krishna (102-140 mg l^{-1} TH) and Penna basin (80-91 mg l^{-1} TH) reservoirs. Dissolved inorganic nitrogen in the range of 0.2 to 0.5 mg l^{-1} may be considered favourable for fish productivity In Indian reservoirs, available-N in water is very low in most part of the year except in monsoon and during pre-monsoon. Owing to its quicker utilization by plankters, higher solubility, leaching loss and dentrification, NO_3-N is a limiting factor in Indian reservoirs.

Phosphorus is considered to be the most critical single element in maintaining aquatic productivity. A significant correlation was found with total-P out of 40 limno-chemical parameters (Reynold, 1998). A direct correlation was observed in some Indian reservoirs (Govind, 1963; Mathew, 1969). Pearshall (1932) has pointed out that in English lakes BGA are able to grow in minimal quantities of phosphorus and nitrate. This appears to be the case in Konar, Nagarjunasagar and also in other Indian reservoirs where *Microcystis* occurs predominantly. In Indian reservoirs, except for a shorter period during monsoon, availability of phosphate is of very low order and rarely exceeds 0.1 mg l^{-1}. Lack of these nutrients in water does not seem to be indicative of low productivity particularly in reservoirs free from pollution because of their rapid turn over and quick recycling.

STRATIFICATION VIS-A-VIS AQUATIC HEALTH

In tropical Indian reservoirs, thermal stratification may not be stable and prolonged as well as degree of thermoclinity is lesser in comparison to temperate reservoirs but definitely it influences tremendously even if for a shorter period Limnological importance of thermal stratification is of manifold as in thermally stratified water bodies the water above (epilimnion) and below thermocline (metalimnion & hypolimnion) do not mix up rendering locking up of nutrients at the bottom. High bottom temperature prevailing in deep tropical reservoir facilitates rapid decomposition of organic matter and in turn accelerating the process of nutrient release. No stable thermal stratification was noticed either in A.P. or in Karnataka reservoirs. Even in deeper Nagarjunasagar and Srisailam reservoir the temperature usually declined by 3 - 6°C from surface to bottom in pre- and post-monsoon periods. In shallow reservoirs, it was 1°C in Wyra and Singur, 1.5°C in Musi, 2.2°C in LMD, 2.5°C in Kadam, 2.8°C in MPD and 1.8°C in Somasila during summer. In Karnataka, the deep reservoir like Bhadra has shown only 4°C difference in summer. But in Harangi, thermocline was noted in summer between 4 and 9 m depth with a clear demarcation of epilimnion and hypolimnion. In monsoon and post-monsoon almost, homothermal conditions prevailed.

Depth profile studies made in some north Indian reservoirs indicate presence of thermal stratification during summer with three distinct phases like epilimnion extending upto 6 m in Getalsud reservoir in Bihar, (mean depth 4.52 m & area 3400 ha at FRL), thermocline at metalimnion (between 7 and 12 m) and hypolimnion below 12m (Pal, 1979). The temperature drop in the thermocline region was 25.3°C at 7m to 20.8°C at 11m.

Thermal stratification with a fall in metalimnion temperature of less than 1°C has been observed in many tropical lakes (Lewis, 1973; Taylor and Gebre - Mariam, 1989). Same was true in case of some reservoirs in the upper peninsular reservoirs of south Bihar, Madhya pradesh and Gujarat which undergo transient phases of thermal stratification during summer.

Thermal stratification is followed by chemical stratification and mostly occurs in pre- and post-monsoon periods in A.P. reservoirs with steeper oxycline in LMD, Kadam, MPD and Somasila and could be categorised as productive reservoirs. In Musi, almost anoxic condition prevailed at 8 m depth due to organic load. Manchanbele exhibited prolonged anoxic condition after 6 m depth set in (1) March to June and (2) Sept & Oct in 1999-2000.

In Karnataka, the strength of oxycline in water column, especially during pre- monsoon is a clear indication of richness of bottom deposits and a dependable index of reservoir productivity. However, in shallow reservoirs, strong wind and wave actions in summer disrupt the stratification making it unstable. Strong oxycline was noted in Manchanbele and Harangi with anoxic condition at hypolimnion. Near anoxic condition at the bottom was also noted in Nugu, V.V.Sagar and Linganamakki.

Thus, the productive nature of a reservoir is indicative in its chemical as well as thermal stratifications and to have a productive reservoir the deep bottom water (if drawdown of water below dead storage level is not voluminous) of the reservoir basin is to be replaced at least once in four/five years and the physico-chemical determinants of productivity will automatically be altered locally by the ongoing biological processes during the intervening periods.

STATUS OF POLLUTION VIS-A-VIS FISH HEALTH

Increasing pace of urbanisation coupled with industrialization, poor environment management in the catchement make the reservoirs vulnerable to ecodegradation. In addition to direct discharge of industrial, municipal, thermal and agricultural wastes, the varying degrees of pollution load carried by upstream rivers is also getting accumulated in the reservoirs rendering the habitat in certain cases unsuitable to fishes and fish food organisms. The ability of a reservoir to assimilate waste load depends primarily on the size and shape of water area, capacity, inflow & outflow, flushing rate, catchment ecology as well as the quantum and characteristics of wastes emptied into the reservoir. Evidently, the self purification in reservoir ecosystem is, to a great extent, a function of morpho-hydro-meteorological conditions.

Siltation

Improper catchment management results in high rate of siltation load affecting biological productivity in the reservoir to a predominant extent. It is the prime basic factor in diminishing the water holding capacity of the reservoir and reducing its life span thus affecting the biota by blanketing the periphytic and benthic communities, hampering the natural recruitment by destroying the breeding grounds rendering retardation of overall production of the ecosystem.

Suspended silt particles carried through inflow is generally precipitated in the lotic sector of reservoir due to gravity. At times, it causes heavy fish mortality by clogging the gills.

Domestic and Industrial wastes

Most of the Indian reservoirs are not polluted by Industrial effluents because the major locations of the Industries are around down stream of river.Instances of ecosystem degradation and fish kill due to industrial effluents from chemical plants, textile and rayon mills, dyeing industries, paper mills, iron and steel foundries, heavy engineering plants etc. have been well documented in some Indian reservoirs.

Thermal pollution

Four super thermal power plants under private sector and one under public sector are getting the supply of water for cooling their different operational units from Rihand reservoir. Adverse effects of heated discharge on aquatic organisms of the ecosystem including mortality of fish and decreasing rate of aquatic life within 50 km of the discharge points due to high temperature of the effluent (46 - 52° C) has been reported.

Satpura thermal power plant located on the site of Sarni reservoir of Betul district (M. P.) releasing its hot effluents into the reservoir which is 5 to 7°C more than the ambient temperature enhances the growth rate and maturity of IMC.

Though fish can withstand a temperature fluctuation of 8 to 10°C, the hot water exerts negative effect on plankton and benthic communities. However, the reproduction of fish is affected due to deposition of fly ash in the marginal areas of the reservoir/river which is their breeding ground by forming mats known as 'blanketing effect.' This prevents the nutrient supply from the bottom sediment to water phase and ultimately complete erradication of bottom macrofauna takes place.

HEAVY METALS AND PESTICIDES

Among toxic heavy metals, Zn, Pb, Hg, As, Cd, Cr are worth mentioning as they exert a significant influence. Bioaccumulation of zinc (mg l^{-1}) to the extent of 4393 & 1710; 2690 & 1186 and 1929 & 251 in the gills and flesh of fishes from K.R.Sagar (Karnataka), Bhavanisagar (Tamilnadu) and Orathupalayam reservoir (Tamilnadu) respectively have been reported (AUW). A significant load of Cu (1668 mg l^{-1}) and Pb (203 mg l^{-1}) in the gills of *G. giuris* of K. R. Sagar have been noted. A substantial load of Hg in the effluents of Soda manufacturing "Kanoria Chemicals" discharged into the Rihand river has been reported (Agarwal and Kumar, 1978) posing serious threat to biotic communities. Macrophytes absorb a considerable amount of heavy metals, particularly Zn, Cu and Hg, both from sediment as well as water phase thereby reducing their load in the ecosystem. Pollution due to pesticide residues in reservoirs have not been well studied.

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Summer School on *Methods of assessment of aquatic ecosystem for fish health care*
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ECOLOGICAL STATUS OF WETLANDS IN INDIA AS SUITABLE FISH HABITAT - CASE STUDIES

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INTRODUCTION

The term wetlands encompass a variety of inland aquatic habitats with characteristics unique to them and of fundamental significance to plant and animal life including fish. A diverse range of water bodies comes under it e.g., marsh, fen, peatland or water impoundment - existing naturally or created artificially, permanent or temporary, in stagnant or flowing state, qualitatively designated fresh, brackish or salty etc. including marine water areas, the depth of which at low tide does not exceed six meters. This definition gives us a broad view, including virtually all types of fresh and brackish water body whether static or flowing and some parts of sea as well. In fact, there are several other definitions available depending upon the purpose of the work concerned. In our country, wetlands are generally found in potamon reaches of major rivers like, Ganga and Brahmaputra. Variation in rainfall over the year, receiving heavy downpour during south-west monsoon causes overspill from the main channel in potamon reaches leading to inundation of huge lateral flat plains and these areas of submergence are called floodplains. These areas may or may not retain water all round the year.

The river upon entering the plain frequently changes its course leaving behind its trace, which is generally horseshoe shaped and is called ox-bow lake. So, ox-bow lakes are generally ancient bend of river, which is now cut off from the main channel and contains standing water.

WETLAND RESOURCE

These diversified ecosystems harbour one of the richest fish diversity. Our country is blessed with ca. 2.02 lakh ha. of such type of fish habitat spreading over the states Uttar Pradesh, Bihar, West Bengal, Arunachal Pradesh, Meghalaya, Manipur and Tripura. They are called by various names in different states (Table1).

Table 1. Local name, area and distribution of wetlands in India

States	Distribution (districts)	River basins	Local names	Area (ha)
West Bengal	24-Parganas, Nadia, Murshidabad, Malda, North and South Dinajpur, Burdwan	Ganga (Bhagirathi, Hooghly), Jalangi, Ichamati, Padma, Matla,Mahananda	*Beel* and *Baor*	42,500
Bihar	Muzaffarpur, East and West Champaran,Samastipur, Sitamarhi	Gandak and Koshi	*Mauns and Chau*	40,000
Assam	Brahmaputra and Barak valley districts	Brahmaputra and Barak	*Beel*	1,16,000
Arunachal Pradesh	East Kameng, Lower Subansiri, Dibang valley, Lohit and Tirap	Kameng, Subansiri, Dibang, Lohit, Dihing and Tirap	*Beel*	2500
Manipur	Imphal, Thoubal and Bishnupur	Iral, Imphal and Thoubal	*Pat*	1650
Meghalaya	West Khasi hills, East and West Garo hills	Someshwari and Jinjiram	*Beel*	213
Tripura	North, South and West Tripura district	Gomti	*Beel*	500

WETLAND ECOSYSTEM AS FISH HABITAT

All freshwater bodies including wetlands are dynamic systems involving continuous interaction not only between organism and physico-chemical conditions, but also the plants and animals interact and may influence both the habitat and one another. Therefore, it becomes pertinent to have a first hand knowledge about the morphology and their physical, chemical and biological features with a view to understand the ecological status of wetlands as fish habitat.

Natural depression/lake like wetlands

These are generally found in the floodplains of Manipur where the flat low-lying valleys accumulate surface run-off from surrounding hills and look like a lake. A good number of natural depression - type wetlands which receive water from the overspill of main river and retain for a considerable period of time and sometimes round the year are found in northern part of West Bengal, eastern part of Uttar Pradesh, in Brahmaputra valley of Assam and parts of Bihar. Water cover starts shrinking with the cessation of monsoon. Wetlands of this category are generally shallow, irregular in shape and support productivity.

Ox-bow lake

These horseshoe shaped wetlands are cut off river meander having relatively narrow shape and shallow depth with a deep pool at meander scroll. The lotic environment of such wetlands during monsoon become lentic with the approach of summer when the link channel with the parent river maintain a feeble or no flow of water. Many of the wetlands in northern Bihar, southern Bengal, Barak and Brahmaputra valleys are typical examples of ox-bow lake.

PHYSICAL ENVIRONMENT

Wetlands being flat and shallow allow transmission of light up to or near to bottom leading to a deeper euphotic zone coupled with greater interaction between water and sediment. A generally warmer temperature regime also favours higher rate of productivity. Barring the monsoon months when silt laden catchment run-off prevents light penetration, transparency is very high in wetland ecosystem. Similarly, relatively shorter duration of winter allowing longer warmer period provides favourable condition for higher aquatic productivity.

During summer the water spread shrinks to a large extent exposing the bottom to solar radiation and aerobic oxidation. This reduces the harmful effect on the biota by rapid deposition of organic matter of both allochthonous and autochthonous origin.

Annual flooding and subsequent resumption of fluviatile condition also facilitates the seasonal removal of accumulated metabolites from the ecosystem and thereby making the system pristine and habitable.

CHEMICAL ENVIRONMENT

Soil

Soils of wetlands located in Bihar and south Bengal are generally alkaline in nature, while the soils of north Bengal and whole of northeastern states were found to be acidic in reaction. Texturally, wetlands soil is sandy with greater degree of variation in silt and clay content. However, the sand percentage in the soils of Assam and Manipur is comparable to other states (Table2).

Organic carbon, an indicator of productivity varies widely from 1 to 17% among the states depending upon the intensity of macrophyte infestation and access of allochthonous input. Soil nutrient, particularly total nitrogen is available in moderate to good concentration. However, another important plant nutrient, phosphorous in wetland soil is generally poor.

Table 2. Soil and water quality of wetlands in different states

Parameters	Centres			
	Bihar	West Bengal	Assam	Manipur
Soil				
Texture				
Sand (%)	69-86	74-87	76-93	80-90
Silt (%)	9-23	3-14	4-17	4-14
Clay (%)	2.5-21	4-19	2-18	4-6
pH	7.3-7.7	4-7.8	4-6	4.3-5
Org. Carbon (%)	1.8-7.9	1.4-7.8	4.8-14.5	3.6-3.9
Total N_2 (%)	0.14-0.42	0.1-0.6	0.08-0.8	0.62-0.79
Available P (mg $100g^{-1}$)	0.02-1.4	tr-3.0	0.4-2.7	3.4-4.0
Water				
pH	7.2-8.7	6.8-9.0	6-8.2	6.8-7.2
Dissolved O_2 (mg^{-1})	3.2-9.2	6.0-12.5	4-13.6	4.8-6.5
Free CO_2 (mg^{-1})	nil-7.4	nil-16	1-19	7.5-11.4
Total alkalinity	68-224	27-212	14-227	34-43
(mg^{-1})	137-410	55-827	18-354	65-75
Sp.Conductivity(µm	tr-0.27	tr-0.56	tr-0.08	0.03-0.08
ohs)	tr-0.06	tr-0.45	tr-0.04	tr-0.008
NO_3-N (mg l^{-1})	7-54	9-248	2-34	4-7.5
PO_4-P(mg l^{-1})	2-19	7-204	1.2-21	5-9
Ca^{++}(mg l^{-1})	3.1-43	1.6-12		1-3.5
Mg^{++}(mg l^{-1})				
SiO_3(mg l^{-1})				

Water

Chemically, wetlands water is generally near neutral to alkaline which is favourable and indicative of good productivity. Dissolved oxygen, another determinant of good habitat, is highly variable with space and time. Fairly good amount is available throughout the water body round the year, particularly during daytime, which is exceedingly favourable for the survival and growth of fishes. However, during night oxygen concentration gradually becomes low and reaches minimum just before sunrise in shallow macrophyte choked area. Nevertheless, favourable concentrations still exist in macrophyte free areas where oxygen sensitive fishes migrate to avoid stress. Diurnal variation in CO_2 concentration is a common feature in all wetlands. Other chemical parameters like sp. conductivity, total alkalinity are highly favourable for the growth of fish food organisms. Concentration of various other plant nutrients like NO_3 N, cations (Ca^{++}, Mg^{++}), anions (Cl^-, SIO_3^-) are favourable for productivity, except the limiting nutrient PO_4^{--} -P (Table2). The source of these nutrients is the allochthonous import through surface run-off from catchment areas.

BIOTIC COMMUNITIES

Macrophyte

Generally shallow ecosystem like wetlands with greater euphotic zone coupled with huge load of plant nutrients encourage the massive growth of higher aquatic plants. Distribution of vegetation in wetlands can be grouped into distinct zones. Amphibious (*Ipomea*, *Ludwigia*) and emergent (*Cyperus*, *Scirpus*, *Phragmitis*) plants occupy marginal areas. Shallow littoral zone up to 2-2.5 m depths are occupied by submerged (*Hydrilla, Vallisneria, Ceratophylum, Trapa, Najas, Chara*) and rooted floating (*Nymphaea, Potamogeton, Nelumbo and Euryle*) plants, while free floating weeds (*Eichhornia, Azolla, Pistia, Salvinia, Lemna*) form extensive mats in the open water and their distribution is influenced by wind and current action.

Phytoplankton

Macrophytes exert allelopatric influence (space, nutrient and shading effect) over the growth of this microscopic producer community. Phytoplankton count depends upon season, turbidity, current and the variety and intensity of macrophyte cover. However, the average phytoplankton count is very poor in wetlands ecosystem ranging from 60-1800ul^{1} .Plankton count is generally higher in summer compared to winter and monsoon.

Consumer

The first level of consumer, zooplankton, is still poorer in count in wetlands. A spatial and temporal distribution, depending upon season (temperature, turbidity), dissolved oxygen, macrophyte cover, is noticeable in wetlands. Higher density is, however, seen associated with the zone of submerged plant and fringes of floating macrovegetation than the open water. The reason may be, zooplankton graze upon microbes associated with the processing of detritus.

The dominant group of consumers in the wetlands ecosystem is the macrophyte-associated fauna. Moliusks dominate this category followed by oligochaetes, insect nymphs and many species of crustaceans. These organisms play a vital role in detritus processing which is very important in the wetlands food web. Benthic organisms are also an important group in wetlands ecosystem. *Tubificidae, Chironomidae*, insect nymphs and molluscs form the benthic community

WHY WETLANDS IS A PREFERRED FISH HABITAT ?

The ecology of wetlands is highly diversified satisfying the basic needs of many of the fishes, drawn to this ecosystem as their preferred habitat. These basic needs are ideal spawning site for reproduction, suitable shelter for refuge and bountiful food to graze upon.

Food assurance

The richness and variability of the wetlands habitat provide a wide range of food organism and substrate. The major sources of food are detritus (vegetable and animal debris, leaf litter and associated communities), benthic community (mud and associated flora and fauna), plankton community (phyto and zoo), vegetable matter (submerged, floating or emergent, including filamentous algae), animal matter (insects, beatles, fleas and worms), epiphytic organism, smaller fishes and crustaceans.

Spawning site

Shallow depth, sandy bottom, feeble current and turbid water are ideal place for spawning for many a variety of fishes. The connecting channel which gets filled with swelling flood-water resuming link with the parent river facilitates riverine fishes to migrate into wetlands for spawning. The resident wetlands fishes which require short distance lateral migration also finds access to neighbouring breeding ground for the release of their gonadal material. Indian major and minor carps, *Gudusia chapra*, *Notopterus chitala* are some of the examples.

Nursery ground

Feeble or no current allows the eggs to hatch out the spawn instead of being drifted away into unfavourable environment. The run–off from the catchment already filled the floodplain with huge load of allochthonous nutrients to be converted into food organisms for the young ones. Plenty of macrophyte associated fauna and flora are favoured food items by the young ones of many fishes. The hydrophytes also provide a hiding place for these newly born tiny creatures.

Secured shelter

The wetlands vegetation, in one hand offers ideal shelter and therefore, many fishes particularly, minnows prefer this place to save themselves from being preyed upon. But, on the other hand, predatory fishes find the place ideal for positioning/hiding themselves from prey organisms and avoid being an easy victim.

DYNAMIC NATURE

The variations in hydrology with season bring changes in habitat also. Fishes preferring current and depth migrate to wetlands when it becomes lotic and deeper during monsoon. Other fishes gather and proliferate in static and shallow water when the ecosystem becomes lentic with the end of monsoon. However, in open *beels*, fishes favouring riverine habitat are dominant. Therefore, faunal diversity is more in closed *beel*, which experiences both lentic and lotic environment at different periods of the year.

The distribution of dissolved oxygen within the aquatic system is one of the main factors influencing the distribution of fish. Diurnal variation and distribution of this life supporting gas in wetlands ecosystem is unique. In shallow and vegetated zone of the wetlands, dissolved oxygen concentration is uniformly distributed over the water column and very high (16-18*ppm*) during daytime, while it reaches very low (1-1.8 *ppm*) in night. Whereas, in meander scroll, where water level is high (8-9 m) and euphotic zone is only 1.5-2m, dissolved oxygen concentration is found to be highly variable. Beyond 3.5m depths, the water column is devoid of oxygen. During summer the surface water temperature coincides with ambient air temperature (32-35°C), therefore becomes very hot. Fishes living in this zone migrate to comparatively comfortable vegetated zone where oxygen level is high and temperature is low due to shading. Further, during night, when oxygen reaches low in vegetated area, fishes migrate to vegetation free clear zone where oxygen level in the surface water is still high.

ICHTHYO-DIVERSITY OF WETLANDS

Survey of wetlands in different states revealed that fishes belonging to a total of 18 families are common inhabitants of this ecosystem. A pooled list of fishes recorded in different wetlands of India is given below. However, the list is not exhaustive (Table 3).

Table 3. Fishes inhabiting wetlands

Species
Catla catla, Labeo rohita, L. calbasu, L. gonius, L. bata, Cirrhinus mrigala, C.reba, Puntius sarana, P.ticto, P.sophore, P.conchonius, Osteobrama cotio, Oxygaster bacaila, Esomus danricus, Gara gotyla, Rasbora daniconius, Chela labuca, Danio devario, Salmostoma phulo, Amblypharyngodon mola, Danio devario, Barillius bola, Aspidopaira morar
Channa marulius, C.straiatus, C.punctatus, C.gachua
Mastacembelus armatus, M.puncalus, Macrognathus aculeatus
Anabas testudineus, Colisa fasciatus, C.lalia, C.chota
Mystus tengra, M.cavasius, M.vittatus, M.aor, M.singhala
Clarias batrachus
Heteropneustes fossilis, H.microps
Ailia colia *Wallago attu, Ompok bimaculatus*
Amphipnous cuchia
Notopterus notopterus, N.chitala
Gudusia chapra, Setipinna phasa
Nandus nandus, Badis badis
Glossogobius giuris
Chanda ranga, C. nama *Lepidocephalus guntea, Botio dario* *Xenentodon cancila* *Tetradon cutcutia*

ENVIRONMENTAL STATUS OF SEWAGE-FED AND ESTUARINE WETLANDS IN RELATION TO FISH HEALTH

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INTRODUCTION

Use of domestic wastes to fertilize water bodies, *e.g.*, ponds, tanks etc., for piscicultural purposes, is an age old practice. The wetlands, locally known as **bheries**, situated in the east of Kolkata City constitute important Fishery resources of West Bengal covering an area of around 40000 hectares. Of this, an area of slightly less than 4000 ha adjacent to the Kolkata eastern fringe constitute the famous East Kolkata Sewage-fed Fisheries. Freshwater sewage-fed wetlands situated in the Kolkata spill area, in the bed of the defunct Vidyadhari river are exploited for growing freshwater fishes and prawn and is a unique example of aqua crop production using Kolkata city sewage. The estuarine wetlands situated below the Kulti lock gate have water salinities of different magnitudes and are accordingly classified as low, medium and high saline wetlands.These freshwater and saline wetlands situated in the North and South-24 Parganas districts of West Bengal contribute substantially to the total fish production of the state. Traditional cultural practices are adopted for growing fish and prawns in these wetlands by the farmers. The freshwater sewage-fed bheries draw raw sewage from the sewage drainage channel while the low-saline sewage-fed bheries just down below Kulti lock gate receive diluted saline water mixed sewage. The low-saline bheries drawing water from other estuaries, e.g., the Ichhamati estuary, do not have any sewage impact . The medium and high-saline wetlands, drawing water from different estuaries virtually are free from any sewage effect. The most important aspect of all these systems is that they receive water directly from the sources without any pre-treatment. Characteristic features of sewage-fed and non sewage-fed estuarine wetlands with particular reference to fish health are depicted below.

CLASSIFICATION OF BHERIES

Freshwater bheries

The Kolkata freshwater sewage-fed bheries can be sub-divided into three different categories depending upon the distance from the initial point of discharge and the organic load.

a) The wetlands that receive concentrated sewage.
b) The wetlands that receive moderately diluted sewage and
c) The wetlands that receive diluted sewage

The Saline Bheries

Depending upon the water salinity, the saline wetlands may be classified (Saha, *et.al.*,1986) as:

a) *Low-saline bheries* where the salinity never exceeds 10 ppt.
b) *Medium-saline bheries* where the salinity does not generally rise above 20 ppt. and
c) *High -saline bheries* where water salinity may even exceed 30 ppt.but never drops below 6 .0 ppt.

CULTURE METHODS

Freshwater Sewage-fed wetlands

The wastewater pisciculture practised in Kolkata wetlands utilizes sewage effluents rich in nutrients for fish culture. These wetlands are generally shallow having water depth ranging from 50 cm to 1 m. The wetlands are stocked heavily with Indian major carps, exotic carps , minor carps and tilapias. There is, however, always some auto stocking of tilapias since it is not possible for the farmers to completely remove tilapias from the system. After the nursery phase the larger fishes are stocked in the bheri. Initially the rearing is done for a short period and harvesting is done when the fishes grow to 150 - 350 g. Table size fishes above 500 g are rarely encountered in the catch. The culture system in the bheries can be called a " continuous stocking and harvesting system" in which the stock is continuously replenished after harvesting.

Saline wetlands

The tidal water from estuaries are drawn into the bheries during full or new moon days when the amplitude of the tide is high . The ingress water enters through the inlet which is guarded by thick meshed nets to prevent entry of large carnivorous fishes . A sluice box is fitted at the inlet. In the saline bheries the inlet and outlet points are the one and the same generally. In larger bheries the inlet-outlet channels facilitate quick filling and draining of water. The draining of water is done during low tide. Though the exchange of water is normally done fortnightly, sometimes the water is retained for a longer period of one to two months. The water exchange becomes necessary to keep the environment conducive for the cultivated fishes and prawns besides ensuring a continuous supply of natural food to them. Wetlands in the high saline zones are now practising selective stocking in addition to natural stocking.

ENVIRONMENTAL STATUS

Freshwater Wetlands

The dissolved oxygen levels in sewage-fed wetlands is a matter of great concern. During mid day the DO level sometimes exceeds 20 mg l^{-1}, particularly in the strong and medium sewage-fed wetlands. The freshwater sewage-fed impoundments generally have a sizeable crop of phytoplankters and the high level of DO results from high photosynthetic activities. This leads to a drastic depletion in the DO level at night and also during cloudy overcast. With such drastically reduced DO level (sometimes to traces) at mid-night the fishes suffer from respiratory stress. This may also lead to stress from other factors which the fish might have tolerated under good DO levels. Sometimes the super saturation with oxygen may also adversely affect the growth and survival of fishes.

The total alkalinity in these water bodies generally remains high (may reach 375 mg l^{-1}). The water pH ranges from 7.2 to 8.6. High alkalinity with high pH renders the water suitable for higher fish production. These wetlands are rich in nutrients, NO_3 -N and PO_4 - P are present in good quantities.The gross primary production in these water bodies is generally high compared to that of the low-saline sewage-fed impoundments. Plankton concentration in these water bodies is generally high. The numerical abundance may be 200 u l^{-1} to 17000 u l^{-1}. The zooplankters sometimes outnumber the phytoplankters. . The wetlands are generally rich in macro-zoobenthos, the gastropods being the principal constituents. The macro-zoobenthos is principally constituted of *Bellamya sp.,Thiara sp., Indoplanorbis sp., Lymnya sp.,* Chironomid and other dipteran larvae, Odonate nymphs, and annelids. The high abundance of natural food in such environments provides sufficient nutrition to the stocked animals and the possibility of fishes suffering from malnutrition is less but over stocking (to the tune of 60000 ha^{-1}) may create health problems.

Saline wetlands

The salinity of water in the low saline wetlands ranges between 0.21-10.49 ppt. as observed during 1999-2001. The salinities of the medium and high saline zones are observed to range from 0.21-14.43 and 1.84-24.95 ppt. in some wetlands studied recently. The salinity in some of the high saline bheries even exceeds 33 ppt. The total alkalinity in the saline wetlands remains within the normal range and is generally found to be highest in the high saline zone. PO_4-P and NO_3-N contents have been found to be higher in the low and medium- saline bheries studied recently but higher phosphate values are generally obtained from high saline bheries. Primary productivity has also been observed to be higher in the low-saline zone, particularly in those which have sewage impact. The pH of water ranges from 7.16-9.01. DO in all the *bheris* is conducive for pisciculture. Diurnal studies indicated that the DO in the saline *bheries* do not deplete to traces or nil as is found in freshwater sewage-fed systems. The free CO_2 is generally found to range between nil and 48 ppm in different wetlands . These water bodies are also shallow and the temperature problem is same as that of freshwater wetlands. The plankton concentrations in these wetlands have been observed to be lesser than those of the freshwater sewage-fed ones. Though qualitatively the macro-zoobenthos differ from the freshwater zone quantitatively it is almost alike.

FISH HEALTH AND DISEASE

The high pH and DO levels generally produce hygenic atmosphere and reduce the possibility of diseases both in freshwater sewage-fed and saline bheries. Heavy loss of fish crops due to diseases is not encountered except the white-spot disease in tiger shrimp in the saline zones.

Ulcerative diseases have been found to occur during post-monsoon and early winter months in the freshwater and low-saline zones and *Channa spp., Cirrhinus mrigala, Labeo bata, Cyprinus carpio, Mystus spp., etc* are observed to be the species mainly falling a victim. Fish louce (*Argulus sp.*) and the anchor worm (*Lernaea sp.)* are also observed in the freshwater sewage-fed zone during late summer/pre-monsoon months. Facultative parasites like fish leech (*Piscicola sp.*) and insects, Helminth, protozoal and bacterial diseases are rarely found. If the heavy metal contents in the sewage are removed as insoluble sulphides in presence of H_2S during the flow of raw sewage down the canal fish health can be maintained. Excess of Zn, Cr, Fe etc., are also removed from the system as insoluble sulphides or hydroxides in presence of ammonia or H_2S. The same authors also state that the count of pathogenic bacteria is drastically reduced by toxic actions of metallic and non-metallic compounds during the passage of sewage towards the wetlands. Excess algal bloom may cause various problems besides, mortality due to gill chocking. The farmers employ tilapias as bio controlling agents to control excess growth of algae.

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BIOLOGICAL MONITORING TOOLS FOR AQUATIC ECOSYSTEM AND FISH HEALTH

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INTRODUCTION

Our interest in the environment, from the fisheries point of view, stems from the premise of harvesting maximum sustainable yield from water bodies. Production of harvestable biological material from an ecosystem is dependent on a very complex community metabolism process in which the solar energy trapped at primary producer level passes through different communities of organisms, before a fraction of it finds its way to the harvestable organisms. Thus, the habitat constraints that have no direct bearing on fish can also impair the fish productivity. Conservation of the whole ecosystem, rather than the specific economic species, is therefore imperative in preserving the biological wealth in inland water bodies. Fisheries development in inland water bodies is becoming increasingly difficult due to the environmental constraints posed by the anthropogenic stresses. Some of these stresses have been recognized as *over-abstraction of water, construction of dams and barrages, siltation of reservoirs and riverbeds* and *pollution due to urban, industrial and agricultural runoff.* The resultant stresses exerted by these developmental processes culminate in mortality of fish and fish food organisms, destruction of breeding grounds and impediments in migration, instances of which are well documented.

EFFECTS OF WATER QUALITY ON FISH AND ITS ENVIRONMENT

Delineation of habitat constraints, based on their impact on the biotic communities, becomes difficult due to their synergistic effect on the ecosystem. The industrial and municipal effluents are as divergent as they are obnoxious. There is a host of harmful chemical toxicants emanating from different industrial units - the nature of substances varies depending on products, production processes and materials used. Similarly, agricultural runoff carries a heavy load of non-biodegradable pesticides. Domestic wastes also contain a variety of chemicals, detergents and organic load. Unfortunately, the impact of these toxicants on the biotic communities is very complex and our knowledge in this regard is grossly inadequate. It is not even possible to prescribe safe limits in respect of any of the chemical pollutants. In fact, the practice of prescribing safe limits is no longer valid as the emphasis now is shifted to a balanced ecosystem rather than to prevent fish kills. The validity of applying the existing safe concentration limits is rather limited, as they are determined under controlled laboratory conditions. In the laboratory, fishes are fed *ad libitum*. They are treated prophylactically, if needed; there are no predators; no competition for spawning areas; and no exposure to extremes of natural water quality.

The effect of 2,4-D on fishes adequately illustrates the gradual unspectacular decline in the quality of aquatic life. Study conducted at the Bureau of Commercial Fisheries Pesticide Laboratory at Gulf Breeze, Florida, indicated that fish exposed to 2,4-D for 1 to 5 months grew and survived at par with the control animals. However, the exposure apparently lowered the general resistance to a microsporidian parasite and a massive invasion of the central nervous system of the fish resulted. More sensational effects like fish kills are easily detected, publicized and corrected and such corrective measures may lead to a sense of complacency towards the chronic, sub-lethal problems which require much more social attention.

Similarly, physiological response of organisms to organic pollution is less understood. More basic studies are required. For instance, it is not clear whether survival in low oxygen phase is affected through better extraction of oxygen or effectiveness to function in low oxygen at cellular level. While dealing with the multiple effluents, not only the specific knowledge on the effluents but also knowledge of the potential chemical and physical changes is imperative. In addition, we must comprehend the potential of combined stress on aquatic life, the effect of which cannot be explained on the basis of a single contaminant. The problems involving pH and metal toxicity are common knowledge where toxicity increases due to decrease in pH values. To protect the ecosystem from gradual degradation, we must provide criteria that will protect the entire life cycle of the desirable species as well as the food chain on which these species depend.

BIOLOGICAL MONITORING OF POLLUTION

Environmental pollution is essentially a biological phenomenon inasmuch as the basic concern is the quality of life of humans or other living things. Nevertheless, despite its essential biological character, environmental quality, especially the water quality, is often understood in terms of chemical parameters. The continuous deterioration of water quality by anthropogenic activities may change rapidly the chemical properties in type and intensity, necessitating appropriate bio-monitoring. One of the most striking advantages of biological monitoring of water quality lies in the fact that it can integrate many different environmental factors over a long period of time. It can detect subtle changes which have a more dangerous ill effect over a period of time, compared to some acute toxicity. Many a times a fish kill due to some local impacts gets sensationalized for publicity. The chronic effects which are more dangerous are not getting attention. On many occasions, chemical monitoring becomes ineffective, either due to combined effects of pollutants or the concentrations being too low to be detected. In determining water quality in relation to fish, biomonitoring assumes greater significance, as it provides a direct measure of the biological qualities conducive to fish productivity. Relative merits of bio-monitoring among various water uses are depicted in Table 1. Normal pattern of induced changes in community structure are as given in Table 2.

Table 1. Relative value of biological indicators in assessing water quality

Use	*Utility*	*Fidelity*	*Reliability*	*Sensitivity*	*Rapidity*
Amenity	Poor (Algae only)	Poor	Good	Good	Good
Fishing	Excellent	Excellent	Good	Good	Good
Recreation	Poor (pathogens only)	Moderate	Moderate	Excellent	Poor
Irrigation	Poor (pathogens only)	Moderate	Moderate	Excellent	Moderate
Raw and treated	Moderate (pathogens only)	Good	Good	excellent	Moderate

Table 2. Biocoenotic responses of indicator value

A	The appearance or disappearance of individual species from a community, *i.e.,* a change in species list
B	A reduction in the numbers of species or taxa present in the community i.e., a reduction in the diversity
C	A change in the population of individual species within the community
D	A change in proportional species composition of the community

Biocoenotic responses of communities and populations to habitat changes are not uniform; some organisms being more sensitive to changes than others. Biological monitoring is basically grouped under two categories *viz., Eco-taxonomic* and *physiological-biochemical methods* (Fig. 1).

THE ECO-TAXONOMIC METHODS

Eco-taxonomic methods utilize the taxonomic affiliations of organisms to know the status of a water body. They include indicator species, which are generally the pollution tolerant species (Table 3).

Benthic invertebrates as indicator species

In flowing waters, it is those organisms, which maintain their position in the river, remaining either at the bed or fixed substrata, that best reflect the general quality of the water. The main determinants and their interaction with benthic communities in river are shown in Fig. 2. Any change in water quality will induce corresponding changes in the benthic biocoenose at a given station in the river with quality. The overall effects of increasing organic enrichment on benthic invertebrate community of riffle are illustrated diagrammatically in Fig. 3.

Bacteria as trophic state index

It has been estimated that due to effluent loadings, nearly a thousand different organic compounds can be detected in the aquatic systems. For decomposition of these dissolved substances, bacteria and fungi play an important role. Among fungi, specific filamentous forms are important in polluting rivers, while yeasts may be important in sewage treatment plants. Among different bacterial types, saprophytic bacteria have high metabolic activity and are reported to breakdown proteins and carbohydrates very quickly. Their higher density reflects the degradable organic substances present in the water. The saprophytic communities are initially high when they are eliminated through grazing by protozoans, rotifers and daphnids in self-purification stretches. Various bacterial indices have been developed to give general idea of water quality.

Table 3. Characteristic indicator taxa for different water qualities

	Polysaprobic (grossly polluted)	αMesosaprobic (polluted)	βMesosaprobic (mildly polluted)
Bacteria	*Spirillum* *Streptococcus* *Beggiatoa* *Spharotilus*		
Fungi	*Fusarium*		
Algae	*Euglena* *Oscillatoria* *Phormidium*	*Ulothrix* *Stigeoclonium* *Oscillatoria*	*Cladophora* *Scenedesmus* *Ulothrix* *Pediastrum*
Ciliates	*Paramecium* *Vorticella* *Colpidium*	*Chilodonells* *Urotricha* *Cyclidium*	*Aspidisca* *Cinetochilum* *Litonotas*
Macrophytes	*Eichhornia* *Scirpus* *Phragmites*	*Juncus* *Typha* *Lemnas*	*Potamogeton* *Ceratophyllum* *Phalaris*
Invertebrates	*Chironomus* *Limnodrilus* *Tubifex* *Heptagenia*	*Nais* *Hydropsyche* *Baetis* *Athripsodes*	*Ablabesmyia* *Aelosoma* *Brachyceru*

Fish as indictor of pollution

Fish has been used as a traditional test animal to study the acute toxicity of a wide range of substances. Consequently, the literature is replete with information on the effects of pollutants on the survival and well being of fishes. A substantial part of our knowledge on tolerance limits, safe concentrations and toxicity levels derives from such experiments. However, these have limited practical applications, since it is not feasible to simulate all determinants, which may be relevant to the protection of fish life. By observing the natural populations of fishes, the wholesomeness of a watercourse can be determined. Use of fish as indicators of water quality often serves to signify restoration of a seriously polluted watercourse. Drastic changes in the fish species spectrum in the Hooghly estuary in the context of changing water quality in terms of salinity are also noteworthy.

Fishes accumulate certain substances in their body tissues, which apparently play no part in their normal metabolism. The most common examples are organochlorine insecticides, polychlorinated biphenyls and heavy metals. This bioaccumulation is significant both from the ecological and public health points of view. The natural fish populations though serve as an important general indicator of water quality, they are less suitable for providing a detailed scientific assessment of water quality, and other sections of biota are preferred. The inherent disadvantage of fish as indictor of water quality is the fact that water quality is not the only factor that limits their distribution. Being highly mobile, they may not represent the water quality of the spot from where they are caught. Many disadvantages associated with the use of natural fish populations can be overcome by keeping them captive in their native environment. Thus fishes caged in watercourses are extensively used to assess the water quality.

The single indicator species tells the status of the ecosystem by their presence or absence without any scope for knowing the magnitude of the problem. Availability of the species to act as the initial inoculums is also important. Various score systems came into vogue to quantify the impact by allotting scores. The common score systems are the *Palmer algal index* and *Nygard index.* Under various score systems, depending on the preponderance of such indicator organisms, quantification of the effects has become possible. Development of Trent biotic index was an important landmark in this direction, paving the way for biological surveillance. However, it is of utmost importance to realize that most biotic indices and saprobic indices cannot be translated into each other; they all have their own values. Experience elsewhere has shown that it is unlikely that any single index would satisfy all requirements. Indeed, it seems desirable that several types of indices should always be used in conjunction. Therefore, both pollution indices and diversity indices should be determined for all environment impact assessment exercises.

COMMUNITY STRUCTURE APPROACH

While the indicator species provide the clues on account of individuals or populations, the community structure approach takes into account the organization, well-being and changes in the community as a whole comprising the whole biotic community or a component community like benthos, plankton, and periphyton in an ecosystem. This approach has the advantage of reflecting the changes affected at various trophic levels. Lot of research has gone into the species diversity indices (SDI). In some ecosystem, there will be large number of species, which are evenly packed while in others the number of species are lesser but their population size may be bigger. The ratio between the species number (S) and abundance (N) is the crux of species diversity indices. Basically, there are two kinds of species diversity indices, *parametric* and *non-parametric*. Parametric indices are sound models, which try to establish predictable mathematical relationship between S and N. There were several attempts like *geometric models, Logarithmic models, lognormal series, Mac Arthur's broken stick models* and so on. However, in nature, such models seldom work. Most of the species diversity models in use are the non-parametric ones, which try to rationalize the relationships between S and N.

Non-parametric SDIs are grouped into α, β and γ indices. The α index explains the diversity in a community or habitat and β describes the diversity along a gradient. The γ indiex can explain the diversity of various habitats in a geographical area. Thus, the α and γ diversity has magnitude and quality; the β diversity has both magnitude and direction. Various species diversity indices are used to assess the community structure. The commonly used α indices are concentration of dominance (C), species richness index (d), evenness index (e) and Shannon-Weiner index (H). Species richness index explains the variety of organism present in the system, while the evenness tells how evenly the organisms in stand are packed. The Shannon-Weiner index has the advantage of packing information on species abundance as well as richness. The popular β species diversity indices are the similarity index, Jaccord index, Czecnowski and Sorenzen index Bay & Curtis index etc. (Table 4).

Table 4. Commonly used non-parametric species diversity indices

Index	Symbol	Formula
α Diversity indices Shannon Weiner index	$\bar{H}$	$\Sigma(ni/N \log_2 ni/N)$
Species richness index	d	$S-1/\log_2 N$
Concentration of dominance	C	$-\Sigma (ni/N)^2$
Evenness index	E	$H/\log_2 S$
β Diversity indices		
Jaccord index		J/(a+b-c)
Czecnowski and Sorensen index		2J/(a+b)
Bray and Curtis index		2jN/(aN+bN)

J- Number of species common to both the ecosystems
a- Number of species in ecosystem a
b- Number of species in ecosystem b
jN- Sum of lower values when some species are common in both the stands

PHYSIOLOGICAL - BIOCHEMICAL METHODS

The physiological and biochemical methods of biomonitoring are more commonly used compared to the biological methods. They are biological function analyses, toxicity testing and avoidance studies. The biological function analyses include ATP, Primary productivity and chlorophyll estimation. Toxicity testing studies are more popular and commonly understood. There are short-term acute toxicity tests (24, 48, 96 hrs), partial life cycle toxicity test (immature juveniles to adults) and life cycle toxicity tests (30 days after hatching of next generation). Under the avoidance studies, stressed conditions are created and fish behaviour is monitored in order to know whether fish tends to avoid such milieu.

ECOSYSTEM RECOVERY

Biopurification of sewage wastes employing aquatic vegetation has been found to be an effective and environment-friendly means to combat the pollutional hazards. A pilot scale technology has been developed using biopurifiers to reduce the extent of environmental pollution. It has been calculated that 20-40 t of *Eichhornia* is capable of removing the nitrogenous waste of over 2000 people and the phosphorus waste of over 800 people. Ecosystem recovery through diversion of point-source heavy metal pollution has also been successful in some cases. In this connection classical cases of two rivers *viz*., Rheiodal and Ystwyth in Wales can be mentioned. It has been reported that due to lead leaching from the nearby mine areas, almost all biological life including fish was destroyed in these two river systems. Later, with the closure of mines, recovery of the fishes and other biotic lives took place. Similarly, improvement in water quality in North American and Canadian rivers took place following successful implementation of pollution control measures. Another splendid example of fish as indicator of ecosystem recovery is the dramatic return of salmon to the Thames.

In India, significant improvement in the water quality and primary productivity rate has been observed in Kanpur due to the positive impact of diversion and treatment of the effluents, prior to their release in the river since 1987. Consequently, the fish production potential of the stretch registered an increase from 8-144 to 111-182 kg/ha/yr (Table 5).

Table 5. Ecological changes in the River Ganga at Kanpur due to diversion of sewage effluents

Zone	*Before diversion*				*After diversion*			
	1	2	3	4	1	2	3	4
Energy fixed by producers (Cal m^{2-1} day^{-1})	4152	2968	3913	222	4352	3212	5309	5256
Photosynthetic efficiency (%)	0.355	0.254	0.330	0.019	0.372	0.272	0.454	04.50
Fish production potential (kg $ha^{-1}yr^{-1}$)	144	103	136	8	151	111	184	182

Zone: 1. Bhagawatghat above confluence 2. Bhagawatghat below confluence
3. Jajmau above confluence 4. Jajmau below confluence

ECOTOXICOLOGY

Ecotoxicology involves a systematic, step-wise evaluation of the environmental effects from discharge and dispersal of toxic substances, their uptake by organisms and their subsequent effects on individuals, populations and ecosystems. Clearly, there is a need for fundamental research in the field with particular emphasis on the mechanisms of toxicity. Since environmental toxicology invariably deals with exposure to more than one compound at a time, it is highly probable that additive, synergistic and antagonistic effects do occur in the use of chemicals, all present in small quantities. However, our knowledge is still at a primitive stage, necessitating in-depth studies on environmental distribution processes, bioaccumulation, persistence and transformation processes, response of organisms and finally the ecosystem reflex.

CONCLUSIONS

The variables involved biological monitoring are so diverse and complex that data management often becomes difficult. A comprehensive computer model to predict, in detail, the physical, biological and economic consequences of environmental degradations is still beyond the realm of reality. Nevertheless, definite attempts in this direction have been made in various parts of the globe, paving the way for defining links among the various components of the complicated biology-driven environment management system. It is time that conservation and rational use of water is considered as prime national need. History is replete with instances where many great ancient civilizations perished not because of invasions or epidemics, but due to drying up of watercourses on the banks of which these were built up. Let us ensure that such histories are not repeated. There should not be any complacency on our part in conserving and efficiently utilizing our precious waters. Biological monitoring tools are becoming more and more relevant in this field. Sooner we realize this, longer the mankind survives. Today's sound foundations of biomonitoring help future generations face boldly the challenges of their times.

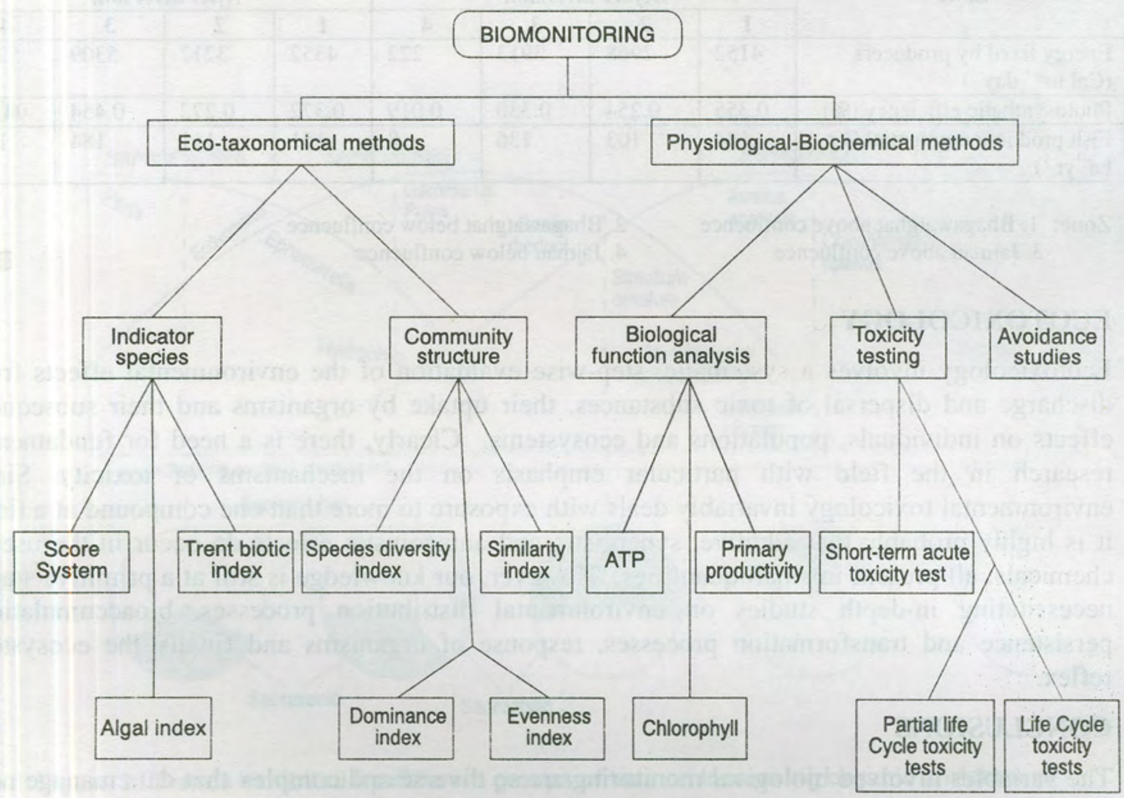

Figure 1: Methods of biomonitoring

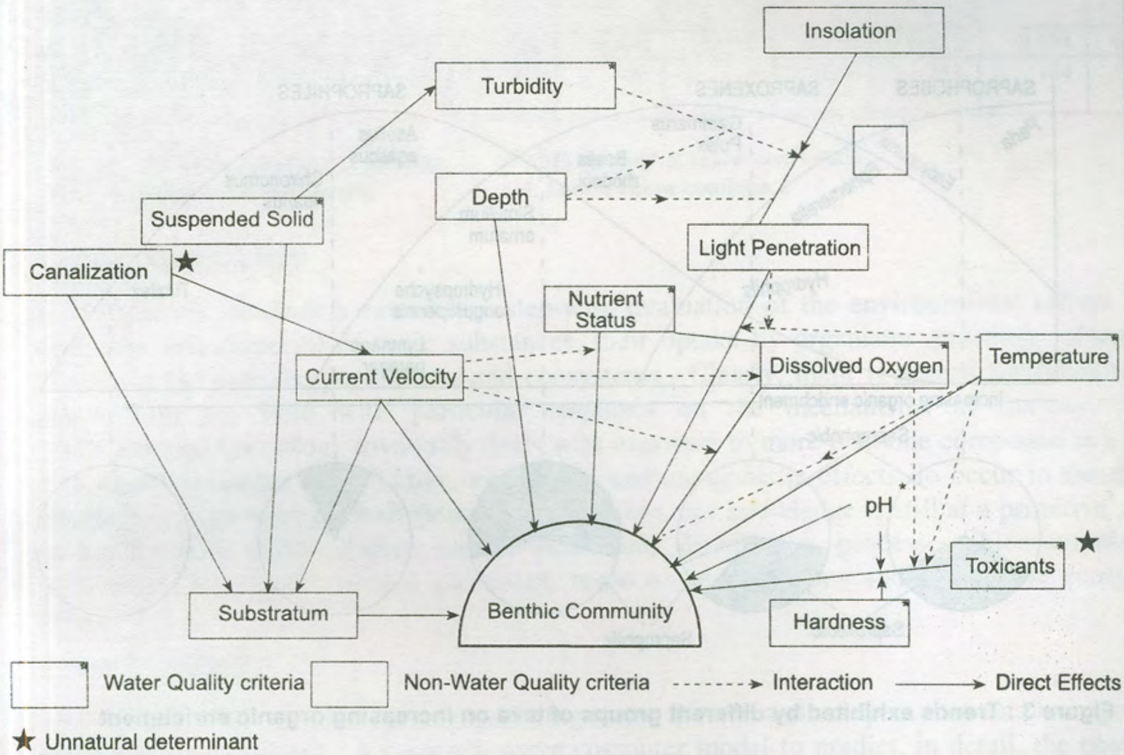

Figure 2 : Water quality and non-water quality determinants of benthic community in rivers

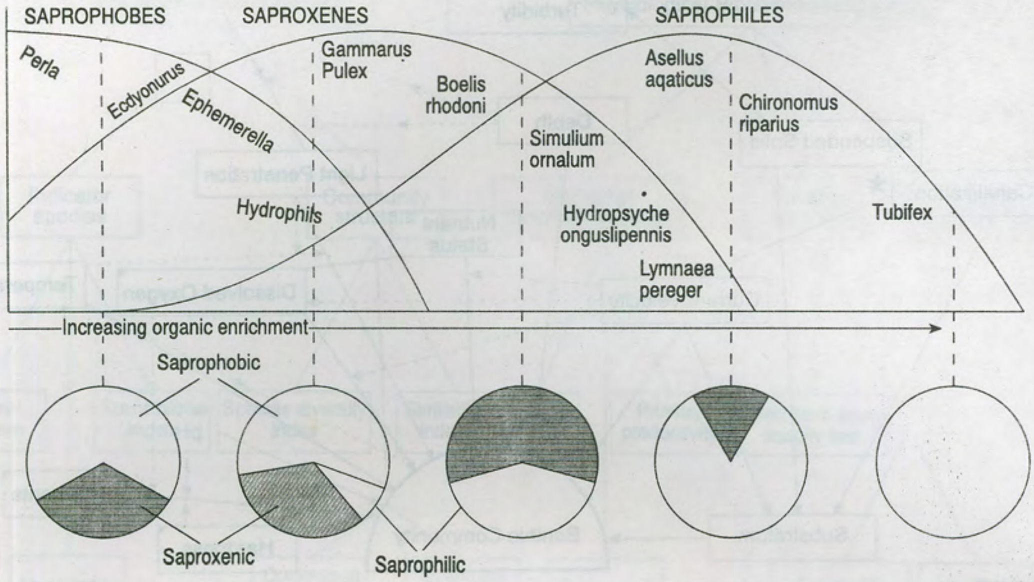

Figure 3 : Trends exhibited by different groups of taxa on increasing organic enrichment

Summer School on *Methods of assessment of aquatic ecosystem for fish health care*
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PHYSICOCHEMICAL PARAMETERS OF WATER IN AQUATIC ECOSYSTEMS IN RELATION TO FISH HEALTH

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INTRODUCTION

Maintenance of a healthy aquatic environment and production of sufficient fish food organisms in a water body are two very important factors for fish production. To keep the water body conducive for fish growth, physicochemical parameters like temperature, transparency, colour, odour, dissolved oxygen, pH, carbondioxide, total alkalinity, toxic gases like ammonia, hydrogen sulphide and nutrient elements like nitrogen, phosphorus and organic matter may be monitored regularly. When the physicochemical factors are in normal or conducive range, the water body is usually productive. But when they are present in quantities above or below the normal range, the fisheries and other aquatic organisms may be under stress which may lead to fish disease or fish mortality in due course. Stress is the sum of the physiological responses by which an animal tries to maintain or reestablish a normal metabolism in the face of a physical or chemical force. Brett (1958) correlating stress with the fish disease situation stated that it is a situation when the normal functioning is reduced significantly and death may result eventually.

In an aquatic ecosystem, there is profound and inverse relationship between physicochemical quality of water and fish disease. As physicochemical conditions deteriorate, severity of infectious diseases increases. Thus proper health maintenance practices can play a major role in maintaining a suitable environment where healthy fish can be produced.

ENVIRONMENTAL STRESS AND FISH DISEASE

Fish prefers an optimal environmental condition for its growth and reproduction. Any adverse change in environmental condition causes stress on the fish. If such a change increases arithmatically, the stress on fish may increase geometrically. Productivity of the ecosystem, which supply food to the fish is also important for the growth and maturation of the fish. The water quality parameters of significance to fish health are discussed below.

Temperature

Every fish has an optimal temperature for its growth and maturation. Indian major carps and many other fishes in our country growth well in temperature ranging between 20-30 °C. During culture experiments water temperature ranging from 23° to 30°C was most conducive for fish growth (Nath *et al.*, 1994). Below 20 °C the growth was slow and above 32°C the fish felt uneasy and stressed. Immune response of a fish is also dependent on temperature. Thus, warm water mirror carp do not produce antibodies when ambient temperature is less than 12°C but cold water trouts may produce antibodies even at 5°C. Roberts (1975) and Anderson and Roberts (1975) have noted that both defence mechanism and susceptibility to disease in a fish are dependent on temperature. With slightly higher than optimal temperature the wound healing of fish is quicker. Solubility of oxygen and other gases also depend on temperature. At higher temperature the fish metabolism is more but solubility of oxygen is less.

Transparency

The optimum transparency of a water body ranged between 20 and 50 cm (Nath *et al.*,1994). Very high transparency (more than 1.5 m) indicates poor productivity, while very low transparency due to suspended clay, silt or plankton bloom is also not desirable in aquatic ecosystem.

The growth and maturation of fishes are dependent on light energy or photoperiod. The growth of fish food organisms is dependent on solar energy for photosynthesis. However, excess solar radiation may inhibit photosynthesis and may cause sunburns in fishes (Roberts, 1978).

Dissolved Oxygen

Dissolved oxygen is absolutely essential for growth and survival of fish and fish food organisms. Dissolved oxygen content in a water body ranging between 5 and 10 mgl^{-1} during morning may be optimum for fish health. Low level of D.O. (Tr – 1 mgl^{-1}) may be lethal to many species if sustained for a long period. Oxygen content ranging from 1.0 to 5.0 mgl^{-1} may have some adverse effects on growth, feed conversion and tolerance to disease. (Sniesz ko,1973; Plumb *et al.*,1976). Under culture conditions, CO_2 and NH_3 content are often high when D.O. content is low. Walters and Plumb (1980) showed the triad of environmental stresses to be more acute than low D.O. alone in causing bacterial infections in fish. A fish may survive 0.5 mgl^{-1} D.O. for a few hours but not for several days. At higher temperature solubility of oxygen in water is low, so aeration may be more necessary during summer than that during winter to avoid fish kill.

Supersaturation with atmospheric gases of waters falling over high dams can cause gas bubble disease and mortality in fish living in streams below. Fish died in a pond when D.O. content reached 300% of saturation - the lethal effect was due to oxygen bubbles surrounding the gills (Mckee and Wolf, 1962). But in fish ponds, the fish kill due to gas bubble disease is not so common. However, supersaturation may adversely affect the fry and eggs of fish, restricted to surface by lack of mobility.

The D.O. may be estimated by Winkler Method as described in A.P.H.A. Polarographic D.O. meter provide an easier and more rapid means of analysis. When using a D.O. meter, it is important to calibrate the apparatus by the Winkler technique.

Water reaction (pH)

pH is the negative log of hydrogen ion activity. pH generally denote the acidic or alkaline nature of water. Slightly alkaline water reaction (pH 7.4-8.0) is optimum for fish production (Nath *et al.*,1994).

Effect of pH on fish health

pH 4.0 and below	- direct fish mortality (Nath,1986)
pH 4-5	- sub lethal effect on fish
pH 5-6	- poor pond productivity, reduced fish growth
pH 7.4 – 8.2	- optimum for fish growth
pH 9-10	- sub lethal effect on fish.

The Ganga and Narmada rivers and Hooghly estuary have slightly alkaline water reaction, which imparts higher productivity to them. Water bodies situated at high altitude in a high rainfall area may have acidic water and soil reaction. Beels and ponds of Assam and North Bengal generally have acidic soil and water reaction which imparts low productivity to those water bodies.

Alkalinity

Total alkalinity which is a measure of bicarbonate and carbonate concentrations, is a very useful factor for predicting the productivity of an aquatic system. Total alkalinity ranging between 80 and 150 mgl^{-1} is optimum for fish culture (Nath *et al.*,1994).

Effect of alkalinity on fish health

0-20 mgl^{-1} – poor fish growth, creates stress on fish (Boyd,1982; Nath,1986)
20-50 mgl^{-1} – low to medium fish growth
80-200 mgl^{-1} – congenial for fish production

Liming of water bodies enhance their total alkalinity contents. The Ganga, Narmada and Hooghly estuary have total alkalinity in the conducive range. But water bodies in Assam, North Bengal and other North Eastern States generally have low to medium total alkalinity which may result in lower productivity.

Estimation : Total alkalinity is estimated by titration to the methyl orange end point (from yellow to pink) with standard H_2SO_4 (or HCl).

Carbon dioixide

In open water systems such as rivers, lakes and reservoirs free CO_2 ranged between trace and 10 mg l^{-1}. CO_2 content is maximum in the morning and minimum or absent during noon or afternoon due to its utilisation in photosynthesis by phytoplankton and macrophytes present in the water body. However, high CO_2 content in water (20 mg l^{-1} and above) indicates aquatic pollution presumably due to industrial or municipal effluents. CO_2 is not very toxic to fish, provided D.O. is plentiful. (Hart,1944). However, CO_2 content is generally quite high, when D.O. is low (Boyd,1982) under low D.O. content, high content of CO_2 hinders oxygen uptake by fish, causing respiratory problem and stress. In fish ponds 5-10 mgl^{-1} of free CO_2 is conducive for carp culture (Nath *et al.*,1994). CO_2 content ranging between 12-50 mgl^{-1} may have sub-lethal effect which may include respiratory stress and formation of kidney stones. High quantity (50-60 mgl^{-1}) of free CO_2 is lethal to many fish species with prolonged exposure (Das and Das,1997). In lakes and reservoirs absence of free CO_2 for prolonged periods generally indicate their unproductive nature.

Estimation : Free CO_2content may be estimated by titrating the water sample with N/44 NaOH usuing phenolphthalein as indicator. The end point is light pink.

Ammonia : Ammonia may enter into the water body as fertilizer. In ponds where high densties of fish are fed with supplemental feeds, the ammonia content may increase to undersirably high levels. In water unionised ammonia exists in a pH and temperature dependent equilibrium with ammonium ions.

$$NH_3 + H_2O = NH_4^+ + OH^-$$

Unionised ammonia is highly toxic to fish but ammonium ion is relatively non-toxic. The higher the pH and temperature, the higher is the percentage of total unionised ammonia (Boyd,1982).

As ammonia level in water increases ammonia excretion by fish decreases and levels of ammonia in blood and tissue increases. The result is the elevation of blood pH and adverse effect on enzyme catalysed reaction and membrane stability. In fishes ammonia causes gill hyperplasia, reduced activity and gross liver, kidney and brain damage also occur. Sub lethal level of ammonia causes pathological changes in fish organs and tissues (Smith and Piper,1975).

Ammonia content ranging between 0.02 and 0.05 mgl^{-1} is safe for tropical fishes and prawn. Sub lethal effect is noted depending on the species in the range of 0.05-0.4 mgl^{-1}. But ammonia content ranging between 0.4-2.5 mgl^{-1} may be lethal to many fishes and prawns.

Ammonia content is generally low in carp culture ponds. But its level may be significantly high in intensive culture ponds of air-breathing cat fishes (magur or singhi) and there may be fish mortality if its content is not monitored regularly. In CIFRI/IDRC rural aquaculture project, the carp culture ponds had ammonia content in safe limit. But the magur ponds, where large quantity of trash fish was used as fish feed, we frequently noted higher levels of free ammonia. Water replenishment was done to avert fish kill.

Estimation : Ammonia content in water may be estimated colorimetrically by Nasslerization. The yellow to brown colour produced by Nessler ammonia reaction is measured by a spectrophotometer at 400-425 mm.

Nitrite : In most natural water bodies, nitrite content is generally low. But, if the water body is contaminated with high organic pollution and has low D.O. the nitrite content may increase to toxic level.

Nitrite content between 1.0-10.0 mgl^{-1} is lethal to many warm water fishes. In the range of 0.02-1.0 mgl^{-1}, it is sub lethal to many fishes.

When fish absorbs nitrite it reacts with haemoglobin to form methemoglobin. Since, methemoglobin is not effective as an oxygen carrier continued absorption of nitrite might lead to hypoxia and cyanosis. Addition of calcium and chloride may reduce the toxicity of nitrite to fish (Boyd, 1982).

Estimation : Nitrite is estimated by measuing the colour of the reddish purple azo dye produced at pH 2.0 to 2.5 by coupling diazotized sulphanilic acid with N (1napthyl) ethelenediamine dihydrochloride. The colour is measured by a spectrophotometer at 543 nm. (APHA, 1980).

Hydrogen sulphide

Under anaerobic conditions, certain heterotrophic bacteria use sulphate and other oxidised sulphur compounds as terminal electron acceptors in metabolism and excrete sulphide as follows:

$$SO_4^{-2} + 8H^+ \rightarrow S^{-2} + 4\,H_2O$$

The sulphide remains in equilibrium with hydrogen sulphide as follows:

$$H_2S = HS^- + H^+$$

$$HS^- = S^{-2} + H^+$$

The pH regulates the distribution of total reduced sulphur amongst its species. Unionised H_2S is toxic to fish but the ions resulting from its dissolution is not so toxic. The proportion of unionised H_2S decreases with increasing pH.

Effect of hydrogen sulphide on fish health :

3 mgl^{-1} H_2S and above – Fish and prawn die instantly

0.01- 0.5 mgl^{-1} of H_2S – lethal to fish

Any detectable concentration of H_2S should be considered detrimental to fish production (Boyd, 1982).

The toxicity of H_2S in a watert body may be reduced by frequent exchange of water and by increasing the pH by liming. Unionised H_2S content at different pH are as follows.

pH	Unionised H_2S (%
5	99.0
6	91.1
7	50.6
8	9.3
9	1.0

Estimation

Iodometric method : Iodine reacts with sulphide in acid solution oxidising it to sulphur. A titration based on this reaction is an accurate method for estimation of sulphide. The method is useful for waste water and partly oxidised water (APHA, 1980).

Total hardness

Total hardness refers to the concentration of divalent metal ions in water expressed as mgl^{-1} of equivalent $CaCO_3$. The total hardness in majority of the freshwater ponds should be similar to the total alkalinity. Liming of fish ponds enhances their hardness content.

Effects of hardness on fish health

0-20 mgl^{-1}	– create stress in fish leading to poor growth
20 mgl^{-1} – 200 mgl^{-1}	– very conducive for fish growth

Estimation : Total hardness is determined by titration with standard EDTA disodium salt using Eriuochrome Black T as indicator. The end point is from reddish brown to blue (APHA, 1980).

NUTRIENTS

Nitrogen, phosphorus and potassium are three elements which enhance productivity of the water bodies. Fish food organisms (phytoplankton, algae, macrophytes etc.) grow profusely if these are present in adequate quantities. In fish ponds these elements are generally supplied as inorganic fertilizers and organic manures to get high fish production. However, the fertilizer or manure should be used in such quantity which will not produce excess algal bloom. Excess algal growth in any system is not desirable since they will consume the D.O. during night causing heavy stress on fish and other organisms. In case of algal growth, it is advisable to stop fertilizer application and maintain the D.O. level always above 2-3 mgl^{-1} and preferably above 5 mgl^{-1} by aeration.

Inorganic nitrogen content ranging between 1.0 to 2.6 mgl^{-1} might be considered optimum for high fish production (Nath *et al.*, 1994).

Similarly, phosphate content ranging between 0.2 and 0.6 mgl^{-1} is considered optimal for fish production in ponds. Indian soil is usually phosphorus deficient. So application of phosphatic fertilizer generally improves aquatic productivity. Fixation of phosphate is minimum in near neutral soil reaction.

Silicate is an essential nutrient for growth of diatoms, an important fish food organism. Silicate content above 8 ppm is conducive for fish growth.

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SOIL CHARACTERISTICS OF IMPORTANCE IN AQUATIC ECOSYSTEM IN RELATION TO FISH HEALTH

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INTRODUCTION

Fish under normal conditions is in a state of equilibrium with the environment and remains healthy even in the presence of pathogens. But when values of one or more physico-chemical and biological parameters of its environment disturb this equilibrium, fish undergoes "stress" which affects their physiological balance. This in turn predisposes fish to infectious and other diseases or even directly causes disease and mortality. Soil is a major component of any aquatic environment, which not only holds water for aquatic animals but also enriches the water body with various nutrients required for biological production. A series of physical, chemical, biochemical and microbial reactions continuously take place at bottom soil resulting in release of different nutrient elements to overlying water. A dynamic equilibrium is maintained between the sediment and water due to their interdependence and thereby exerts a favourable influence on the environment for aquatic animals. It is, therefore, necessary to have a proper knowledge of the most important physical and chemical properties of soil having a bearing on disease susceptibility in fish.

Soil Texture

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

Soil reaction (pH)

pH of soil is one of the most important factors for maintaining the productivity of any water body since it controls most of the chemical reactions. It not only influences the soil microbial activity but also affects the availability of nutrients to pond water – either native or when applied externally. The rate of mineralization of organic matter, fixation of P and other elements and growth and survival of different biotic communities are greatly influenced by pH. In acid soil phosphorus fixed or rendered unavailable as iron and aluminum phosphate and in alkaline soil as calcium phosphate. The response of different nitrogenous fertilizers depends on soil reaction. It was observed that the loss of added nitrogen is minimum with ammonium form in acid and neutral soil and with nitrate form in alkaline soil. Soils are classified in to acidic (pH < 7.0), neutral (pH 7.0) and alkaline (pH > 7.0) according to its pH or H^+ ion concentration. When sediments contains high organic matter with slower decomposition rate, acidity develops due to humic and short chain fatty acids leading to less productivity, pH of overlying water to a great extent depends on pH of soil. Fish become more vulnerable to the attack of parasites and host of diseases in acid soil. Soil pH in the range of 6.5-7.5 is considered ideal.

Organic matter

Soil organic matter or humus are more varied and complex in nature. They strongly influence the physical, chemical and biological activities in soil. They are also important as a source of energy for the microbes participating in various biochemical processes resulting in release of different nutrients. It improves soil structure, aeration, and increase water holding capacity, buffering and exchange capacity in soil including solubility of soil minerals. It also serves as a storehouse of various nutrients essential for biological production and as food source for benthos feeding fishes and invertebrates. Soils of floodplain wetlands, ponds and reservoirs contains more organic matter than upland field due to accumulation through autochthonous as well as allochthonous sources Soils having less than 0.5% organic carbon are considered low productive while those in the range of 0.5-1.5% and 1.5-2.5% are considered medium and high productive respectively. Soil with high organic carbon may cause oxygen depletion in the overlying water. "Gill rot" disease occurs when the temperature of water is very high during summer and excessive organic matter present in the soil.

C/N Ratio

The carbon to nitrogen (C/N) ratio of soil influences the microbial activity of soil to a great extent and thereby affects the rate of release of nutrients from organic matter When the C/N ratio is very wide soil microorganisms will consume most of the mineralized nitrogen for their sustenance. Most productive range of C/N ratio is 17:1 to 10:1. Below 10:1 decomposition is very slow and consequently availability of nitrogen is not up to satisfaction.

Soil Nutrient status

A large number of elements needed for the existence and nutrition of biologically productive organisms in aquatic environment are obtained from the soil and atmosphere for the enrichment of water. Among these nitrogen, phosphorus and potassium are termed as primary nutrient elements; calcium, magnesium and sulphur are termed as secondary nutrient elements and boron, copper, manganese, zinc, molybdenum, iron and cobalt are termed as micronutrients on the basis of their requirement.

Nitrogen

Nitrogen being a basic and primary constituent of protein is required to stimulate primary production in aquatic environments and is essential for the formation of living matter. In soils nitrogen occurs almost entirely in organic form, which is gradually mineralized to soluble inorganic nitrogenous compounds (NH_4, NO_3, NO_2) by obligate as well as facultative anaerobes and subsequently utilized by fish food organisms. It is the easily decomposable form of organic nitrogen, known as available nitrogen, that is important in aquatic productivity. For any productive soil available nitrogen must be above 250 mg kg^{-1}.

Phosphorus

Phosphorus is another element essential for assimilation of nitrogen into cellular matter besides respiration, cell division, metabolism, growth and synthesis of protein. It is considered a key element in maintaining the productivity of water ecosystem In soil, both organic and inorganic forms of phosphorus occur but organic-P is of little significance in supplying phosphorous to primary producers because of its slower rate of mineralisation under anaerobic condition at the bottom in aquatic ecosystem.. The native phosphorus status of most soils is rather low compared to nitrogen and potassium. Moreover, inorganic form of phosphorus becomes unavailable as insoluble ferric as well as aluminium and calcium phosphates under acidic and alkaline conditions respectively A productive soil must have above 30 mg kg^{-1}. of available phosphorus. Sediments of most of the Indian ponds, reservoirs and beels are poor in available phosphorus.

Potassium

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

Calcium, magnesium and sulphur

Calcium, magnesium and sulphur are termed as the secondary nutrients. Calcium is an integral part of the plant tissues. Sulphur is an essential constituent of protoplasm. Ca and Mg influence the concentration of CO_2 in water. Calcium also acts to increase the availability of other ions in water and in general ameliorates the chemical conditions of water. Calcium is generally present in soil as calcium carbonate. The amount of exchangeable phosphorus in the sediment is inversely related to the calcium carbonate- organic matter ratio so that in highly organic soil with low calcium soluble phosphorus remain adsorbed in exchangeable forms and when sediment is very low in organic matter and high in calcium, phosphorus is fixed as insoluble precipitate. The availability of these elements are more in floodplain wetlands than in upland soils.

Micronutrients

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

CONCLUSION

Soil quality parameters directly or indirectly are responsible for the outbreak of disease. The quality of overlying water is a mere reflection of the complex chemical, bio-chemical and electro-chemical changes taking place in the bottom mud. An understanding of physico-chemical conditions of soil through regular monitoring system and adopting proper management practices will lead to the maintenance of desired water qualities which minimize the disease outbreak and favour increased fish production.

STATUS AND METHODS OF ASSESSMENT OF HEAVY METALS IN AQUATIC ECOSYSTEM IN INDIA IN RELATION TO FISH HEALTH

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STATUS OF METAL CONTAMINATION IN WATER AND SEDIMENTS

In India systematic information on metal contamination is lacking for the major river systems except for a few, like rivers Ganga, Jamuna, Damodar and Hoogly estuary. In Ganga the fluctuation in metal contents in water during 1992-95 was narrow, ranging between 0.02 and 0.03 mg l^{-1} for Zn; 0.01 - 0.17 mg l^{-1} for Cu, 0.005 - 0.03 mg l^{-1} for Cd and 0.03 - 0.68 mg l^{-1} Pb at different centers. Zinc was in maximum concentration near Allahabad, while Cu at Farakka; Cd at Tribeni and Pb near Varanashi (Table-1). Hooghly estuary which flows though the industrial cities of Calcutta and Howrah recorded high levels of metals; Cu: 0.237 mg/l; Cd: 0.080 mg l^{-1} ; Cr: 0.180 mg l^{-1}; Pb: 0.410 mg l^{-1} and Zn : 0.293 mg l^{-1}. In river Yamuna, maximum level of Cu (63.3 μg l^{-1}); Cr (4.7 μg l^{-1}); Cd (2.25 μg l^{-1}); Pb (7.9 μg l^{-1}) and Hg (0.09 μg l^{-1}) were recorded at Agra. Maximum Zn level (85 μg l^{-1}) was recorded at Allahabad. Mean Zn, Cr, Cd and Pb concentration at Delhi was observed as 68.0, 284, 0.625 and 4.35 μg l^{-1}. In river Hindon concentrations of heavy metals in water were Cd: 1.50 - 6.75; Co: 7.50 - 15.00; Cr: 12.5 - 210.00; Cu: 16.50- 175.00; Fe: 53.70 -500.00; Mn: 30.00 - 200.00; Ni: 9.75 - 21.25; Pb: 10.00 - 142.50 and Zn: 13.00 - 23.50 μg l^{-1}.

Table 1. Metal Concentration in Water and Sediment in Ganga River System

Metal	Kanpur	Allahabad	Varanasi	Farakka	Tribeni	Rishra
Zinc						
Water	0.03-0.09	0.16-0.23	0.03-0.09	0.03-0.12	0.02-0.08	0.03-0.08
Soil	249.00	50.00	-	63.90	145.85	165.60
Copper						
Water	0.03-0.04	0.06-0.17	0.02-0.09	0.005-0.19	0.01-0.007	0.01-0.07
Soil	128.15	32.10	10.20	41.95	52.50	35.50
Cadmium						
Water	0.005-0.007	0.005-0.007	0.005-0.007	0.005-0.007	0.008-0.017	0.003-0.007
Soil	9.95	2.20	2.10	7.75	7.70	2.25
Lead						
Water	0.08-0.20	0.08-0.20	6.02-0.68	0.05-0.07	0.004-0.08	0.003-0.008
Soil	47.15	35.50	30.55	29.56	36.40	24.05

The metal concentrations in water at all the sampling points of rivers Ganga and Yamuna apparently remained within the drinking water standard prescribed by ***WHO.*** However, in one instance Cr level at Kanpur and Agra appeared to cross the safe limits prescribed for the fish and other aquatic organisms.

Sediment load of metals by and large are higher than those of the water phase. Samples from Ganga clearly indicate that the metal contents were higher in sediments compared to the water phase. The range for different metals were 50 - 249 mg kg^{-1} (Zn), 10.2-128.15 mg kg^{-1} (Cu), 2.1 - 9.95 mg kg^{-1} (Cd) and 24.05 - 47.15 mg kg^{-1} (Pb.). Among all the sampling points highest sedimentary contents of metals were near Kanpur while lowest values varied with different metals and centres. River Hindon contained high level of metals in sediments and individually that of Cd ranged from 0.12 - 0.02; Co: 3.90- 7.50; Cr: 6.67 - 13.42; Cn: 1.92 - 4.60; Na: 11.70 - 19.20; Pb: 1.57 - 3.15 and Zn: 20.25 - 35.5 mg g-1^{-1} on dry weight basis.

METAL STATUS IN BIOTIC COMMUNITIES

Metals from water and soil phases gradually accumulate in biotic communities like the plankton, benthos, hydrophytes and finally fishes through the processes of absorption, ingestion, digestion and assimilation. Since the methods involved in estimating metals in biotic materials are difficult and costly, detailed information on the accumulation status of metals in river and estuarine biota is limited. It is, however, worthwhile to mention that accumulation of metals in the Gangetic benthic organisms have been recorded for Zn (11.8 - 17.6 mg kg^{-1}); Cr (1.8 - 3.4 mg kg^{-1}) and As (1.2 - 2.8 mg kg^{-1}). Among the benthic organisms maximum accumulation of metals was in gastropods. Of all the biotic component, fishes have been frequently studied in respect of metal accumulation in comparison to other organisms. Estimation of metals in various tissues from the Ganga river system revealed Zn in the range of 1.6 - 25.0 µg g^{-1}, Cu: 0.3 - 2.9 µg g^{-1}, Cd: ND - 0.76 µg g^{-1} ; Hg: ND - 0.56 µg g^{-1} and Cd: ND- 0.56 µg g^{-1} in body organs of four different species and among those *Labeo calbasu* and *Mystus gulio* had the highest metal concentrations. However, more detailed information is available on a sedentary, omnivore catfish, *Rita rita* with regard to the status of accumulation of heavy metals and health conditions from the Ganga river system. The other species having similar information is *Pama pama* ascending the Hooghly estuarine system from the Bay of Bengal. The former species from the Ganga river system indicated increasing trend in heavy metal accumulation at some locations. Variations, however occur in accumulation rates within the organs. (Table - 2). The variability in organ wise metal contents was conspicuous. The gill accumulated metals at lower level compared to kidney. The range of metal accumulation in gill fluctuated between a lowest of 56.42 mg l^{-1} at Farakka in non-industrial zone and a highest of 1128.44 mg l^{-1} at Kanpur in industrial zone of the Ganga river system. The test fish samples from Kanpur recorded lower metal levels in comparison to those of Rishra which falls within the industrially contaminated stretch of the Hooghly estuary. The order of accumulated metallic ions in gill, which are considered as inlet points for toxicants in the fish, was Cd> Zn> Pb> Cu while the trend in kidney considered to be the outlet point, was almost in reverse order Pb> Zn> Cu> Cd. In case of the other species *Pama pama*, the total load of Zn, Cu, Cd and Pb was maximum at Diamond

Harbour stretch of the Hooghly estuary in comparison to Rishra and Farakka. Among the fish organs the difference were significant in accumulation levels of the metals. Kidney accumulated maximum of metals followed by the liver and gills. (Table - 2) . The fishes examined from Diamond Harbour stretch were diagnosed with organell deformities and poor growth performance.

Table 2. Metal Accumulation (mgl^{-1}) in *Rita-rita* in Ganga River System

Metal	Kanpur	Varanasi	Farakka	Tribeni	Rishra
Zinc					
Gill	287.60	60.91	40.78	31.60	70.38
Kidney	302.43	60.00	92.23	59.44	1160.52
Copper					
Gill	80.84	12.31	3.12	16.63	9.60
Kidney	64.36	38.12	32.84	830.67	241.88
Cadmium					
Gill	760.0	19.20	12.32	22.15	21.47
Kidney	1410.70	76.25	38.23	92.16	455.61
Lead					
Gill	ND	0.36	0.20	82.80	128.80
Kidney	ND	ND	0.63	321.95	3296.28
Total					
Gill	1128.44	92.78	56.42	153.18	230.25
Kidney	1777.49	174.37	134.93	1304.22	5184.29

Methods of metal assessment

The methods of heavy metal analysis which initially depended on titrimetry, now employ instrumental analysis including sophisticated instruments such as atomic absorption spectro-photometer. The work has become easy and flawless in recent times. However, the methods of sample preparation prior to analysis is still crucial and varies from one method to method.

Water sample analysis

The sample of water for metal analysis needs to be filtered and afterwards added with required volume of acid. The acid added water sample may be thoroughly shaken. For heavy metal analysis water samples must be collected in glass bottle. The sample must be analyzed at the earliest opportunity. This is more so for samples containing very low levels of metals.

Sediment sample analysis

The samples of sediments after sun drying/oven drying at 45-50^{0}C are ready for for analysis. A required quantity of dried sediment samples is dissolved in acid mixture and digested for complete solution of the metal elements in the acid media. Afterward the acid metal mixture is diluted with double distilled water to get a known volume of the solution for metal analysis in the AAS.

Biotic sample analysis

The biological samples, whether plant or animal in origin, are either dry ashed or wet ashed for metal analysis by the AAS. In dry ashing method known quantity of the sample is ashed in Muffle Furnace (550 - 600^{0}C) and then dissolved in tri acid mixture. The acid mixed with the ash is afterwards diluted with double distilled water and made to the required volume for metal analysis. For wet ashing the known quantity of the sample in dissolved and digested in tri acid mixture. The digested samples on cooling to room temperature is diluted with double distilled water to required volume and then analyzed in AAS.

Fish sample analysis

For metal analysis in fish either the whole body or certain body parts or organs are used. As a precautionary measure the fish samples need proper cleaning and preservation. In case of whole body analysis the fish sample is covered in aluminum foil and preserved in ice. The ice preserved sample on arrival to laboratory is unfolded and either dry ashed or wet ashed for analysis of metals in AAS. If the fish sample is big and it needs organ or tissue wise analysis of metals the tissue from different organs are taken out carefully with sharp cutter and folded in aluminum foil and the preserved in ice. The rest of analytical process is like that of the whole fish.

STATUS AND METHODS OF ASSESSMENT OF PESTICIDES IN AQUATIC ECOSYSTEMS IN INDIA IN RELATION TO FISH HEALTH

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INTRODUCTION

India is the third largest consumer of pesticides in the world (Agnihotri 2000). During the last four decades, the consumption has increased several hundred folds, from 154 ton in 1953-54 to 80,000 ton in 1994-95. However, after that, the consumption has steadily declined to the present level of 54,135 ton (based on 1999-2000 data) (Table-1). The decline is primarily because of ban or restrictions imposed on use of organochlorine pesticides such as HCH (BHC), DDT, aldrin, etc. which have high rate of application. Introduction of Integrated Pest Management program has also reduced pesticide consumption to some extent.

Table 1. Production and consumption status of technical grade pesticides in India

Year	Production (ton)	Consumption (ton)
1953-54	N.A	154
1985-86	54,900	N.A
1989-90	65,800	N.A
1994-95	90,758	80,000
1996-97	94,350	66,677
1998-99	88,751	57,240
1999-2000	88,700	54,135

N.A = Data not available

Source : Directorate of Plant Protection, Quarantine and Storage, Faridabad and Department of Chemicals & Petrochemicals, Ministry of Chemicals and Fertilizers, Government of India.

Up to mid 1990s the major group of chemicals used was insecticide (80%) which has declined to 60% during 1999-2000. The type of insecticide use has also altered. Percentage of organochlorines decreased from 40% to 14.5%. On the other hand, there was a sharp increase in organophosphate use from 30% to a level of 74% during the time. The leading organochlorine used up to 1995-96 was technical HCH (BHC) which accounted for about 40% of total pesticide consumption. In the year of 1999-2000, its production has been totally stopped.

It is interesting to note that only 25-30% of total cultivated area is under pesticide cover. Yet the residues of pesticides have heavily polluted our agricultural produce and different components of environment. This is mainly due to improper handling, wrong use-schedule, non-awareness about the chemicals and their residue behavior.

The chemistry and the property of the molecules, in fact, have a direct bearing on the environmental fate of pesticides in general. Compounds with poor water solubility are more persistent in soil and aquatic environments. Among the insecticide groups, both the organophosphates and carbamates are esters which undergo various types of hydrolysis leading to quick degradation in the environment. On the other hand, the organochlorine compounds are highly persistent in nature, especially in cold atmosphere. The compounds of the group are also lipophilic and can accumulate along the food chain. Many of the organochlorine pesticide metabolites are carcinogenic. Realizing all these adverse effects, use of these chemicals has gradually been phased out in advanced countries from 1970 onwards. In India, however, organochlorine pesticide consumption rate went on rising even up to 1995 due to their simple manufacturing process, low price, wide spectrum of activity, etc. At last, understanding the total adverse effect, use of these chemicals has been stopped. However, due to longer persistence, higher residues are still reported from various components of the environment.

RESIDUE STATUS OF INSECTICIDES IN INDIAN INLAND WATER BODIES

The residue levels of organochlorine insecticides in Indian inland water resources are presented in Table 2. Among the rivers, the highest concentration of HCH and DDT was reported by Kulasrestha (1989) in Kshipra river in central India. Relatively lower concentrations of organochlorines had been reported by Thakar (1986), Ray (1992), Agnihotri *et al.*, (1994) and Samanta (2000) in river Ganga. The HCH residues generally consisted of α, β and γ isomers (Mohapatra *et al.*, 1995). The detected level of DDT in the river Ganga was up to 4000 ng l^{-1} as reported by Halder *et al.*, (1989). In Yamuna river system, similar residue level was reported by Agarwal *et al.*, (1986). The residue levels of Jalmahal and Mahala reservoirs of Jaipur was also found to be very high (Kumar *et al.*, 1988 and Bakre *et al.*,1990).

Table 2. **Organochlorine insecticide residue concentrations in Indian inland water resources (ng l^{-1})**

Water Resource	HCH	DDT	Aldrin & Dieldrin	Endosulfan	Reference
River					
Hooghly (Ganga)	1- 400	2-560	—	—	Thakar (1986)
Hooghly	—	6-4000	—	ND – 97	Halder *et al.*, (1989)
Hooghly	ND-258	ND			Samanta (2000)
Ganga	1- 971	ND – 1240		ND – 2890	Ray (1992)
Ganga	ND – 1119	ND – 832	ND – 120	ND – 232	Agnihotri (1993)
Yamuna	—	40-3400	—	—	Agarwal *et al.*, (1986)
Yamuna	ND – 34	ND – 34	—	—	Samanta (2000)
Kshipra (av)	272000	21900	—	—	Kulshrestha (1989)
Vellar	26- 3900	1-5	—	—	Ramesh *et al.*, (1990)
Lake					
Lucknow (av.)	1450	121	—	—	Nigam *et al.*, (1998)
Reservoir					
Jalmahal, Jaipur	10 – 4600	40 – 47000	—	—	Kumar *et al.*, (1988)
Mahala, Jaipur	ND - 46530	70 – 33630	110 – 25040	—	Bakre *et al.*, (1990)

ND = not detected i.e. below detection limit of instrument. av. = average value

Concentrations as high as 2890 ng l^{-1} of endosulfan was reported earlier in Ganga river water (Ray, 1992). Other workers have reported much lower level. Aldrin residue was studied by very few workers like Agnihotri, (1993). Very high level of aldrin was reported in Mahala reservoir by Bakre *et.al.*,(1990).

The Environmental Protection Agency, USA, has recommended acceptable limit of organochlorine pesticide residue for potable water and also for organisms living a water body : α-HCH 3.9 ng l^{-1}, β-HCH 14 ng l^{-1}, γ-HCH 19 ng l^{-1}, 4,4'-DDT 0.59 ng l^{-1}, 4,4'-DDE 0.59 ng l^{-1}, 4,4'-DDD 0.83 ng l^{-1}, aldrin 0.13 ng l^{-1}, dieldrin 0.14 ng l^{-1} Weiner (2000).Comparison of these limits with the data of Table-2 clearly shows that Indian water bodies are highly polluted with the organochlorine insecticides which can cause harm to the aquatic organisms and also to general consumers.

Monitoring data of organophosphorus insecticide residues in aquatic environment is relatively few in number. Malathion, methyl parathion and dimethoate were detected in many samples of river Ganga (Ray, 1992). In the same river, Agnihotri (1993) however found very low concentrations of organophosphorus insecticides.

Table 3. Concentration of organophosphorus insecticide residues in Indian rivers (ng l^{-1})

River	Monocrotophos	Dimethoate	Malathion	Me-parathion	Ethion	Reference
Ganga	_	ND-2694	ND-6982	ND-279	ND-1995	Ray (1992)
Ganga (1993)	ND-185	ND	ND	ND-137	ND-1	Agnihotri

The data on pesticide residue in fish samples in India as recorded in literatures is presented in Table 4. The maximum levels of HCH and endosulfan was reported for Kolkata market samples by Kole et.al.,(2001). In other studies the residue level was much less. Ramesh *et.al.*,(1992) compared the HCH residue level of fish from Indian literature with that of other countries and concluded that the residue levels are comparable.

Table 4. Organochlorine insecticide residue concentrations in fish in India (ng g^{-1} wet weight)

Source of fish	HCH	DDT	Aldrin & Dieldrin	Endosulfan	Reference
Hooghly River (av)	— —				10.6-235 — Joshi (1986)
Vellar River (1992)	0.5-150	0.9-75	—	—	Ramesh *et al.*,
Ganga River (av.) (1993)	77	160	5.6	—	Kannan *et al.*,
Farmed Prawn (1994) of Tuticorin (av.)	5.3	10.3	3.6	—	Radhakrishnan
Kolkata Market	10-9720	—	—	10-1410	Kole *et al.*, (2001)
Ganga	0.1-9.0	1.4 – 95.9	ND – 7.7	ND – 13.0	Samanta (2002)

av. = average value

Method of pesticide residue analysis for samples from aquatic environment

In any pesticide residue analysis program, four basic steps are involved. These are:

- i) Sampling – Sample should be representative of the population.
- ii) Extraction – Transfer of pesticide residues from sample into desired solvent.
- iii) Clean up – Removal of undesired co-extractives from extracted material.
- iv) Detection – Quantification of the pesticide residue.

Residue includes the parent compound and its metabolites.

Method of organochlorine pesticide residue analysis in fish

The method commonly used for estimating the total organochlorine pesticide content in fish is as described in *Food and Drug Administrations* ,United States of America (PAM 1972).

The fish samples are collected fresh and immediately after collection, the samples are preserved in ice and transported to the laboratory. The ice-frozen samples are then kept in –70°C freezer till further processing.

At the earliest opportunity the frozen samples are thawed, skin is removed from dorsal side of fish and 25g flesh is collected from an individual. In case of composite samples, uniform amount of flesh is collected from individuals to make 25 g. Anhydrous sodium sulfate (kept overnight at 140°C before use) is added and macerated. The homogeneous mixture is then put in Whatman glass micro fiber thimble and Soxhlet extracted for 6 h with 350ml petroleum ether (60-80°C fraction). All the solvents are re-distilled before use. The Soxhletted extract is again passed through sodium sulfate and concentrated in Kuderna Danish evaporator to about 5 ml. It is then partitioned thrice with 15ml acetonitrile (previously saturated with petroleum ether) in 60 ml separating funnel. In each time the acetonitrile fraction is transferred to a 1 litre separating funnel containing 600ml water, 100ml petroleum ether (60-80°C fraction) and 40 ml saturated sodium chloride solution for second stage of partitioning. The petroleum ether fraction is collected here after passing through anhydrous sodium sulfate. The second stage of partitioning is repeated for two more times with fresh petroleum ether. The total petroleum ether content is again concentrated in Kuderna Danish evaporator. The concentrate is then added to a glass column made of 25g Florisil (PR grade of Fluka and activated overnight at 140°C before use) with 5g and 10g anhydrous sodium sulfate placed in bottom and top respectively. The column is cleaned with 100ml petroleum ether before concentrate addition. It is eluted first with 200 ml 6 % diethyl ether in petroleum ether and then with 15 % diethyl ether in petroleum ether. The fractions are concentrated and final volume is made to 1ml.

Quantification of organochlorine pesticides is made in gas chromatograph. In CIFRI laboratory, Hewlett Packard : 5890 model instrument equipped with a DB-608 column (30m length, 0.45mm ID, 0.7μm film) and ^{63}Ni electron capture detector is used. The initial column temperature is 135°C, it is increased at a rate of 5°C/min to 165°C and held for 10min. Then the temperature is again increased at a rate of 2°C/min to 210°C and held for another 10 min. Final temperature increment was relatively fast of 10°C/min to attain 250°C where it is held again for 15min.The injector is kept at 250°C while detector at 300°C. The carrier gas is nitrogen (IOLAR

1) with flow rate of 4ml min^{-1}. Detector make-up gas (N_2) supply rate is 56ml min^{-1}. The total run time is 67.5min.

The 608 calibration mixture and individual standards obtained from Supelco, USA are used for peak identification and quantification. The recovery efficiency is first worked out before analysis of samples. The results are reported on fish wet weight basis.

Schematic Presentation

Fish tissue (25 g)

↓

Maceration and drying with anhydrous Na_2SO_4 (100 g)

↓

Soxhlet extraction with Petroleum ether (350 ml)

↓

Petroleum ether condensation to about 5 ml

↓

Partitioning with Acetonitrile (15 ml x 3)

↓

Partitioning Acetonitrile fraction with Water and Petroleum ether (100 ml x 3)

↓

Condensation of Petroleum ether fraction to about 2 ml

↓

Column chromatography with Florisil (25 g)

↓

Fraction collection

1st fraction with 6% Diethyl ether in Petroleum ether

2nd fraction with 15% Diethyl ether in Petroleum ether

↓

Condensation of fractions to 1 ml

↓

Analysis by Gas Liquid Chromatograph with ECD detector

Calculation :

$$\text{Residue level (ppb)} = \frac{\text{Peak area of unknown} \times \text{ng of standard injected} \times \text{Final volume of sample extract (ml)} \times 1000}{\text{Peak area of standard} \times \mu\text{l of sample injected} \times \text{Weight of sample (g)}}$$

Method of organochlorine pesticide residue analysis in water

The method used for water sample analysis is as described in *Environmental Protection Agency* (method no. 608), United States of America (Roberts Ailey 2000).

Water samples are collected in previously cleaned glass bottles, quickly transported to laboratory and preserved at 4°C. At the earliest opportunity the samples are processed. Before extraction step, the samples are brought to room temperature. Desired volume of water sample is taken in separating funnel and extracted thrice with 60 ml methylene chloride. The sample bottle is also washed with the solvent to avoid residue loss. The methylene chloride layer is passed through 10 cm column of anhydrous Na_2SO_4 and concentrated in Kuderna Danish evaporator to about 2 ml. Then 50 ml petroleum ether (60-80°C fraction) is added and again concentrated. The concentrate is then added to a glass column made of 20g Florisil and processed in the similar way like the fish samples.

Schematic Presentation

Water Sample

↓

Partitioning with methylene chloride (60 ml x 3)

↓

Methylene chloride fraction is passed through 10 cm anhydrous Na_2SO_4 column

↓

Methylene chloride fraction is concentrated to 2 ml, 50 ml Petroleum ether is added and again concentrated to about 2 ml

↓

Column chromatography with Florisil (20 g)

↓

Fraction collection
1st fraction with 6% Diethyl ether in Petroleum ether
2nd fraction with 15% Diethyl ether in Petroleum ether

↓

Condensation of fractions to 1 ml

↓

Analysis by Gas Liquid Chromatograph with ECD detector

Calculation :

$$\text{Residue level (ppb)} = \frac{\text{Peak area of unknown} \times \text{ng of standard injected} \times \text{Final volume of sample extract (ml)}}{\text{Peak area of standard} \times \mu\text{l of sample injected} \times \text{Volume of sample (l)}}$$

IMPACT OF PESTICIDE RESIDUE ON FISH HEALTH

Two types of toxicity effect occur in the environment. First one is the acute toxicity. Several instances of mass mortality of fish had been reported immediately after application of insecticides. Since most of the insecticides are toxic to fish also, such mass mortality is due to acute toxicity. After pesticide application, runoff from agricultural fields brought the poison into the aquatic ecosystem to cause mass mortality. Other group of pesticides may also be acutely toxic to fish. In Scotland, dinoseb and MCPA have been identified as pesticides responsible for fish kills in small streams in the same way as insecticides (Murty, 1986).

The second type is chronic toxicity. In many cases it causes more damage than the instant acute effect. The chronic effects are like slow poison. In absence of instant changes, these may be overlooked but the effect continues year after year and may persist for decades even. Schmitt and Winger (1980) cited several instances where sport and commercial fisheries had to be closed down because of occurrence of high pesticide residues in fish in USA. The discharge of 90.7 ton chlordecon into James river estuary during manufacturing of the compound at Hopewell Va. between 1966 and 1975 led to the closure of commercial and sport fishing in the estuary (Lunsford 1981).

Pesticides when applied in recommended dose may even cause disturbances in the aquatic environment. In African rivers Abate was applied for blackfly control. There was no mortality of fish but the behavioral changes (stressed swimming, altered behavior and preferences) caused a change in population structure, with certain species being more prone to be captured (Abban and Samman 1982). Dursban when applied in recommended doses for control of mosquitoes in ponds caused mass mortality of bluegills and bass, ducklings and invertebrates (Mecek *et.al.*, 1972 and Hulbert *et.al.*, 1970) .

Pesticide residues also exert their harmful effect on fish health by indirect means. The phytoplankton and zooplankton population changes quickly with the toxic residues. Thus, in the absence of proper food organisms, fish will suffer from starvation. Ultimately the biodiversity of the aquatic ecosystem gets altered.

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Summer school on ***Methods of Assessment of Aquatic Ecosystem for Fish Health Care***
18 July to 16 August, 2002

EUTROPHICATION AND ITS IMPACT ON FISH HEALTH

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INTRODUCTION

Eutrophication-excessive loading of nutrients- is a major problem in both lakes and reservoirs. Whenever the rates of synthesis and input of organic matter exceed the rates of recycling and output, an accumulation of matter within the aquatic system occurs, leading to its extinction. From season to season, considerable allochthonous energy accumulates in lentic water system and this either gets deposited, accelerates eutrophication or else enters the food chain in significant quantities.

Eutrophication is a problem, which became widely recognized by the scientific community in the 1940's and 50's. This is the term used to describe the biological effects of an increase in concentration of plant nutrients-usually nitrogen and phosphorus on aquatic systems. It is difficult to define precisely, because a description of the trophic nature of any one lake, river or estuary, is usually made relative to a previous condition or to a reference state of lower nutrient concentration, called mesotrophic (intermediate) or oligotrophic (low in nutrients). The German botanist Weber (1907) first used the adjective 'eutrophe', to describe the nutrient conditions which determine the plant community in the initial Stages of development of raised peat bogs. He only put forward the related terms, 'mesotrophe' and 'oligotrophe'. These three terms were used in limnology some 12 years later by the Swedish botanist, Naumann (1919) to describe freshwater lake types. These concepts fitted well with other contemporary approaches to the classification of lakes in Europe. Ideas of lake evolution were then taken further in the United States. Lindeman (1942) in a classic paper which developed the concepts of energy flow through the different levels of aquatic food webs, suggested that eutrophication was a natural stage in lake's life as it gradually filled in with sediment eroded from its catchment and with organic matter from its own metabolism. Fig. 1 illustrates an extension to Lindeman's natural eutrophication due to anthropogenic activities. Eutrophication is an important part of the successional process by which lakes pass from their original nutrient -poor or oligotrophic condition through an intermediate mesotrophic condition to a very productive steady state of eutrophy (Fig.2.). This might last for a very long time i.e. thousands of years until it becomes shallower with sedimentation and smaller with encroachment of marsh and finally to a closed swamp or fen (Fig.3)

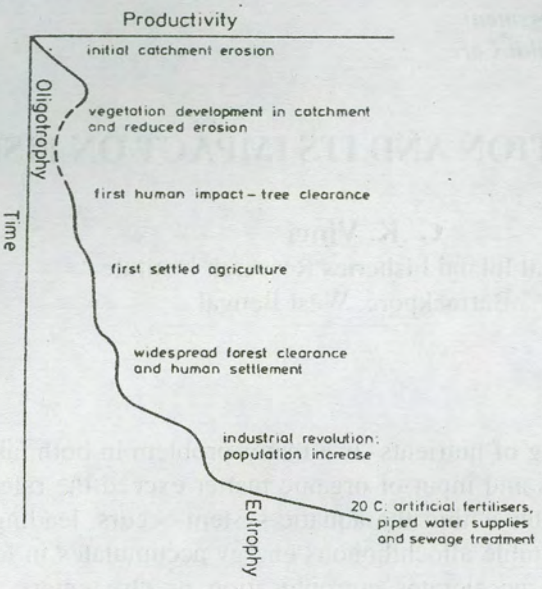

Fig. 1. An extension to the lake phase of Lindeman's successional graph

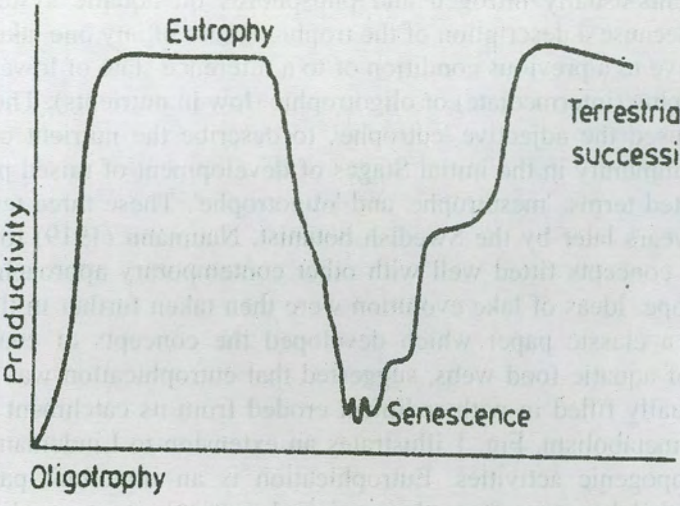

Fig. 2. The concept of lake productivity change with age from oligotrophy to eutrophy. Modified from Lindeman (1942)

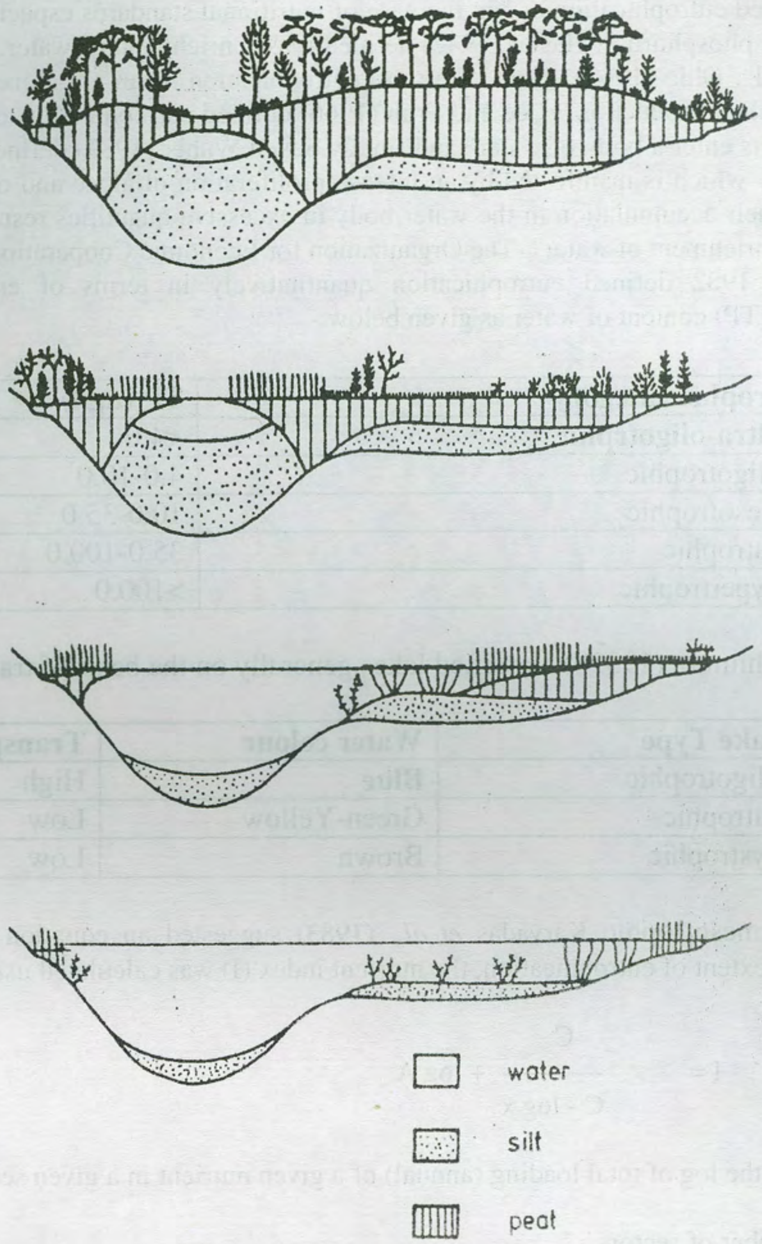

Fig. 3. Diagrammatic representation of successional changes of a lake from open water to closed fen

Definition

There are a number of definitions put forward on eutrophication by different authors. Naumann (1931) defined eutrophication as "an increase of nutritional standards especially with respect to nitrogen and phosphorus"; Hasler (1947) defined it as "enrichment of water, be it intentional or unintentional"; Ohle (1965) stated "the term eutrophication mean enrichment in nutrients and increase of plant production"; Lee and Fruh (1966) defined eutrophication as "the rate at which plant nutrients enter a body of water" and finally Seven Waher (1989) defined it as "the state of a water body which is manifested by an intense proliferation of algae and other higher aquatic plants and their accumulation in the water body in excessive quantities resulted as blooms due to nutrient enrichment of water". The Organization for Economic Cooperation and Development (OECD) in 1982 defined eutrophication quantitatively in terms of enrichment of total phosphorus (TP) content of water as given below:-

Trophic category	**TP (ug/l)**
Ultra-oligotrphic	<4.0
Oligotrophic	4.0-10.0
Mesotrophic	10.0-35.0
Eutrophic	35.0-100.0
Hypertrophic	>100.0

Yoshimura (1933b) classified lakes generally on the basis of transparency:-

Lake Type	**Water colour**	**Transparency**
Oligotrophic	**Blue**	High
Eutrophic	Green-Yellow	Low
Dystrophic	Brown	Low

I = 3-5 is mesotrophic Karyadas *et al.,* (1983) suggested an equation to understand the quantitative extent of eutrophication, the nutrient index (I) was calculated using the equation:

$$I = \frac{C}{C - \log x} + \log A$$

Where 'C' = the log of total loading (annual) of a given nutrient in a given sector

'X' = the number of sectors

According to this method the classification for estimation of 'I' is

I > 5 is eutrophic
I = < 3 is oligotrophic

Balanced ecosystem

Any ecosystem is said to be balanced where the species diversity is high and there is a balanced trophic relationship with one another. There is a surplus of oxygen if there is a balance between the production and decomposition of organic matter as well as between the production and consumption of oxygen. Besides oxygen and energy, organisms also need large number of essential nutrients for their growth which are cycled again and again from soil → water → plant → animal and then, trophic level → trophic level through bio-geo-chemical cycling. Thus, there is a self-regulated process of nutrients in oligotrophic water bodies. Such ecosystems are infested with large number of plant species like *Hydrilla verticillata, Chara* spp., *Potamogeton crispes, Utricularia fexinosa, Ceratophyllum* spp., *Nelumbo nucifer, Nymphyaes* sp., *Nymphoides* sp., *etc.* in the shallow region of the littoral zone of the lake whereas limnetic zone is dominated by phytoplankton and zooplankton. Oxygen content is rich which favors the production of fishes and other animals.

First stage of eutrophication

Excess influx of allochthonous nutrients through washings of the catchments or through direct loading of domestic sewage promote algal blooming and acceleration of macrophytic growth. Thus, the existing healthy community structure will give way to forced changes due to the addition of toxic substances and organic pollutants which in turn increase the range of more tolerant species.

Second stage of eutrophication

After the disappearance of sensitive species, other species like *H verticillata, Ceratophyllum* sp., *Najas major* etc. form the dominant stand with *Spirodela* sp., or *Azolla* sp., or a mono specific stand (Kulashrestha, 1981) If the first two species are present *Hydrilla* completely destroys the latter and form the mono specific stands (Kulshrestha and Gopal,1983). *Nymphaea* and *Nymphoides* sp., may be present at this stage in deep waters in mesotrophic lakes (Billore and Vyas,1981)

Third stage of eutrophication

If free floating weeds like *Eichhornia crassipes, Pistia* or *Salvinia* sp. are present in any ecosystem receiving sewage and effiuents containing phosphate and nitrate in particular, they will start multiplying again and again and cover the whole water surface within 2-3 years.

Effects of eutrophication on phytoplankton

Nutrient levels are one of the most important determinants of the detailed pattern of species change because the same taxa of algae tend to dominate the changes in lakes of similar trophic status but differ between lakes of different trophic status. Table 1 shows the typical phytoplankton species available in lakes of different trophic status. When algae reach densities close to carrying capacity of lakes (blooms) they have adverse biological, physical and economic effects (Harper, 1995). The algal taxa responsible for such blooms in freshwater are cyanobacteria.

Table 1. Typical phytoplankton species dominating lakes different trophic states.

Oligotrophic	Mesotrophic	Eutrophic
Staurastrum, Cosmarium Staurodesmus (desmids)	*Staurastrum, Closterium* (desmids)	Melosira, Asterionella, Stephanodiscus, (diatoms)
Tabellaria, Cyclotella, Melosira, Rhizoselenia (small diatoms)	*Cyclotella, Stephanodiscus, Asterionella* (diatoms) *Pediastrum, Eudorina* (green algae)	*Scenedesmus, Eudorina* (green algae)
Dinobryon, (chrysophyte)	*Peridinium, Ceratium* (dianoflagellates)	*Aphanizomenon, Microcystis, Anabena* (cyanobacteria)

After Harper, 1995

Factors responsible for bloom formation

The following factors are responsible for bloom formation, a forerunner of eutrophication.

- Heavy doses of inorganic fertilizers, like, urea, superphosphate and weedicides
- High temperature, light
- Fluctuation of low and high DO
- High pH, 7.8 -9.5
- High organic matters (10-15 ppm)
- High N & P inorganic nutrients
- Concentration of nitrate in excess of 0.3 mg/l

Effects of eutrophication in a water body

A. Desirable

Eutrophication is an indication of productivity of a water body. Perhaps the most obvious benefit of eutrophication is the increase in the biomass, which can support any particular body of water. Additional nutrients due to the death and decay of plant and animal life allow more rapid growth of plankton and a subsequent increase in fish production. Algae help in the purification of water by symbiosis with aerobic bacteria.

B. Undesirable

The undesirable effects of eutrophication out number the desirable effects. The changed aesthetic values, increase of algal mats and macrophytic vegetation, changes in fisheries and induced fish kills, problems in water treatment plants, undesirable tastes and odours in water and increased costs of operation, development of anaerobic zones in lakes and toxic algae are the major adverse effects.

Some algae are objectionable not only in creating oxygen demands, but also for releasing toxic substances which kill fish and other animals as well. Four notorious species of blue-greens were cited by Prescott (1948), *Aphanizomenon, Microcystis spp*. (2 nos) and *Gloeotrichia*. Several species of Anabaena were also included in the list.

Water quality changes in reservoirs

Lower carbon dioxide level is noticed in the epilimnion (surface) due to the increased photosynthetic action by plants, which use the gas for energy. The content of carbon dioxide in the hypolimnion, where there is no sunlight, increases as a result of the carbon dioxide given off by the bacteria in cell synthesis (Fig.4).

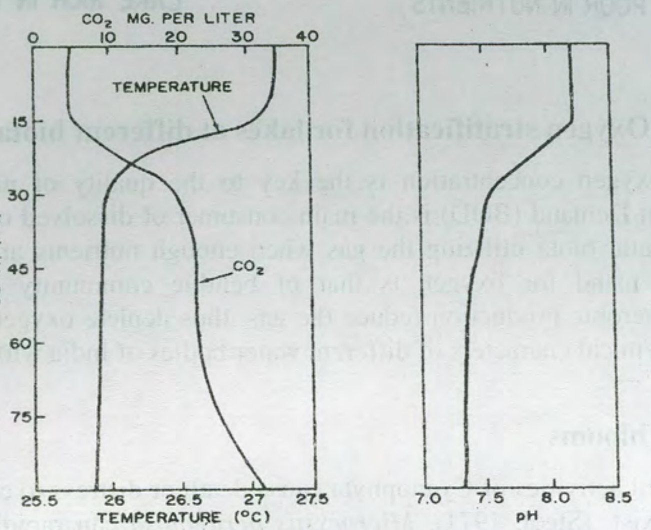

Fig. 4. Temperature, carbon dioxide and pH stratification in a eutrophic lake

Oxygen and carbon dioxide are the two complimenting agents in metabolism When the carbon dioxide in the epilimnion decreases an increase in oxygen is expected. Same way at the hypolimnion when CO_2 increases there is a decrease in O_2 level. Often the productivity of a lake can be estimated from the nature of O_2 curve. (Fig. 5). This is the positive side of eutrophication when seen as an indication of lake productivity.

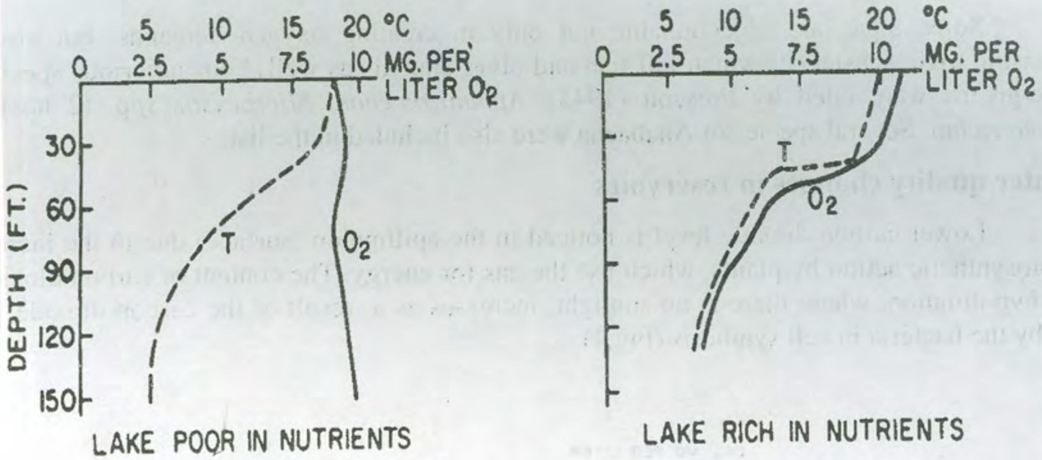

Fig. 5. Oxygen stratification for lakes at different biota levels

However, oxygen concentration is the key to the quality of natural water bodies. Biochemical Oxygen Demand (BOD) is the main consumer of dissolved oxygen. This demand is the result of aquatic biota utilizing the gas when enough nutrients are available for their growth. Another demand for oxygen is that of benthic community where both aerobic assimilation and anaerobic production reduce the gas. thus deplete oxygen in the system. The status of physico-chemical characters of different water bodies of India with their nutrient status are given in Table 2.

Problems of algal blooms

The increased activities of Cyanophyta cause death or distress to cattle which drink the water where they exist. (Steel, 1971). *Microcystis aeruginosa* can rapidly produce toxins in laboratory extractions (Bishop). Algae, even when relatively sparse, can change the character of the medium to make it unacceptable. The ubiquitous *Asterionella formosa* (diatom) can cause serious problems either by forming a surface mat or the individual cell penetrating into the water filter in the water supply system. *Stephanodiscus* (diatom) found in the eutrophic reservoirs of the lower Thames Valley posed much difficulty in filtration during water supply. *Tribonema* spp. and *Melosira* spp. also cause filtration problem after death due to their silica shells. *Microcystis* sp. produces one extracellular mucopolysaccharide, particularly when moribund, which causes flocculance in soft drinks (Taylor,1966). Requirements for bloom formation for different species of algae are given in Table 3.

Table 2. Physico-chemical characteristics of different water bodies in India

Water body/place	Limnologic type	PO_4 mg/l	NO_3 mg/l	O_2 mg/l	pH	Reference
Rajasthan						
Pichhola lake, Udaipur	Eutrophic	0.29-0.65	0.6-108	9.8-22.2	7.4-86	Billore & Vyas, 1981
Mansagar reservoir, Jaipur	Highly Eutrophic	1.9-6.00	0.6-1.5	10.3		Sharma et al., 1978
Durgapura Impoundment, Jaipur	Highly Eutrophic	3.0-7.5	2.0-8.5			-do-
Ramgarh lake, Jaipur		traces	0.34	9.0-14.0		Kulshreshtha, 1981
Ghana Bird Sanctuary, Bharatuur				5.5-6.0	7.1-8.4	
Uttar Pradesh						
Naini lake, Nainital	-	-	-	1.5-35	-	Das, 1980
Ramgarh lake, Gorakhpur	Eutrophic	0.036-0.125	0.14-0.47			Sinha & Sinha, 1978
Bihar						
Chaurs, Darbhanga	Highly Eutrophic	0.08-1.04	-	5.88	7.6-79	Raj & Datta, 1981
Andhra Pradesh						
Kolleru lake	Eutrophic	traces-0.1	0.2-2	5.6-13.0	8.2-8.2	Seshavathram & Venu, 1981
Orissa						
Chilka lake		traces	traces	0.3-10.4	6.8-9.7	Subba Rao et al., 1981
Jammu & Kashmir						
Anchar lake		0.012-0.029	0.095-0.580	4.2-10.85	7.5-9.5	Kaul et al., 1978
Dal lake		0.006-0.025	0.080-0.691	0.8-12.05	7.4-9.5	-do-
Malangpura wetland	Eutrophic	0.047-0.148	0.014-0.327	1.85-49.0	7.8-8.7	-do-
Hoakerser wetland	Eutrophic	0.019-0.079	0.228-0.374	3.2-12.5	7.2-9.0	-do-

After Saxena and Kulshreshtha, 1985

Table 3. Requirements for bloom formation differs among species.

	Chlamydomonas certeria	*Pandorina & Chlorogonium*	**Volvox**	**Euglena Polymorpha**	*Microcystis aeruginosa*
pH	Neutral	Medium 8.6	High alk.	7.2	9.6
Organic matter	High	Low	-	High	Very high
Iron	High	-	-	High	High
PO_4	High	-	High	High	-
DO	Low	High	-	Lower	High
NO_3	Low	High	-	-	High
HCO_3	-	High	Hardwater	-	-
Chloride	-	-	-	High	High

After Verma, 2002

When algal blooms occur and luxuriant growth of macrophytes takes place the death and decomposition of these plant groups lead to the formation of hydrogen sulphide, high rate of free carbon dioxide and reduced oxygen content in the water which often result in mass fish mortality. An algal mass of about 1.2 -1.6 ha in area was released through the lochs of Yahara river, Wisconsin. This decomposing mat of algae and the resulting anaerobic condition was regarded by Mackenthun, *et al.* (1948) as the main causative factor for mass mortality of fish. Later experiments attributed to toxic substances in the water possibly, hydroxylamine/H_2S or other proteinaceous derivatives. Some algae are objectionable not only in creating oxygen demands, but also because a few can release toxic substances, which kill fish and other animals as well. Four notorious species of blue-greens were cited by Prescott (1948), *Aphanizomenon, Microcystis* spp. (2 nos) and *Gloeotrichia.* Several species of *Anabaena* were also included in the list.

Cyanobacteria (mainly, *M aeruginosa* and *Anabaena* sp.,) blooms are very common in Indian reservoirs, which are indicators of eutrophication. The toxins of BGA (blue-green algae) commonly known as cyanotoxins are classified into hepato, neuro and cytotoxins .Defined by their chemical structure, cyanotoxins fall into three groups : cyclic peptides (the hepatotoxins, microcystins and nodularin), alkaloids (the neurotoxins, anatoxins and saxitoxins) and LPS (lipopolysaccharides). The species most often implicated with toxicity are given in Table 4.

Table 4. Toxicity of Cyanobacterial toxins

Toxin	LD_{50} (μg/kg. i.p. mouse	**Organism**
1. Microcystins-LR	50	M. aeruginosa, Aph. Flos-aquae, M. viridis
2. Microcystins- LA	50	M. aeruginosa, M. viridis
3. Microcystins-YR	70	M. aeruginosa, M. viridis
4. Microcystins-RR	600	M. aeruginosa, Anabaena sp., M. viridis
5. [D- Asp^3] microcystin-LR	50-300	M. aeruginosa, Aph. Flos-aquae, M. viridis, O. agardhii
6. [D- Asp^3] microcystin-RR	250	O. agardhii, M. aeruginosa, Anabaena sp
7. [Dha^7] microcystin-LR	250	M. aeruginosa, O. agardhii, Anabaena sp
8. [(6Z)-Adda] microcystin-LR	>1200	M. viridis
9. [(6Z)-Adda] microcystin- RR	>1200	M. viridis
10. Nodularin	50	N. spumigena
11. [D-Asp 1]nodularin	75	N. spumigena
12. [(6Z)-$Adda^3$] nodularin	>2000	Aph. Flos-aquae, Anabeana sp, Oscillatoria sp.
13. Anatoxin-a	200-250	Aphanizomenon sp., Cylindrospermum sp.,
14. Anatoxin-a(s)	20	Aph. Flos-aquae
15.Saxitoxin	10	Aph. Flos-aquae, A. circinalis, Cylindrospermopsis raciborskii, L. woliei
16. Cylindrospermopsin	2000	C. raciborskii, Umezakia natans, Aph.

After Pandey and Dwivedi, 2002

Sedimentation

Suspended solids, *i.e.,* turbidity are another major problem of eutrophication. Sedimentation plays the lead role in the succession of oligotrophic to eutrophic condition of a water body. Turbidity may be directly caused by high cell density of algae and bacteria, thereby producing disagreeable tastes and odors in the water. When the cell die they represent an organic load with high oxygen demand. Sedimentation is responsible for filling lakes and over a period of geological time results in conversion of a lake to swamp. This process is referred to as lake aging and a dead lake is one that is filled with sediment. Prior to this extreme end point, however, sediments can exert undesirable effects such as, elimination of fish spawning grounds and depletion of oxygen at the lake bottom interface due to oxidation of the organic portion of the sediment.

Effects of eutrophication on fish

Fish are generally in the upper levels of the aquatic food web and are thus affected directly or indirectly by several levels below them. 'Biomanipulation' of eutrophic lakes *i. e.*, the management of fish stock to control the lower trophic levels and alleviate the worst effects of environment is the new area of study in fishery science. The recruitment success of newly hatched fish often depends upon the short-term combination of favourable environmental and biological conditions.

Direct effects of oxygen concentration on fish

Eutrophication causes an increase in plant production in lakes; this may result in oxygen supersaturation of lake waters during day time photosynthesis and depletion by night time respiration. Day time photosynthesis may also elevate pH to lethal values. The ultimate consequence of plant production is an increase of detritus and hence bacterial oxygen demand, which itself may deplete oxygen concentration, particularly at high temperatures. Adult and juvenile fishes can avoid this condition by moving out of affected areas but they may encounter other unfavourable conditions. However, their eggs which cannot move out will be destroyed. Several examples exist of sudden and complete fish kills in nutrient rich water bodies (Sreenivasan, 1964).

Biomass and taxonomic changes

The overall population sizes and biomass of fish increase in a eutrophic lake when compared to oligotrophic lakes (Fig. 6).

Ecosystem interactions with eutrophication

Direct effects of eutrophication occur on primary production and macrophyte vegetation. In many cases, it has a positive effect on the fish biomass with the luxuriant growth of plankton and macrophytes. But the production of both these are inversely related. Fishes which take shelter under macrophytes and those with detrital food habits can get a complementary effect. Most species of cyprinid have planktivorous food habits the depletion in plankton due to increased macrophytes or algal blooms and decreased light penetration, will affect their production and the species diversity in the water body. In short, this may lead to the decline of economically important species from the ecosystem.

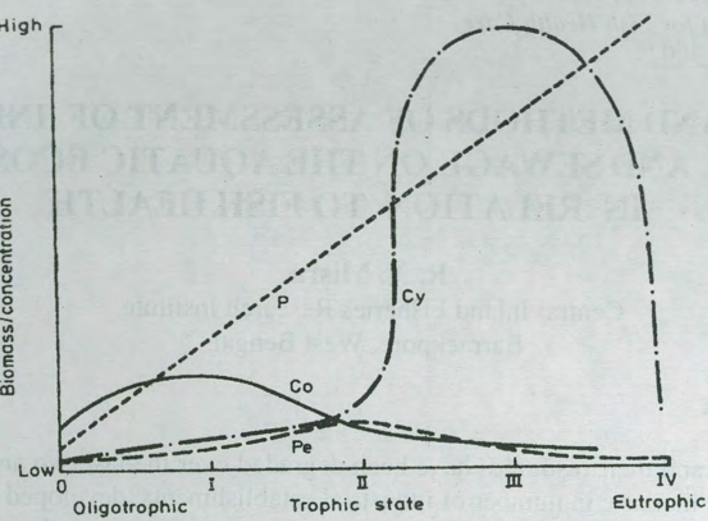

Fig. 6. Yield of fish under different trophic status in a European lake

Management of eutrophication

Extensive attempts to manage the adverse effects of eutrophication have been implemented in developed countries. Eutrophication control strategies can be divided into two areas:

1. Reduction in nutrient loads to lakes particularly of phosphorus and
2. Manaaging the existing high nutrient lakes to minimise the adverse effects.

There are methods to:

1. Manage the discharge points of effluents
2. practise nitrogen removal technologies
3. practise phosphorus removal technologies
4. control sedimentation which is a source of nutrients

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*Summer school on **Methods of Assessment of Aquatic Ecosystem for Fish Health Care***
18 July to 16 August, 2002

STATUS AND METHODS OF ASSESSMENT OF INDUSTRIAL WASTE AND SEWAGE ON THE AQUATIC ECOSYSTEM IN RELATION TO FISH HEALTH

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INTRODUCTION

The aquatic bodies and their resources have been degraded over the last two and a half decades, coinciding with the increase in number of industrial establishments, developed with little regard to environmental planning. The wastes generated by these industries are released untreated into the water which have resulted in detrimental effects on the aquatic ecosystem. Deterioration of water quality and contamination of water with heavy metals also takes place thereby threatening the fish and fishery of the aquatic ecosystem. In this connection it will be pertinent to bring the case of the river Hooghly to understand the impact of industrial waste and sewage on the water body.

Industrial Wastes :

Nearly 80% of the industries, located in the vicinity of Hooghly discharge their effluents into the river Hooghly without any treatment . The average daily discharge of effluents from various industries is 0.05 million m^3 of which pulp and paper industry alone contributes 49.86% whereas 22.5% from miscellaneous industries. The average total pollution load per day from all the industries calculated in terms of BOD, total solids, suspended solids and dissolved solids are 66.188, 894.053, 412.142,and 481.910 tonnes respectively . Pulp and paper industry contributes 28.59 tonnes BOD (43.2%), 547.40 t total solids (61.2%), 299.20 t suspended solids (72.5%), and 248.20 t dissolved solids (51.5%). The tonnage of BOD, total solids, suspended solids and dissolved solids for miscellaneous wastes are 14.92 t (13.95%), 164.235 t (7.08%), 55.305 t (5.23%) and 108.93 t (8.64%) per day respectively.

Domestic and municipal sewage:

Significant quantities of domestic and municipal sewage amounting to 68.95% of the total waste (0.79553 t/day) are discharged into the river. The total load in terms of BOD , TS, SS, and DS are 40.08, 1424.36, 645.40 and 778.96 tonnes per day respectively. The total volume of industrial, domestic and municipal effluents, disposed into the Hooghly river are about 1.1538million m3 /day which amounts to 106.268 t /day BOD, 2318.413 t TS, 157.542 t SS and 1260.87 t

The above wastes can be broadly classified as follows :

Organic wastes from processing of biological materials and / or from biological processes).

1. **Biological**	:	Pulp and paper, cotton textiles, tannins, distillery and yeast factory
2. **Hydrocarbon**	:	Wastes from rubber
3. **Miscellaneous**	:	Paints and varnishes, shellac, oil/storage/refinery and hydrogenated vegetable oil and soap.

Implications of industrial wastes and sewage on aquatic ecosystem

The untreated effluents discharged into the water body have extremely variable chemical composition. They include mineral acids, bases and many other toxic substances of non-biodegradable and bio-degradable nature. The impact depends on lateral, vertical and longitudinal mixing which is dependent on turbulance. Turbulance in turn depends on discharge, slope, depth, bed roughness and configuration, wind action and flow of water. Continuous discharge of these various effluents raise the bed of the river, reduce plankton, eliminating food producing riffles, spawning grounds, fish egg and larval population. Increased oxygen demand by organic sediments and high ambient temperature result in a marked deficiency of dissolved oxygen beneath the slime, though it may not be absent in the surface waters. Biodegradable materials like domestic sewage and effluents from tannery, distillery, yeast, pulp and paper, rubber, oil are main agents in changing ecological balance in the water bodies. Some of the major alterations caused are :

❖ High temperature during summer and monsoon accelerates the bacterial decomposition of organic matter and results in the formation of carbon dioxide and reduces the amount of dissolved oxygen at the soil water interface.

❖ The liberation of carbon dioxide in large quantities helps to cause thick algal blooms.

Dissolved oxygen varies inversely with concentration of dissolved organic matter present

❖ pH shows inverse relationships with the dissolved organic matter. Low concentration of organic matter is associated with high pH values and with the increase in organic content of water, pH decreases.

❖ Phosphates shows a direct relationship with organic matter. A rise in organic concentration is followed by a rise in phosphate content .

❖ Hydrogen sulfide generates below the surface and gets oxidized leaving behind an anaerobic zone of unsaturated inorganic and organic materials at the soil water interface.

❖ Benthic organisms may be wiped out completely and the equilibrium of the system changes drastically.

❖ Productivity becomes low around the outfall of sulfite pulp and paper mills.

❖ Bioaccumulation of heavy metals occur as seen from residues found in the tissues of fish, mollusces and the crabs in kidney and gonad of fishes in river Hooghly.

Methods of Assessment of the impact of industrial wastes and sewage on fish health

Physico-chemical and biological studies around the effluent discharge points of industries and sewage are important in determining their impact on the aquatic ecosystem. Estimation of different soil and water quality parameters *viz.,* pH, alkalinity, specific conductivity, dissolved oxygen, dissolved solids, BOD, COD, turbidity, plankton, primary productivity, suspended solids, concentration of toxic metals, etc., sand, silt, clay, chalk, gypsum content. Histopathological examination of liver, pancreas, spleen and gonads are generally employed. Density and surface area of pigmented macrophage aggregates (PMA), presence or absence of inflammatory, preneoplastic and neoplastic changes are evaluated in spleen and liver. Stages of maturity of the gonands are also determined. Several Biomarkers utilized for assessing the health of fish living in habitats degraded by industrial wastes and sewage are :

1. Body and hepatosomatic indices (HSI).
2. Histopathology of liver, spleen and gonads and gills.
3. Levels of hepatic detoxifying enzymes.
4. Mixed function oxygenases (MFO)
5. Muscle acetylcholinesterase (ACHE)
6 Condition factor (K)
7. Health Assessment Index (HAI)
8. Population age structure

Diagnostic system of fish health is substantiated by their clinical and pathological symptoms and histopathology of the disturbances in the cell structure of both organs and tissues. The express diagnosis of toxicoses at micro level is most informative system for assessing fish health under industrial waste and sewage.

Effect of industrial waste and sewage on fish health

The industrial and domestic sewage released on water bodies can introduce a variety of pathogens and stress situation unfavorable for fish in the water body. Any change in turbidity, pH, DO, CO_2, BOD, immediate oxygen demand and heavy metal concentration in the water affects the survival, growth and reproduction of fish and other organisms. Probable effects may be summarized as:

1. Finely suspended particles, possibly lignin clog the gill filaments which affects respiration in fish
2 Effluents have synergistic effect due to asphyxia and poisoning of gastro-intestinal tract.
3 Pathological changes in the gill, thickening of epithelial cells and often fusion of the adjacent lamellae. In some individual even fin rot may be observed
4 Pathological symptoms that may be observed are
   - i) reduction in size of the liver (6.5%)
   - ii) inflammeted gall bludder filled with either red or green fluid (8.0%)
   - iii) release of excess fatty droplets from liver (9.0%)
   - iv) caudal fin rot (5.55%)

v) anemic gills (6.55%)

vi) parasitic copepods (10.0%)

vii) leech (6.0%).

5. Deoxins, frames and other organic contaminants exhibit signs of physiological stress in fish.

6. Pulp and paper mill wastes depresse sex hormone levels in certain fish and cause shows external abnormalities.

7. Deposition of biodegradable materials in the vicinity of outfall promotes dense growth of sphaeratilus protozoa and zooglea covering the waterbed and smothering benthic biota.

8. Reduction in the supply of food due to the adverse effect of effluents on plankton and other biota , destruction of spawning grounds and direct and indirect effects of suspended solids affects fish adversely.

9. Coloured effluents particularly from pulp and paper, textile and paint industries and also from distillery affects the plankton adversely.

10. Heated discharge from the thermal power stations into the water has adverse effects on the resident aquatic organisms. This includes mortality of fishes and absence of aquatic life within 50 km of discharge points owing to high temperature (46 – 53^{o}C) of the effluents. The main ecological consequence of heated discharge into the aquatic ecosystem are increase in water temperature, alteration in chemical parameters and changes in metabolism and life history of aquatic communities.

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USE OF PLANKTON AND PERIPHYTON AS BIOINDICATORS OF OPTIMUM WATER QUALITY FOR FISH HEALTH

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INTRODUCTION

Detection of pollution or eutrophication using biotic communities including the plankton and periphyton has been pursued for many years. Many workers like Stein and Danison (1967) maintain that biological indicators are better than chemical or physical features used alone. The fact remains that chemical factors indicate the conditions whereas biological observations measure effects. With the manifold increase in environmental perturbations in aquatic ecosystems, their rapid surveillance has become imperative. Evidently, biomonitoring using biotic communities as indicators has a definite role to play in assessing water quality quickly. It is an established fact that changes in aquatic environment exert a selective action on flora and fauna and the effects produced on them can be used to establish biological indices of water quality. Of late, simple, rapid and reliable methods for assessing the degree of purity or contamination of waters have been developed to such an extent that a number of them merit consideration, as applicable over a wide variety of waters.

The basic argument, however, is on the groups of organisms that are better suited for such studies. There is lack of unanimity in the use of bio-indicators as different people have used different sets of organisms for the assessment of pollution load in a system. For instance, the animal based indices have been criticized that they are often motile, as such move from the site. A similar objection has been made to the use of phytoplankton, as it is carried away by waves and currents thus can not provide the authentic assessment of a site. Evidently, the organisms, which exhibit little locomotion or sedentary in habit could be considered as the best suited organisms for biomonitoring studies. The use of periphyton and benthic organisms, therefore, is more relevant as such organisms are, by and large, localized in origin. Among algae periphytic species in general and diatom species in particular have received more attention and greater acceptance amongst the aquatic biologists (Zelinka and Marvan, 1961). Similarly, among zooplankton rotifers have widely been used as the indicators of organic load in an aquatic system.

TYPES OF BIOLOGICAL TESTS

There are two types of biological tests through which measurement of aquatic systems can be attempted, such as:

- All organisms present in a water body are identified and their relative frequency is established. These are *direct ecological tests,* which involve all kinds of organism present or they may be limited to a few groups, one group, individual species or few types of individuals.

- *Indirect or physiological methods* are used to estimate the living activity of organisms. They may be limited to a particular species, which is cultured in laboratory and inoculated into a sample of water to be tested. Certain selected reactions serve as indices of water quality (WHO, 1963, Bulletin).

CONCEPT OF BIO-INDICES

The concept of the presence of species indicating certain conditions is based on practical observations verifiable by almost anyone who has contact with environment. Rapidly producing populations of microorganisms, such as bacteria, fungi, protozoa and certain algae are among the best indicators indicating organic load in a system. Concurrent with the development of Kolwitz and Marsson' s saprobian system, classifications for lakes began to focus on oxygen content and biological components (Thienemann, 1925). Considerable debate on the assignment of valences (a ranking of the indicator value of a species for levels of pollution) and application of biotic indices is a continuous process (Guhl, 1987; Foissner, 1988). The concept of species diversity revolved round the theory that the organisms living in pollution free environment exhibit wide variety of species with relatively smaller community size. Therefore, any change in the natural environment or presence of any stress factor resulting in reduction in species but increase in biomass of certain tolerant or favourable species. Accordingly, different workers have assigned different index values, such as:

- 3 (clean water), 1-3 (moderately polluted) and <1 (grossly polluted) - Wilhm and. Doms 1966.
- 3.0 -4.5 (mild enrichment), 2.0-3.0 (mild pollution), 1.0 -2.0 (moderately polluted) and 0.0- 1.0 (heavliy polluted).

THE IDEAL ORGANISMS FOR BIOTIC INDICES

The biotic communities to be used as bio-indicators should qualify the following criteria:

- Easy to identify by non-specialist
- Cosmopolitan in distribution
- Numerical abundance adequate
- Low genetic and ecological variability
- Body size reasonably large
- Limited mobility with relatively longer life-history
- Ecological characteristics are well known
- Suitable for use in laboratory studies

SOME COMMONLY USED BIOTIC INDICES (AT A GLANCE)

Certain common biotic indices are given in Table 1.

Table 1. Important biotic indices

Indices	**Input data**	**Taxonomic precision,**	**References**
Based on Indicator species			
Saprobity index	Abundance by species	High	Pantle & Buck, 1955
Based on species diversity			
Shannon index	Abundance by species or proportional abundance	Moderately high	Simpson, 1949
Brillouin index	Abundance by species	-do-	Brillouin, 1951
Margalef index	Species number, total abundance	High	Margalef, 1958
Sequintial comparison	Runs, total individuals	Low	Crains & Dickson, 1971
BMWP score or BBI	Family score of macro-invertebrates	Low	Woodiwiss, 1964; Armitage *et al* 1983; Pauw &Vanhooren, 1983
Invertebrate community index	Abundance by species, expected values, categorical score	Moderately high	**Ohio, EPA, 1986**
Biotic Integrity	Abundance by species	-do-	Carr *et al*, 1986

BMWP = Biological Monitoring Working Party, BBI = Belgium Biotic Index

USE OF PLANKTON AND PERIPHYTON IN WATER QUALITY ASSESSMENT/BIOTIC INDICES

Many workers used plankton or periphyton communities for the assessment of pollution / eutrophication or classification of water bodies in various ways. Some such systems are as under:

1. **Fjerdingstad (1967) system of classification**:

He classified water bodies based on the texture of plankton and periphyton into eight categories.

Category I:	Coprozoic	: Bacterium and bodo communities
Category II;	α-polysaprobic :	*Euglena -Rhodo* bacterium communities
Category III:	β-polysaprobic :	*Beggiatoa* community- *Thiothrix* community- *Euglena* community
Category IV:	γ- polysaprobic :	*Oscillatoria community-Sphaerotilus tenue*
Category V:	α--mesosaprobic	: *Ulothrix-Oscillatoria-Stigeoclonium* communities
Category VI:	β -mesosaprobic	: *Cladophora-Phormidium* communities
Category VII:	γ –mesosaprobic	: Rhodophyceae -Chlorophyceae communities
Category VIII:	Oligosaprobic	: Chlorophyceae- Diatom (pennales)- Rhodophyceae-Phormidium communitie

2. KNOPP (1954) Index:

$$\text{Relative pollution load} = \frac{\Sigma\,(\text{a-mesosaprobic species number} + \text{ß -mesosaprobic species number})}{\Sigma\,(\text{oligosaprobic species No.} + \text{a-mesosaprobic species No.} + \text{ß-mesosaprobic species No.} + \text{polysaprobic species No.})}$$

3. Pantle & Buck (1955) Saprobial Index:

$$SI = \frac{\Sigma\ \text{polysaprobic \% x 4 + a-mesosaprobic \% x 3+ p-mesosaprobic \% x 2 + Oligosaprobic \% x 1}}{100}$$

4. Dresscher & Mark (1976) Sabrobic Index:

$$\textit{Sabrobic index} = \frac{C + 3D - B - 3A}{A+B+C+D}$$

Where,

Group A = Ciliates indicating polysaprobic condition

Group B = Euglenoids indicating α-mesosaprobic condition

Group C = Chlorococcales + Diatom indicating β -mesosaprobic condition

Group D = Peridinians+Chrysophyceae +conjugales indicating oligosaprobic condition

(Values vary between -3 and + 3)

5. Weber (1973) Autotrophic or Saprobic Index:

$$AI \text{ or } SI = \frac{\text{BIOMASS (dry weight organic matter)}}{\textit{Chlorophyll a}}$$

Biomass used in this case is either plankton or periphyton to avoid taxonomic enumeration of the communities. The values are low at unpolluted water and high in polluted water.

6. Shannon and Weaver Index:

$$H = \Sigma (n_i/N) \log_e (n_i/N),$$

Where, N = total number of species, ni = No. of species in *i* th species

The evenness (J) is calculated as:

$J = H/H\ max$

H max = log$_e$ X s, where s = number of species

7. Use of diatom species as bio-indicators

Members of diatoms are considered as one of the best test organisms for the use in freshwater biomonitoring, the reasons are:

- Ubiquitous in distribution
- Available throughout the year
- More prone to environmental perturbation being mero-benthic in origin
- Taxonomically well documented and prevalent as periphyton

$$\textit{Diatom Index (DI)} = \frac{\text{No. of Centrales}}{\text{No. of Pennales}}$$

(Higher the value higher the saprobity)

8. Nygaard (1949) indices of saprobity:

Nygaard (1949) developed a saprobity system using various groups of algae growing at various niche but the accuracy of his indices are dependent on identification of organisms up to species level. The indices proposed by him are as under:

(i) Myxophycean Index (MI) = $\frac{\text{No. of species of Myxophyceae}}{\text{No. of Desmids}}$

(ii) Cholorophycean Index (CI) = $\frac{\text{No. of species of Chiorococcales}}{\text{No. of Desmids}}$

(iii) Diatom Index (DI) = $\frac{\text{Number of centric diatom}}{\text{Number of pennate diatom}}$

(iv) Euglenophycean Index (EI) = $\frac{\text{No. of Euglenophyceae}}{\text{No. of Myxophyceae + No. of Chlorococcales}}$

(v) Compound Index (COI) = $\frac{\text{Nos. of Myxophyceae + Chlorophyceae + entric diatom + Euglenophyceae}}{\text{No. of Desmids}}$

Nygaard argued that since Myxophyceae and Chlorophyceae proliferate more luxuriantly during warmer months, as such the application of MI and CI are more relevant during summer months. However, the DI could be used anytime as the members of this group are generally ubiquitous in distribution. The range of values suggested by Nygaard (1949) given in Table 2.

Table 2. Phytoplankton indices for oligotrophic and eutrophic waters

Saprobity status	MI	CI	DI	EI	COI
Oligotrophic	0.0-0.4	0.0-0.7	0.0-0.3	0.0-0.2	0.0-1.0
Eutrophic	0.1-3.0	0.2-9.0	0.0-1.75	0.0-1.0	1.2-25.0

9. Saprobicity Index (German concept)

This mode of assessment of saprobicity is a modification of Kolkwitz and Marssons' Saprobic Index, based on relative frequency of organisms. The practices followed in East Germany are, that each organism is assigned a number from 01 to 04. The number is based on its position in the saprobity system and its frequency (WHO Bull, 1963). The organisms prevalent in oligotrophic zones are assigned as 0l and so on through the 4 zones. The frequency (h) is divided as rare = 1, common = 3 and abundant = 5. Thus the Saprobity Index (S) can be calculated for each sampling zone following the formula:

$$S = \frac{s \times h}{h}$$

Where, s = assigned number of species, h = frequency. Relative values are given in below Table 3.

Table 3. Sabrobity values (German concept)

Saprobity index	Degree of pollution/Eutrophication
1.0-1.5	Mild
1.5-2.5	Moderate
2.5-3.5	Moderately high
3.5-4.0	Very high

10. Biological Index of Pollution using producers and consumers

Taking cognizance of both producers (algae) and consumers (protozoa + zooplankton) a saprobic index has been developed (Horasawa, 1942) by comparing the number of *chlorophyll bearing* and number of *non-chlorophyll bearing* organisms, which is known as biotic index of pollution, such as :

$$\text{Biological Index of Pollution (BIP)} = \frac{B}{A+B}$$

Where, A represents the producers (algae) and B represents the consumers (mainly protozoa). The values expected and the interpretations made are as under:

> 0.6 = zone of clean water

< 0.6 to > 12 = zone of moderate decomposition

< 12.to > 30 = zone of active deposition

< 30.0 to < 50 = septic zone

CERTAIN INDICATOR SPECIES FROM PLANKTON AND PERIPHYTON

Certain important indicator species established by various workers from different aquatic regimes are presented in Table 3:

Table 4. Organisms indicating various level of saprobity

Class/Indicator species	Types of load indicating	Indifferent to pollution
Mxophyceae		
Microcystis aeruginosa	Mild to high organic load Industrial + Sewage	*Phormidium* spp *Merismopedia tetrapedia*
M. flos-aqaue	Industrial pollution	
M. protrubens	Organic pollution	
Merismopedia glauca	Relatively clean water	
Rhapidiopsis spp		
Euglenophyceae		
Euglena virdis	Mild to high organic load	
Phacus spp	-do-	
Trachelomonas spp	relatively clean water	
Clorophyceae		
Member of Volvocales	Mild organic load	*Scenedesmus* spp
Pediastrum spp	Mild to high organic load	*Pediastrum duplex*
Ankistrodesmus falcatus	Relatively clean water	
Members of Desmids	Oligotropic or acidic waters	
Bacillariophyceae		
Pennates (except the following)	Oligotrophic	*Gomphonema angusta*
Nitzschia palea	Mild organic load	*Achnanthes* spp
N. chlorie	-do-	*Fragilaria intermedia*
N.sigma	-do-	
Gomphonema parvulum	-do-	

Dinophyceae	Prefer to grow better in clean water	
Zooplankton		
Protozoan Rotifers Copepods Cladocera	Organic load Organic load Relatively clean water Clean water	Many forms of these groups are indifferent too.

CONCLUSION

In this age of rapid development considerable attention has been made to reduce the time required for obtaining information on biological communities. Diversity indices provide a single value for the content of a community even without detailed taxonomic enumeration.

The plankton and periphytic organisms could be the attractive tools for biological monitoring because they are widely distributed and posses diverse groups of organisms. However, it requires fair degree of precision and ample sample size for making it authentic and representative. The members of periphyton in particular react sharply to environmental perturbations as remain attached at the solid-liquid interface in an ecosystem. Thus periphytic organisms are more useful in quick assessment of an ecosystem as compared to plankton.

The population of the world, especially of the third-world countries, is increasing at a very rapid pace suggesting additional pressure on environment at a very faster rate then ever before. It is imperative, therefore, that biological monitoring systems be developed to follow environmental changes so as to protect the ecological integrity of aquatic ecosystems including the biotic resources.

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Summer school on ***Methods of assessment of aquatic ecosystem for fish health care***
18 July to 16 August, 2002

USE OF BENTHOS AS BIOINDICATOR OF WATER QUALITY IN RELATION TO FISH HEALTH

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INTRODUCTION

Aquatic environment are subjected to various physico-chemical stresses either of short or prolonged duration due to anthropogenic activities. Macrobenthic invertebrates with wide species range and distribution have importance in stress effect evaluation based on their community behavior, density distribution and environmental sensitivity.

Effect of water quality on benthic invertebrates

The organic and inorganic enrichment in the aquatic system causes sludge deposits in the bottom and decrease in dissolved oxygen which affects the respiratory and digestive process of macroorganisms. The extent of anaerobic conditions depends upon the degree of pollution, rate of fluid flow and temperature. Under these conditions the number of pollution intolerant species is drastically reduced. Organisms like molluscs specially the gastropods, annelids (oligocheate worms) and chironomid insect dominate in eutrophic environment and act as indicators of pollution. Gastropods show preference for semi-decomposed or decomposed organic matter and require a minimum level of oxygen to survive. Oligochaetes multiply faster, if the environment is anaerobic and the organic materials are in decomposed state. Leech (Annelida) is the only indicator of the fresh water and does not survive even in least polluted zone. It has been observed that in a less polluted zone the number of species is always higher with relatively few individuals of each species, while in a heavily polluted zone, the number of species decreases.

Due to heavy dilution in the rainy season, the impact of polutional load is not significant and the abundance and variety of macroorganisms are affected. After rains, the recovery is generally noticeable. Summer is the best period for the qualitative and quantitative estimation of macroorganisms.

The presence of species and their relative abundance have been shown to accurately reflect the degree of contamination in an aquatic habitat. Species richness has also been used in many studies and forms the basis for derived measures. A component of species diversity, species richness is a quantifiable measures of the number of species present per unit area or volume. The abundance of species has been a standard of measure for 'Good quality' habitat. The rate at which species richness changes in response to contamination is a function of the nature of the species being exposed. Relative abundance is a measure of how the number of individual in a community are distributed among the species present.

Practical utility of benthos as bio-indicators

The benthos is an excellent biotic indicator of ecosystem change for several reasons. The length of their life cycles provides long-term exposure to toxic substances, relative to others such as zooplankton. Secondly, the benthic macroinvertebrates live in intimate contact with the sediments, which enhances their contact with many pollutants. Thus, the toxins build up to easily detectable levels in benthic macroinvertebrates. Thirdly, decomposition, the fundamental process where in dead organic matter is broken down into CO_2 and simple inorganic molecules takes place in the benthos. Studying rates of decomposition, therefore, provides an effective vehicle for assessment of ecosystem functioning.

Although some chironomidae and culicidae have short life span (around 20 days at temperature >25^0C), many benthic macroinvertebrates have only one generation per year. Some Megaloptera, Odonata and Placoptera live upto four or five years (Meritt and Cummins, 1984) and crayfish can live much longer. This is in contrast to very short (days to weeks) life cycles of phytoplankton and zooplankton. Therefore, benthos will endure sustained exposure to environmental hazards that can lead to population and community changes.

The sediments are repositories of accumulated nutrients and toxins that are some of the principal causes of environmental deterioration and creating stress conditions for fishes in freshwater systems. Benthic macroinvertebrates live in the sediments. Hence the zoobenthos are likely to represent changes in the chemical or pollution status of a lake or stream. Benthic macroinvertebrates bioaccumulate and biomagnify toxins such as heavy metals and pesticides.Furthermore, benthic macroinvertebrates can affect cycling of a contaminant in aquatic ecosystems through bioturbation and sediment resuspension (Reynoldson, 1987).

Diversity index and rapid assessment

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

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

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

1. *Richness measures*

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

2. *Enumerations*

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

3. *Community diversity and similarity indices*

i) Shannon's index - Calculated as: $\sum_{i=1}^{s} pi \log2 pi,$

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

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

Calculated as:

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

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

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

4. *Biotic indices*

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

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Summer School on ***Methods of assessment of aquatic ecosystem for fish health care***
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THE FISH AND ITS ENVIRONMENT - METHODS FOR STRESS DIAGNOSIS IN FISH

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INTRODUCTION

Fish are poikilothermal animals that live in water. In order to survive they need continuous acclimation with the environmental changes which occur in the water body due to alterations in the quality of the habitat because of many anthropogenic factors. Despite these man caused factor they have resistance enough to withstand such disturbances. To have a clearer understanding of the interaction of a fish with its environment, one must understand its salient anatomical features and its more important physiological mechanisms and process.

ANATOMICAL FEATURES

Skin and scales

Most of the freshwater fishes are scaly though some (catfishes) are devoid of scales. The skin is semipermeable and helps save the fish from the problems arizing by osmosis. The mucous cells of the skin gives protection against an adverse environment by reducing permeability of epidermis and protection against infection. Scales give added protection to the fish by preventing entry of pathogens.

Fins

Fins are the locomoter and balancing organs of fishes. Dorsal, pectoral, pelvic caudal and anal fins help in maintaining upright position, turning, steering, propulsion or braking. However, for movement in water fishes have to face great resistance termed as fluid drag. To overcome the resistance, body muscles help in dragging the fish through water by wriggling movement from the anterior end to the posterior end of the body.

Muscles

Fishes have two types of muscles; dark and white. Dark muscles are capable of producing energy through aerobic mechanism as they are richly vascularised. White muscles produce energy through anaerobic process and build up lactic acid which is the end product of carbohydrate metabolism.

Gills

Respiratory organs of fishes are their gills though some fishes have accessory respiratory organs. Freshwater fishes use their gills for their excretory purposes *i.e.,* they are amnolytic in habit and excrete ammonia. Compared to urolytic fishes which excrete urea through urine.

They are four pairs of gills in teleosts. These are borne on the first four branchial arches. Each gill filament is composed of several lamellae. Lamellae receive venous blood through afferent artery from ventral aorta and the blood carries away oxygen from lamellae through efferent arteries to the dorsal aorta. Oxygenation of blood is done by the process of diffusion. Ordinarily blood flow in gills is regulated by acetylcholine, an enzyme, while under stressed condition of a fish adrenaline (epirephrine) increases blood flow through the gill lamellae to facilitate diffusion of more oxygen in blood. There are chloride cells at the base of the gill filaments to regulate osmosis.

Swim bladder

It is an organ for maintaining buoyancy of the fish. Generally there are two types of swim bladder (i) physostomous and physoclistous having connection with oesophagous or not respectively. Naturally, fishes having physoclistous swim bladder takes a longer time in their vertical movement.

Digestive tract

Like all other vertebrate digestive tract of fish starts with the mouth which may be either a tubular sucking types or a grinding grasping type. However, according to food preference fishes, are classified as herbivores, carnivores and omnivores. Accordingly the type of mouth of fishes show variations; some fishes have teeth and others do not. From buccal cavity (which has taste buds) the food passes to the stomach (absent in cyprinids). In stomach, the food get mixed with mucous and gastric juices which is acidic. Rest of the alimentary canal is alkaline in nature because the secretions therein are alkaline. As such, the whole length of alimentary canal of cyprinids is alkaline. The intestine opens to the exterior through the anus which lies adjacent to the urinogenital aperture.

Haematopoetic tissue

Blood forming organs of fishes are anterior kidney, liver, spleen and thymus. Haemoblasts (totipotent cells), give rise to small and large lymphoid haematoblasts. Small lymphoid haematoblasts are transformed into erythrocytes (RBC) and probably into thrombocytes. Large lymphoid hematoblasts are transformed into granulocytes. However, circulating macrophages may have relation with both small and large lymphoid hematoblasts cells.

Sensory organs

Sensory organs of fishes are many. Each olfactory sac of a fish possesses two apertures of which the anterior is provided with a valve. However, nostrils are not ment for smelling. Smelling and testing facilities in fishes are dependent on a chemoreceptor system. Barbels serve the purpose of touch and taste. Some taste buds may be found in oesophagus but generally present in mouth. Chemoreceptors are distributed over the body surface in some fishes. Barbels are of great help in fishes which search for food in muddy bottom where eyes are of little use. Eyes are specialized organs for looking in an aqueous medium in fishes. The eye of a fish has a spherical lens which is covered by cornea and the same is supported by retractile muscles and ligaments. Though eye of fish is meant for looking at an object in aqueous medium but some fishes can see in air though the image may vary due to change of refractive index. However, such fishes have the capacity to aim at their prey flying in air. The auditory organ of a fish is a paired specialized large sized otolith.

This organ is mainly a gravity detector helped by 3 semi circular canals. However, apart from the paired otolith, lateral line also acts as a vibration detector. Lateral line system (the neuromast organ) of a fish is a characteristic organ composed of several units. Each unit has a opening through a scale. Each unit is a chamber which receives stimulus from an adjacent chamber through a pore and sends information to the other adjacent chamber through another pore. Thus the chambers, arranged in a row, form a continuous tube. In each chamber exists, an organ known as cupula which receives nerve fibres. Each cupula is a sensor of a neuromast organ and is composed of sensory hair or neuromast hair. Neuromast organs extend on either side of the trunk and tail.

PHYSIOLOGICAL MECHANISMS AND PROCESS

Swimming

All fishes can swim but swimming capabilities differ. Some are very active while others are sedentary. A fish has to swim through a medium which is 800 times denser than air. Energy requirement to swim fast is multiplied manifold when the normal speed of a fish is doubled.

Respiration

Like all other organisms, fishes need oxygen for their metabolic activity but they live in an environment where the rhythm of oxygen, caused by various factors, fluctuate a great deal. Further oxygen does not easily dissolve in water and its solubility in water and the water temperature have an inverse correlation. As such dissolved oxygen in freshwater ranges between 0-14 mg l^{-1}. This means that for required energy a freshwater fish must get a lot of water passed over its gills. It is reported by various workers that at standard temperature and pressure (STP) a fish gets 3.33 calories per 1 mg of oxygen used. Standard metabolism of a man is measured when he is completely at rest. The same cannot be measured for fish as it is to spend some energy for its floating. For production of energy, consumption of oxygen is a must. But diffusion of oxygen in water is temperature dependent. Further, compared to oxygen, carbondioxide is more easily soluble in water. As a result, fish may have to spend in a non-congenial environment at times. As such for maintenance of homeostasis (which means maintenance of physiological condition within narrow limits of an organisms) there are certain environmental limitations for a fish. Transfer of oxygen from water to the blood of a fish is a physiological process. Simply stated, that is by diffusion. But this transference becomes complicated process when the ambient water itself is deficient in dissolved oxygen.

Digestive system

In fishes the digestive mechanism is similar to those of other vertebrates but this is not so in carps as they do not possess a stomach. The food taken in by the fishes is digested by different enzymes which act upon carbohydrates, fats and proteins. Pepsin secreted by stomach acts on protein. Liver secretes bile to emulsify fat and to transform the same into glycogen. Pancreas secretes pancreatic juice to act upon proteins, carbohydrate and fat. The ducts of both these glands open in the anterior part of the intestine.

Blood circulating mechanism

Blood is a fluid which interacts with every organ of a fish flowing through arteries, capillaries and veins. The ventricle acts as a pump where the pressure for flow is generated. The pressure falls when blood reaches the gills, falls further as it reaches dorsal aorta. The pressure becomes almost nil when the blood flow reaches the capillaries. The blood reaches the auricle back into the heart, by almost a negative pressure as if by suction and by rhythmic squeezing of fish muscles during swimming. During a state of stress, epinephrine has a role to play in regulating blood flow. Two hormones, acetylcholine and adrenaline regulate blood flow through gill filaments. The former controls the flow when the demand for oxygen is low, keeping the blood in the internal cavities of the gill filament. During stressed condition of a fish under the influence of adrenaline epinephrine, blood flow is routed through gill lamellae when the gas exchange is maximum.

Osmoregulation

Freshwater fishes live in a hypotonic medium while marine fishes live in a hypertonic medium. As such, osmoregulation of a fish is a complex process which mainly governs homeostasis of a fish. In freshwater fish a lot of ambient water gets diffused in the fish through gill epithelia so to maintain salt water balance the fish excretes almost ion free urine. Marine fishes live in a hypertonic medium, as such a lot of water contianing Na^{+} K^{+} Cl^{-} ions comes out of fish gill epithelia.

Osmoregulation is a regularly continuing process among fishes but creates great problem among freshwater fishes as they are amnolytic in nature. Thus the freshwater fish has to retain its body salts but excrete almost ion free urine. As such for osmoregulation, a freshwater fish has to spend a lot of energy to maintain homeostasis. Kidneys of a freshwater fish also play an important role in osmoregulation and resultant homeostasis. As such, the symptoms of dropsy develop when kidney fails to function.

Mechanism of the endocrime system

Endocrine systems (which are ductless by definitions) of fishes have some diffused as well as some clear-cut glandular structure devoid of ducts. Pituitary, interrenal, corpuscles of stannius, chromaffin body and urophysis are the usual ductless glands while thyroid and pancreas are the diffused ones. Pituitary secretes prolactin, Adrenocorticotropin hormone, thyroid stimulating hormone, gonadotropins, somatotropic hormone, melanocyte stimulating hormone and corticotropin. Thyroid secretes thyroxin, calcitonin is secreted by Corpuscles of stannius. Estrogen and testosterone are secreted by the gonad; corticosteroids (including cortisol and cortisone) are secreted by interrenals (adrenal). Pancreas secretes both Insulin and glycogen. Several urotonsins (Arginine, vasotocin) are secreted by urophysis. Pituitary, controls the activies of other ductless glands but the pituitary itself is controlled by brain of fish.

CONCEPTS OF STRESS AND METHODS OF STRESS DIAGNOSIS IN FISH

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 light or severe exertion.

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

Haemoglobin/Haematocrit

Its 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

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POLLUTION INDICES – THEIR USE FOR EVALUATING ECOSYSTEM IN RELATION TO FISH HEALTH

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INTRODUCTION

Aquatic ecosystems are gradually accumulating pollutants due to burgeoning anthropocentric activities. So, it has become imperative to know the extent and magnitudes pollution in an aquatic system. This can be done by application of water pollution indices. These are of two types 1) chemical 2) biological. In the biological monitoring a number of organisms are taken into consideration *e.g.* bacteria, plankton, periphyton, macroinvertebrates, and fishes. In the present communication only biological pollution indices are described.

BIOLOGICAL INDICATOR

Advantages of biological methods

Biological assessment is often able to indicate whether there is an effect upon an ecosystem arising from a particular use of the water body. It can also help to determine the extent of ecological damage. Some kinds of damage may be clearly visible, such as unusual colour in the water, increased turbidity and the presence of dead fish. However, many forms of the damage cannot be seen or detected without examination of the biota.

Aquatic organisms integrate effects on their specific environment throughout lifetime. Therefore they can reflect earlier situations when conditions may have been worse. This enables biologist to give an assessment of the past state of the environment as well as present state. Micro-organisms such as ciliated protozoa, periphytic algae or bacteria, reflect the water quality one or two weeks prior to their sampling and analysis, whereas in larvae, worms, snails and other macroinvertebtrae organisms reflect more than a month, and possibly several years.

Biological methods are very quick, cheap and integrated into other studies. Compared to Physico-chemical analysis much less equipment is necessary and a large area can be surveyed very intensively in a short time.

Types of biological assessment

Biological assessment of water, water bodies and effluents is based on five approaches :

1. **Ecological methods**
   - analysis of the biological communities (biocenoses) of water body,

- analysis of biocenoses on artificial substrate placed in a water body, and presence or absence of a specific species

2. **Physiological and biochemical methods**
   - oxygen production and consumption, stimulation or inhibition
   - respiration and growth of organisms suspended in the water, and studies of the effects on enzymes.

3. **The use of organisms in controlled environment**
   - .assessment of the toxic (or even beneficial) effects of samples on organisms defined under laboratory conditions (toxicity tests or bioassays) and
   - assessing the effects on defined organisms (*e.g.,* behavioral effects) of water and effluents in situ, or on-site, under controlled situations (continuous, field or "dynamic " tests).

4. **Biological accumulation**
   - studies of the bioaccumulation of substances by organisms deliberately exposed in the environment (monitoring), and
   - studies of the bioaccumulation of substances by organism deliberately exposed in the environment (active monitoring).

5. **Histological and morphological methods**
   - Observation of histological and morphological changes, and embryological development or early life stage tests.

Advantage of using benthic-macroinvertebrates in bio monitoring

Benthic-macro invertebrates offer many advantages in biomonitoring, which explain their popularity. Some of these are intrinsic to the biology of the animals. First, they are ubiquitous, therefore, they can be affected by environmental perturbations in many different types of aquatic systems and in habitats within those waters. Second, the large number of species involved offers a spectrum of responses to environmental stresses. Third, their basically sedentary nature allows effective spatial analysis of pollutant or disturbance effects. Fourth, they have long life cycles compared to other groups, which allows elucidation of temporal changes caused by perturbations. As a result, benthic macro-invertebrates act as a continuous monitor of the water they inhabit, enabling long term analysis of both regular and intermittent discharges, variable concentrations of pollutants, single or multiple pollutants, and even synergistic or antagonistic effects.

RAPID ASSESSMENT METHODS

The rapid assessment methods have been divided into five categories: 1) richness, 2) enumeration, 3) community diversity and similarity indices, 4) biotic indices, and 5) functional feeding groups measures.

Richness method

This method is based on the number of distinct, specified taxonomic units in a collection or at a site, richness is a components and estimate of community structure. Macroinvertebrate species richness because it is based on specimens identified to the lowest taxonomic level, rather than on nominal species, which often requires rearing of specimens and taxonomic expertise for accurate identification. Often species are separated by perceived differences and are given designations (sp. A; sp. B, etc.). These groups may, or may not correspond to distinct species. Separation of various stages of the same species into different taxa would result in over estimation of taxa richness. More often however, similar appearing species are not separated, which results in under estimation of taxon richness.

Enumeration method

All collected organisms are counted to estimate relative abundance of different taxonomic groups (number of individuals in certain orders, families, or species or numerically dominant taxa in these groupings). Essentially no taxonomic effort is required for total number of individuals, require distinctions based on the group under consideration (e.g. numbers of individuals for a given order, family or species).

Community diversity and similarity indices methods

These measures of community structure usually require taxonomic distinctions at the species level (or at some higher taxonomic level of macro invertebrate richness). Total number of taxa provides a richness component in calculating the value of diversity indices, the number of individuals for taxon provides an evenness component. Among many diversity indices that have been proposed (Washington, 1984), the regularly used is Shannon's index (H').The Index is based on information theory and may be defined as

$$H' = -\sum_{i1=I}^{S} \frac{ni}{n} \; Ln \; \frac{ni}{n}$$

Where S is the number of the species in a sample, n the total number of the individuals in the sample, and ni the number of the individuals of each species I of the sample from of a population *i. e.* n =∑ ni

The concept of species diversity is based on the theory that in aquatic biotic community living in pollution free environment is characterized by the presence of a wide variety of species but only by a moderate number of each species. A change in the biotal community structure resulting in less species but greater abundance of select tolerant ones reflects the advent of condition of environmental stress. Wilhm gave the different values of H to denote the aquatic pollution. Value of H between 3-5 indicates clean water, and 1.0-3.0 as moderately polluted and below 1.0 as substantially polluted. Staub *et al.*, (1970) gave a slightly different value for H in terms of species diversity which is 3.0-4.5, 2-3, 1-2, 0.1, the degrees of pollution being slight, light moderate and heavy respectively, also indicating a negative correlation between H and pollution. Community similarity indices are used to compare community structure in space (e.g. among different sites) or overtime (year to year). A similar level of taxonomic discernment among the communities being compared is implicit in their use. Some community "Similarity Indices "stress richness (e.g. Jaccard index) or both richness and abundance (e.g. Pinkhan-pearson Index) have been often used.

Biotic Indices

It is an index of water pollution based on study of biota. "Biotic Indices" use pre-established water-quality tolerance values for taxa (families, genera, or species) that have been collected and identified. The relative abundance of taxa, weighted by tolerance values, sometimes may be included in the calculation of a biotic index. About 10 (ten) biotic indices are known out of these a few (Beak index, the Trent Index, Chandlers biotic score or CBS and Chutter index) are frequently used in pollution studies. For the Ganga River system a scoring system has been developed. In this method all families or species present are listed, scores are prescribed to each of these families according to the values indicated in table 2. The score for all families are added to give the total cumulative site score. It will be appreciated that the better the biological quality at the chosen sampling site, the higher will be the biological score. In fact, values well in excess of 200 could be expected in Himalayan river reaches.

Functional feeding groups method

These measures are community measures that are based on the morphological structure and behaviors responsible for food acquisition by given species at a site. Apparently, some discrepancy exists to how functional group designations currently are made and how they were intended to be made. Functional groups, as currently used in the ecological data table, reflect trophic levels (*i.e.* herbivores, detritivores, and carnivores) and are based on digestive tract analysis.

It may be concluded that most kind of the biological analysis can be used alone or as part of an integrated assessment system where data from biological are considered together with data from chemical analyses and sediment studies. A full appreciation of natural changes and anthropological influences in a water body can only be achieved by means of a combination of ecological methods and bio-tests.

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Table-1. Principal biological approaches to water quality assessment; their uses, advantages and disadvantages.

	Ecological methods		Microbiological method	Physiological and biochemical methods	Bioassays and toxicity tests	Chemical analysis of biota	Histological and morphological studies
	Indicator species* *e.g. biotic indices	Community studies** ** e.g. diversity or similarityindices					
Principal organisms used	Invertebrates, plants and algae	Invertebrates	Bacteria	Invertebrates, algae, fish	Invertebrates, fish	Fish, Shellfish, Plants	Fish, Invertebrates
Major assessment Uses	Basic surveys, Impact surveys, trend monitoring	Impact surveys, trend monitoring	Operational surveillance impact surveys	Early warning monitoring, impact surveys	Operational surveillance, early warning monitoring, impact surveys	Impact surveys trend monitoring	Impact surveys, early warning monitoring basic surveys
Appropriate pollution sources effects	Organic matter pollution, nutrient enrichment, acidification	Organic matter pollution, toxic wastes, nutrient enrichment	Human health risks(domestic and animal faecal waste) , organic matter pollution	Organic matter pollution , nutrient enrichment ,toxic wastes	Toxic wastes, pesticide pollution , organic matter pollution	Toxic wastes, pesticide pollution, human health risk (toxic contaminants)	Toxic wastes, organic matter pollution, pesticide pollution
Advantages	Simple to perform, relatively cheap. No special equipment or facilities needed	Simple to perform Relatively cheap. No special equipment or facilities needed. Minimal biological expertise required	Relevant to human health. Simple to perform. Relative cheap. Very little Special equipment required.	Usually very sensitive. From simple to complex methods available. Cheap or expensive option. Some methods allow continuous monitoring	Most methods simple to perform No special equipment or facilities needed for basic methods. Fast results. Relatively cheap. Some continuous monitoring possible	Relevant to human health. Requires less advanced equipment than for the chemical analysis of water samples	Some methods very sensitive. From simple to complex methods available. Cheap or expensive option
Disadvantages	Localized use. Knowledge of taxonomy required. Susceptible to natural changes in aquatic environment	Relevance of some methods to aquatic systems not always tested. Susceptible to natural changes in aquatic environment.	Organisms easily transported, therefore, may give false positive results away from source	Specialized knowledge and techniques required for some methods	Laboratory based tests not always indicative of field conditions	Analytical equipment and well-trained personnel necessary. Expensive	Specialized knowledge required. Some special equipment needed for certain methods

Table 2. Suggested biological-scoring system for the river Ganga based on BMWP method.

Siphlonuridae,Heptageniidae, Leptophelebiidae, Ephemerellidae, Potamanathidae	10
Ephemeridae(Ephemeroptera)	10
Taeniopterygidae,Leuctridae, Capniidae, Perlodidae, Perlidae	10
Chloroperlidae(Plecoptera)	10
Aphelocheiridae(Hemiptera)	10
Phryganeidae,Molannidae, Beraeidae, Odontoceridae, Leptoceridae	10
Goeridae,Lepidostomatidae,Brachycentridae, Sericostomatidae (Tricoptera)	10
Lestidae,Agriidae,Gomphidae,Cordulegasteridae,Aeshnidae,Corduliidae	8
Libellulidae (Odonata)	8
Psychomyiidae,Philopotamidae(Tricoptera)	8
Caenidae (Ephemeroptera)	7
Nemouridae(Placoptera)	7
Rhyacophilidae,Polycentropodidae,Limnephilidae(Tricoptera)	7
Neritidae, Viviparidae, Ancylidae, Unionidae (Mollusca)	6
Hydroptilidae(Tricoptera)	6
Corophiidae,Gammaridae,Paleamonidae (Crustacea)	6
Nereidae,Nephthyidae(Polychaeta)	6
Platycnemididae, Coenagriidae (Odonata)	6
Mesovelidae, Hydrometridae, Gerridae, Nepidae, Naucoridae, Notonectidae	5
Pleidae,corixidae (Hemiptera)	5
Haliplidae, Hygrobiidae, Dytiscidae ,Gyrinidae ,Hydrophilidae	5
Helodidae, Dryopidae, Elminthidae, Chrysomelidae, Curculionidae (Coleoptera)	
Hydropsychidae (Tricoptera)	5
Tipulidae, Simuliidae (Diptera)	5
Planariidae, Dendrocoelidae (Platyhelminthes)	5
Baetidae (Ephemeroptera)	4
Sialidae (Megaloptera)	4
Piscicolidae (Hirudinea)	4
Valvatidae, Hydrobiidae, Lymnaeidae, Physidae, Planorbidae, Sphaeriidae (Mollusca)	3
Glossiphoniidae, Hirudidae, Erpobdellidae (Hirudinea)	
Asellidae (Crustacea)	
Chrironomidae	2
Oligochaeta (Whole class)	1

PRINCIPLES GOVERNING BIO-ASSAY AND USE OF TOXICITY TESTS ON FISH AS A TOOL FOR BIO-MONITORING

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INTRODUCTION

Bio-assay refers to an evaluation of toxicity of an effluent or other material on living organisms such as fish. The bioassay may be used for many purposes, including the determination of :

(1) permissible wastewater discharge rates;

(2) to relate sensitivities of various animals;

(3) the effects of physicochemical parameters on toxicity;

(4) the compliance of discharge with effluent guidelines;

(5) the suitability of a chemical;

(6) the safety of environment and

(7) possible synergistic and antagonistic effects.

METHODS

The acute tests are conducted by exposing the test organisms to test solutions, which contain various concentrations of the test materials. One or more controls are taken which the organisms are exposed to similar conditions but without toxicant to provide a measure of experimental acceptability. The controls indicate the suitability of the dilution water, test conditions, handling procedures etc. Death is generally used as the criteria of a change in the 96-hour test while the extension of duration can be adopted for investigations of the various other related physiological, biological or behavioral changes. The concentration, which causes a 50 % live-death response, is defined as the lethal concentration or LC-50.

1. Acute Toxicity tests

The acute toxicity testing has become the useful tool for detection, evaluation and abatement of water pollution,. Information generated from various toxicity tests can be of use for (i) prediction of environmental effects of wastes; (ii) comparison of toxicants or animals or test conditions and (iii) regulation of discharge.

Acute toxicity tests are mainly used for determination of the condition, which produces a 50 % mortality. The value for median lethal response on median tolerance limit (TLM) is determined through the acute toxicity tests. The median values of the toxicant are termed as median lethal concentration (LC 50, TLM) or the median effective concentration (EC 50). Some toxic materials, such as acids and detergents, act primarily on the external epithelium. In such situation, the application of material should be regarded as LC 50 or LD 50 is polemical. Acute toxicity measures effect on survival over a 24 to 96 hour period. Such period is decided on the nature of toxicant and also the type of test organisms. In general the larval stages are exposed for a shorter period and the biodegradable toxicants are exposed for comparatively less time considering the fast changing toxic characters of the same.

Methods of acute toxicity bioassay are mainly of two types, static and flow through. Based on characteristics of toxic ants and also conditions of the site of toxicity studies, suitable methods of these two are applied.

2. Static toxicity tests

Static toxicity tests are performed without replacement of the experimental media. Depending on the characteristics of the toxicants and also the requirements of the tests organisms, the test media are renewed at an interval of few hours to a day. Effluents of quick degradable in nature, sediments and dredged materials are often tested in renewal acute toxicity study. Static and static renewal tests are usually not appropriate if the material is unstable, sorbs to the test vessels, is highly volatile, or exerts a large oxygen demand. A flow through system is preferred in such cases.

3. Flow through tests

The flow through system is designed to replace the toxicant and dilution water either continuously or intermittently through regulatory mechanisms. Different types of fabrications are designed for the effluents and also the test organisms. Mostly the effluents with high BOD are tested in flow-through toxicity bioassay system.

Dose/Dilution Selection

In toxicity testing, selection of doses / concentration / dilutions need scientific approach, Rapid or exploratory tests are performed initially using dose / concentration of wider range for a period of 24 hours. Accordingly actual doses / concentrations are selected as per the standard chart commonly used.

Selection of experimental concentration based on progressive bisection on interval on logarithmic scale

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

End Point

The end points can be determined from the data on mortality percent over the exposure period by a number of statistical approaches, Wilcoxen approach is most often use, which consists of plotting the survival and test chemical concentration data on log-probability graph paper drawing a straight line through the data, checking goodness fit of the line with chi-square test and reading LC 50 or EC 50 value directly off the graph.

4. Chronic toxicity test

It considers the sub-acute toxicity condition affecti the ability of the organisms to reproduce, grow or behave abnormally, but probably is not often a direct cause of death in nature. Laboratory studies of growth, reproduction and other related biological functions are most difficult and time taking. Evaluation of toxic effect on reproduction permitting study of development of gametes, fertilization, embryonic development, hatching and survival of young is difficult and not possible for al the organisms, since many of them do not mature and breed in confinement.

End point

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

APPLICATION OF BIOASSAY RESULTS

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

ENVIRONMENTAL PARAMETERS THAT AFFECT TOXICITY RESULTS

1. Dissolved oxygen

The DO levels should be below 5 ppm for cold water fishes and below 4.0 ppm for warm water fish, If DO falls respiratory rates in fishes increased. The lethality of many toxicants increased at low DO. When oxygen decreases and temperature increase, the metabolic rate of fish also increase. Water has to be pumped through the gills at a faster rate to supply oxygen to fish. As such toxic chemical many come into contact with the gills at an increased rate.

2. Temperature

The bioassay tests should be conducted at constant temperature. The changes will effect the rate of reaction and possibly the sensitivity of the fish to pollution as well the toxicity of some chemical in water. The internal physiology of the fish is altered in relation to temperature changes. With a reduction in water temperature by 10°C the time of manifestation of poisoning symptoms accelerates by 1.9 to 3.4 times.

3. pH

The toxicity of ammonia, ammonium salts, cyanides and certain compounds of chromium, iron (chloride and sulfate), manganese, copper and lead is influenced by the pH of the dilution water. The effect of pH toxicities of different metals is well documented. Ammonia toxicity increases in alkaline media. The toxicity of cyanide decreases as the pH increases. The variation should not exceed ± 0.05 of a pH unit.

4. Hardness

The toxic effect of ammonia, salts of alkaline earth metals and heavy metals increases in hard and seawater. Highly mineralized water containing calcium, potassium, sodium, magnesium and barium salts decreases the solubility of toxic substances, forming insoluble sediments with them and hence reducing their toxicity. A close relationship exists between the tolerance of fish to toxic effect of heavy metals and the degree of hardness of water.

CONCLUSION

The demand for sensitive and specific biological assay to assess the effect of pollutants on fish populations has recently led to a number of sophisticated analytical methods. Detection of the primary interaction between toxicant and fish can serve as early warning indicators and thus, be of maximum productive value in terms of protection of the whole population and ecosystem,. Two different systems, have been identified that represent detoxifying mechanisms active at the sub-cellular level; the Cytochrome P-450 monoxygenase system also named the mixed-function oxidase system (MFO), and metallothioneins (MTS). The MFO system metabolizes many drugs and a variety of organic contaminants, while MTS can bind certain heavy metals. Exposure of fish to polycyclic aromatic hydrocarbons (PAHs) or heavy metals induces MFO or MTS. The induction results in an increase of proteins, or activity, which can be assessed by various biochemical methods. These methods may represent the most sensitive and specific early warning indicators for assessing the effect of contaminants on wild fish.

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Summer school on *Methods of assessment of aquatic ecosystem for fish health care*
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STATUS AND USE OF BIOCHEMICAL MARKERS IN FISH FOR ASSESSING FISH AND ECOSYSTEM HEALTH

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INTRODUCTION

The body responses of biotic organisms can be fruitfully utilized towards the assessment of water quality and health of an ecosystem. Majority of these body determinations appear suitable for occasional assessments but fewer determinations appear suitable for the routine ones. Such body responses are developed with respect to particular environment, specific organisms etc. These are highly qualitative in analysis. These tests are usually advanced ones, using the determinations of blood plasma indices or determinations in specific tissues like the liver, muscle, gill, kidney, gonad etc. They serve as indicators of stress in the environment. Many a times, measurements of the activities of specific enzymes in specialized tissues of aquatic organisms are done that can serve as indicators of oxygen depletion in the media or the presence in water of certain toxic or xenobiotic compounds. Fortunately, fish responds to many of such tests and are conveniently used as a tool to indicate the ecosystem health.

BIOINDICATORS AND MARKERS

The term 'bioindicator' points to the species level using the sensitivity of the species in demonstrating responses to a range of contaminants present in the environment and within the individuals of a bioindicator species, an in-depth study will reveal the 'marker' which will produce alterations in structure and functions of specific organs, particularly the physiological and biochemical changes in cells or tissues as a consequence of exposure to contaminants. Thus, 'biomarkers' are responses of living organisms (bioindicators) that indicate exposure to contaminants including the prediction of possible future effects.

A biomarker response states that a contaminant has been present in the environment that appeared available to the organism. It also ensures that the contaminant has reached the tissue or organ that has been affected by amounts over a period, considered adequate in exhibiting observed marker responses. The harmful response depends on the progression level. The initial progression exhibits that a phenomenon called 'harm' has been started. Further, the adverse effect advances and that the deleterious effects started hindering growth, behaviour, reproduction etc. Finally, the response leads to death of the organism that demonstrates significant population effects.

Although biomarkers are studied individually, the most practical application relates to a battery of markers to assess the total environmental impact. A single biomarker test is usually carried out when only a single contaminant or a class of contaminants are present and where a highly sensitive biomarker test for their assessment is available. A number of markers are particularly useful for investigating various types or categories of contaminants.

Specific biochemical markers for environmental impact assessment (EIA) studies

Inhibition of Cholinesterase enzyme system

The utility of the enzyme 'cholinesterase' as a biomarker has been indicated for various species, including the fish. The cholinesterase-blocking pesticides like the organophosphates (malathion etc.) and carbamates (carbaryl etc.) are extremely neurotoxic that can demonstrate death of aquatic species by inhibition of this enzyme. Acetyl -choline is involved in brain synaptic transmission during which the enzyme acetyl-cholinesterase (AChE) hydrolyses the compound to choline and acetic acid. Although designed to kill insects and pests in agricultural fields, the ability of the organophosphates and carbamates to exhibit death in vertebrates provides an opportunity of assessing the effect of exposure of these compounds to fish. The cholinesterase activity is normally measured in brain tissues. However, blood measurements are also carried out. It is advan- tageous in the sense that, first of all, the enzyme is reported to be distributed in many tissues including the circulatory tissue (blood). Secondly, the estimation in blood does not necessitate the decapitation of the test species. Thirdly, the effects of continuous exposure can be studied. More than half of inhibition of the brain enzyme activity together with presence of pesticide residues in the tissues are reported to be the causes of death. Fish presents a valuable tool in demonstrating this, with reported brain enzyme inhibition varying between 40-80%.

Inhibition of ATPase enzyme system

Target responses in fish can be demonstrated by the persistent group of highly toxic organochlorine pesticides. Organochlorines, like the DDT and a number of other insecticides and pesticides primarily act upon the ionic balance of nerve membrane that regulate the coordinated functions of the organisms. All types of ATPases, like the Na+ - K+ -ATPase, Mg++ -ATPase etc. were found to be significantly affected by the organochlorines such as toxaphene, endrin, lindane, chlordane, aldrin,endosulphan, DDT, dicofol etc. DDT being the first generation of the organochlorine insecticides, majority of researches were directed towards the target actions of DDT on fish ATPases. The potentialities of these compounds to alter the membrane-bound ATPases remain impressive. It is demonstrated that the actions of organochlorines extend to the other ATPases, like the Cd++, Zn++, Mg++ and Ca++ - ATPases in fish liver.

It has been established that the Na+ - K+ - ATPase is the key enzyme that is involved in active transportation of sodium ions by biological membranes. DDT and other organochlorine group of toxicants were found to inhibit Na+ - K+ - ATPase in a microsomal membrane preparation from brain of fish. In gills and kidney, Na+ - K+ - ATPase were also found to be inhibited by these group of xenobiotics.

The target action of the organochlorine compounds is the disruption of the ionic balance in nerve and non-nerve cells. It has been shown that both the Na+ - K+ - ATPase and Mg++ - ATPase were inhibited in rainbow trout liver at a DDT level of 0.3 and 1.0 nano g/l. Significant inhibition is recorded in gills and kidney of fish exposed to 2.75 and 8.30 microgram/gram of diet. Goldfish exposed to sublethal concentrations (17.0-35.0 nano g/l for 330 hrs.) of DDT resulted in disturbed osmotic and ionic balances. *In vitro* inhibition of bluegill brain Na+ - K+ ATPase was demonstrated by several cyclo -diene insecticides. Mitochondrial Mg++ - ATPase is found to be most sensitive to inhib -ition by these compounds. Aldrin, chlordane, endrin, heptachlor, lindane and toxaphene demonstrated lesser oxygen consumptions. The effects of DDT on inhibition of various membrane-related functions were demonstrated in salmonids, where both the enzymes were involved. Only after several reports of fish disease and innumerable reports of fish death, attention was focused on the causes of the same involving the inhibition of these biomarker enzymes.

Induction of metallothionein protein system

The metallothioneins (MTs) are low molecular weight proteins (approx. 6000-7000 daltons) containing appreciably high amounts of sulphur-containing amino acids, 'cysteine' (approximately 30%). Cysteine of metallothionein contains –SH (thiol or sulphydryl) group and this group is exceedingly capable of binding toxic heavy metal ions like the Cu, Zn, Hg, Cd, Bi, Ni etc.The protein is synthesized by the presence of the said heavy metal ions and hence is and inducible protein, although some non-metal factors are also reported to induce MT. These proteins act as detoxyfying agents for metals. The metallothionein estimation is slow and costly. Therefore in some cases, instead of the estimation of MT, the causative agents (heavy metals) are directly estimated in the body tissues to assess the quality of water with respect to contamination by heavy metals.

The estimation of MT protein indicates the entry, pathway and time of exposure to the metal ions. Heavy metal ions, on entering the cells, induce the synthesis of MT proteins which then bind to the metal ions. Quicker methods of MT estimation are now-a-days coming up that are linked to the antibody-coupled reactions. Continuous upgradation of metallothionein assay method and its validation are necessary to apply it on a wider basis. The use of metallothionein estimation has been included as a biochemical marker for detecting the heavy metal contamination in water environment, as virtually all the vertebrates and invertebrates appear to exhibit the presence of MT. Fish is reported to induce MT synthesis on exposure to heavy metal ions and the amount of MT in fish tissues is considered to be a marker of the extent of contamination by these metals.

Induction of hepatic microsomal mixed function oxygenase (MFO)

Biological oxidations are usually carried out by the enzymes called dehydrogenases and oxidases with the resultant production of ATP. However, there are altogether a different groups of oxidation reactions that are being carried out in the body by the enzymes called 'oxygenases'. These oxygenases, instead of producing ATP, are involved in the breakdown of poisonous or harmful substances (xenobiotics/ toxic foreign chemicals etc.) that a living system encounters. Enzymes of this category catalyse the incorporation of oxygen into a foreign substrate. Of particular interest is the monooxy -genase enzyme system whose induction is used as a biomarker in assessing the presence of toxic compounds like the pesticides, drugs, polycyclic aromatic hydrocarbons (PAH), steroids etc. in water. These systems are called microsomal MFOs because they are found in the microsome / endoplasmic reticulum of liver cells together with the cytochrome P-450, which is a iron-containing (heme) protein.

This system is also called the drug-metabolizing enzyme system and among the foreign compounds metabolized by this system are benzpyrine, aminopyrine, aniline, morphine, benzphetamine etc., drugs such as phenobarbital as well as several pesticides and insecticides that are capable of inducing the formation of hepatic micro -somal MFOs and cytochrome P-450s.

There are about 50,000 commercially available chemicals, a large number of which are released into the biotic and abiotic world almost daily. Although, the world chemical production exceeds 300,000,000 tones per year, it is still increasing and new range of products are constantly being manufactured. The damages posed by these amounts of chemicals to the life processes are easily imaginable. This strengthens the massive search for systems of elimination from, or detoxification processes by the body. One of the most prominent examples of these systems is the monooxygenase system itself.

Cytochrome P-450 system

A group of haemoproteins called the cytochrome P-450s are there that are linked to detoxification processes in the body. These are present almost in all the tissues, but found in exceedingly high amounts in liver. Being the central organ of metabolism, the liver receives special attention. These haemoproteins are found to be inducible and are induced by a variety of toxic,foreign and organic chemicals. In aquatic organisms, like the fish, the activities of the cytochrome P-450 dependent enzyme system prove to be a meaningful bioindicator of pollution with respect to polycyclic aromatic hydro- carbons (PAHs) and poly chlorinated benzenes (PCBs). Chlorinated hydrocarbons like the organochlorine pesticides and insecticides which are found in the aquatic system induce cytochrome P-450 dependent enzymes in the hepatic microsomal fraction of fish. The enzyme is so named because it is blocked by the poisonous gas, CO and the CO-saturated complex shows absorption maxima at 450 millimicron of the spectrophotometer. Of particular interest is the environmental biomonitoring of aquatic bodies using fish, in which several environmental contaminants are able to induce the system. Many of the inducing agents are well-known aquatic pollutants. They have greatly enhanced research with respect to fish cytochrome P-450 system. Elevated levels of specific cyto -chrome P-450 activities in fish liver were reported from near the paper-mills, bleaching-craft mill effluents and oil-drill platforms.

Glutathione system

An oxidative damage is sometimes seen in an organism when it is exposed to halogenated aromatic hydrocarbons, polyaromatic hydrocarbons, many other industrial organic solvents and some metals like the selenium. Their metabolites are also seen to cause oxidative damages. When an oxidative stress or damage occurs, the protective systems, which are usually the antioxidative systems, exhibit adaptive responses. The cellular macromolecules are seen to be modified. Finally, the tissue damage occurs. These alterations in the antioxidant system or modification of the macromolecules (proteins, nucleic acids, lipids) are used as biomarkers towards the exposure to contaminants. The protective systems may include oxidized glutathione (GSSG), reduced glutathione (GSH), glutathione reductase as well as some other enzymes like catalase, superoxide dismutase, peroxidase and compounds like L-ascorbic acid (vitamin) and alpha tocopherol (vitamin) etc.. Metallic selenium is reported to exhibit increased gluta -thione peroxidase, glutathione reductase activities and oxidized / reduced gluta -thione ratio. Polluted sites in aquatic environments exhibit elevated glutathione peroxidase activity compared to unpolluted sites. Exposure to oils demonstrates varying levels of reduced glutathione.The utilities of adaptive responses to oxidative stress in organisms exposed to contaminants are impressive. These markers can demonstrate effectiveness against a wide range of contaminants. However, it is better to use this marker in association with other markers, owing to slightly lesser specificities.

Thermoprotein system

These are the group of proteins called 'stress proteins' synthesized in the body in response to heat shock. Additionally, their amounts are increased in response to a variety of chemical and non-chemical stresses. These proteins can be used as biomarkers to some extent against stress in general and thermoshock in particular. They are classed on the basis of molecular weights. Five classes of molecules have been reported so far, that synchronizes with 90 K.Dalton, 70K Dalton, 60 K.Dalton, 20 K.Dalton and 7 K.Dalton. The low molecular weight heat stress proteins are usually not detected in non-stressed organisms. Heat stress is seen to induce proteins, the pattern of induction being specific to the types of stressors. The concept of heat stress proteins is modified increasingly.

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STRESS EFFECT EVALUATION IN FISH - ORGAN INDICES AND GROWTH ASSESSMENT METHODS

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INTRODUCTION

Fishes at the top of the biotic strata are worst affected in respect of habitat loss and physico-chemical stresses faced in contaminated environment. Struggle of the fishes starts with micro-level alterations in physico-chemical status of the environment which gradually intensifies with contamination of the food chain systems. In the process of population growth many of the fishes succumb to the ill effect of degraded environment while the others survive with poor health conditions. Since recent past the importance for fish health assessment has been recognized all over the world.

ORGAN INDICES FOR STRESS EVALUATION

Normalcy in animal life continues on the functional harmony of all the organs. The vertebrates posses well developed organs and so also the fishes, and every organ follows definite pattern of growth. Beside natural factors, organell growth may also be influenced by environmental stresses arising from the gross alteration of physico-chemical properties of the media, contamination of food niches and disease infestation. Interestingly every stress factor is not equally harmful and the stress effects are not always equally perceivable in all the organs. The perceivability depends on characteristics and severity of the stresser and extent of damage caused by the stresser to the affected organ. Of all the responses, abnormalities in growth and structural deformities in organs are well visualized and can be expressed by measurements of weight and size respectively. The organs acceptably, retaining definite relationship for size with that of the body also bear similar correlation for weight too. The correlation may be drawn for an individual, a group of individuals or population of a species. Generally the organs with comparatively higher weight are tried for organ indices. Apart from weight, size/surface area also gives indication of stress impact on the affected organ.

Gill area: Body surface area ratio

In fish, the gills perform the function of respiration, and the structure and size of the organs vary from one species to the other. The physiological efficiency of gills depends on structural built up and size or surface area available for gaseous exchange between the organs and the surrounding media. Fishes exposed in environmentally stressed condition often suffer from lameller erosion of gill and as an eventuality face respiratory problems. For estimating the degree of damage caused to the organs, the effective surface area is measured and expressed in relation to the body surface area of the affected fish. The value obtained from the calculated ratio of gill surface and body surface area is compared with that of the normal fish for expressing the extent of damage caused in the fish exposed to stress conditions.

Hepato-Somatic index

Hepato-Somatic index

Among all the body organs liver is considered most important in respect of the multifarious roles played in digestion, circulation and other physiological functions by the organ. In fish, size of liver is conspicuous and its mostly bi-lobed in shape. Change in shape and size of the organ in female fishes during breeding season is phenomenal when they minimize, even stop feeding and the ovary enlarges in size and occupies major space of the body cavity. When exposed in stress conditions the fishes try to adjust themselves to the best of abilities but fail to do so as the conditions cross beyond their tolerance limits. In the process of adjustment the organs suffer and get gradually damaged. Inflammation of the whole organ, enlargement of lobe and atrophy are very often encountered in livers of severely stress-affected fishes. All these modifications can easily be converted into weight loss or gain compared to the normal ones. Finally a relation between the liver weight and that of body is drawn in view of developing hepato-somatic index.

$$HSI= \frac{\text{Weight of liver X 100}}{\text{Weight of body}}$$

Spleno - somatic index

Spleen though comparatively sampler in size plays vital role in blood cell formation. The organ is highly sensitive to environmental stresses. Atrophy of spleen is often encountered in fishes from industrially contaminated environment. Like liver the spleen weight can also be correlated with the body weight and an index can be formulated

$$SSI = \frac{\text{Weight of spleen X 100}}{\text{Weight of body}}$$

Gastro-somatic index

Resembling individual organ index similar expression can also be made for complete alimentary organ and the index can be called Gastro-somatic index. The sign of degeneration of alimentary organ is encountered when fishes are exposed to stress conditions for a prolonged period. Many of the stress elements like heavy metals, pesticides etc. affect alimentary organ by way of inactivating the secreting cell and turning the whole system dis-functional. For Gastro-somatic index the weight of alimentary canal and that of body is correlated.

$$GSI = \frac{\text{Weight of alimentary organ X 100}}{\text{Weight of body}}$$

Gonado-somatic index

For an animal success in population propagation is considered as the highest achievement in life. In fish this part of life is not wholly under their control since their progenies has to face man made and also natural hazards in the process of development and growing to adult stages. The only positive point for the fish in this respect is high fecundity, which balances the developmental loss of the embryos, and the recruitment is continued. This clearly indicates the importance of high fecundity for the fish. In stressed condition, particularly when exposed to highly toxic heavy metals on pesticides, the reproductive development in fishes suffers and results gonadal abnormalities and poor breeding success at the end. The abnormalities may be variability in gonad size, irregular egg size in ovary and so on. The variability in size of the gonads can be converted into weight and expressed in terms of the body weight.

Growth assessment for fish

Growth of organisms means a three-dimensional change in body and also of weight with increasing age. This change in organisms is due to conversion of food matter into building matter of the body through the process of nutrition. When body length and weight of an individual are plotted against specified times, the graph comes out with a vector diagram known as growth curve which appears S-shaped (sigmoid) and illustrates the rate of growth of the organism through time.

The rate of growth in fishes varies from species to species, with change of habitat, alteration of seasons or with the external factors of the environment influencing the physiological functions. The growth pattern and growth rates are highly species specific in fish. Under normal conditions the growth determining factors consist of (1) optimum temperature (2) adequate and correct food (3) presence of vitamins in food, particularly vitamin C whose deficiency may cause retarded growth and (4) periodicity of seasons of rapid and slow growth in the year.

Length - Weight relationship

Weight of fish is the function of its length. Theoretically, it is expressed by the formula (the cube law):

$W = KL^3$, where w = weight, L = length, K = constant.

Since the cube formula does not hold good throughout the life history of the fish, as the value of K is not constant but subject to great variation. The most befitting formula is:

$W = L^n$ in which W = weight, L = length and n = constants.

This can also be expressed as:

$\text{Log } W = \log C + n \log L$

The values for the constants (a and n) are determined empirically from data, as the coefficient of condition.

Condition factor or Coefficient of condition

Condition factor is an expression of the condition in which the individuals fish, has been during certain period. Thus the mathematical expression of condition coefficient is a most effective and accurate method of evaluating the impact of environmental stresses on over all health condition of the affected fish.

Condition in general expresses the relative plumpness of fish with respect of the same species taken from different water bodies. It is expressed by relating length of fish to its weight. A fat fish will give a higher factor for condition than is given by a lean and thin fish. The methods of determining condition coefficient are as follows:

Coefficient of condition

$$K = \frac{\text{Weight in gm X 100}}{\text{Standard length 3 in cm}}$$

Condition factor

$$CF = \frac{\text{Weight in lb. X 100,000}}{\text{Total length in inch}}$$

Index of Condition.

$$C = \frac{\text{Weight in lb. X 10,000}}{\text{Total length 3 in inch}}$$

The values of the factors will indicate greater plumpness while the lover values will reflect poor condition of the organism.

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HISTOPATHOLOGY - AN EFFECTIVE TOOL FOR ASSESSING ENVIRONMENTAL IMPACT ON FISH HEALTH

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INTRODUCTION

One of the very effective methods for assessing fish health in degraded aquatic environment is histopathology.The importance of histology in the investigation of fish health lies in the fact that it can detect the exact location of the pathogen in the body and can also demonstrate various abnormalities caused in their organs due to environmental stress or disease. Previously, animal histology aimed primarily to morphologically clarify the fine structures of animal body. However, more recently the main aim of histology changed to focus on the study and functions of the body at the tissue level and the clarification of the physiological functions from the viewpoint of cellular correlation. Histopathological lesions are related to biochemical changes that occur in the organism. Chemical changes are the results of lesions that can be seen histologically. Histopathology, as an assessing factor of stress is highly valuable especially for biomonitoring purposes as lesions are caused by the chronic stress, generally the kind of environmental stress experienced under field conditions. It can be sensitive while at the same time being unaffected by the external factors such as seasons or stress of capture. To use this method as an effective tool, microscopic observations are subjected to quantitative assessment and the data analysed numerically and evaluated statistically. While conducting surveillance by this method one must have a complete fish atlas of normal histology for the species from the non- polluted areas.

GENERAL PATHOLOGICAL CHANGES

Various morbid states are usually observed when living animals cannot maintain a normal condition because of various disturbances in physiological function of a part or the entire body. The general changes are circulatory disturbances, regressive changes and progressive changes.

Circulatory changes

It is the morbid condition of blood and tissue fluid flow and represented by the following symptoms :

Hemorrhage — Leaking of blood from the blood vessel.

Hyperemia — It is the stagnant condition of arterial blood flow.

Congestion — Is the stagnant condition of venous blood flow.

Hydrops or dropsy — Stagnant tissue fluid which has leaked from capillaries to the tissue, bodycavity and eye orbit. It is caused by the congestion, kidney lesion, and failure of osmoregulation, exhalation of vascular motor neurons, toxic substances, and bacterial infection. All these induce permeability changes in capillaries. Hydròps of subcutaneous tissue is known anasarca and other tissue is edema.

Regressive changes: Are the morbid state of cells and tissue caused by the hypo functioning of the cells and tissues and involve atrophy, degeneration and necrosis.

Atrophy is the morbid state in which the number and volume of the cells and the amount of intercellular substances, organising tissues and organs are reduced. It is caused by the deficiency in the local supply of nutrients and is also an effect of poisonous substances.

Degeneration It is the state in which the physiological substances present in tissues morbidly increases or appear in other places. Various types of degeneration appear depending upon the nature of substances.

Granular degeneration It is the morbid state in which proteinous granules form in the cell. Cloudy swelling and hyaline droplets are distinguishable. Cloudy swelling is the results of distend cells with fine eosinophilic granules in the cytoplasm.

Colloidal degeneration It is the morbid state in which cells are caused to swell by large amount of colloidal proteins accumulated in cytoplasm. Cytoplasm stains weekly and indicates a reticular or vacuolar shape. This is also called as vacuolar degeneration when vacuolar structures are marked. This may also occur in nucleus. Colloidal droplets are eosinophilic.

Hyaline degeneration This types of degeneration occur in connective tissue. Fine fibers gradually thicken and finally become homogeneous.

Keratine degeneration Caused by the eosinophilic keratin in cytoplasm. The nucleus becomes pycnotic and then disappears.

Fatty degeneration This degeneration is results from a large accumulation of lipids, and accompanied by pycnosis and necrosis.

Glycogen degeneration It is caused by the accumulation of glycogen in cytoplasm.

Calcerous degeneration In this type of degeneration calcium salt precipitates within the cells and intercellular spaces which form soft tissues. It is sometimes accompanied with pycnosis and necrosis.

Pigment degeneration It is the state in which the vital pigments (Melanin, Hemosiderin, bile pigment) are present in morbidly large amounts or in places where they do not usually appear.

Necrosis is the state in which the cells and tissues lower the activity and eventually die. The nucleus undergo pycnosis, hyperchromatosis etc., and cytoplasm becomes homogeneous. Necrotic cells are eventually destroyed and absorbed. They sometimes cause calcification.

Progressive changes: This indicates hyperplasia and hypertrophy of cells and tissues, the functions of which usually become elevated. This occurs in the hyper functional state of the organs, that physiological activities are to be changed.

Inflammation It is the protective reaction of living animals when physical and chemical stimuli and parasite strongly affect local tissue. In severe cases necrosis, cloudy swelling and atrophic cells are observed.

Tumor It forms when cells and tissues are undergo autonomous proliferation It can be differentiated in two groups Benign and Malignant tumors. These may be either epithelial or non-epithelial.

Histological response Are conducted using standard histological techniques. Observations are done in a way so as to be quantified. Lesions in various organs are categorised and graded according to severity. For this purpose data sheets were made in such away as to give information regarding:

Location where in the body it is located/ name of the tissue.

Change what type of lesion it is.

Extent whether it is focal, multifocal or diffuse.

Severity how severe the lesion is mild, moderate or severe.

Histological examination of fish tissue is an essential step in determining the effect of xenobiotics on fish diagnosing fish diseases. However, pathological lesions for specific disease or toxicant are rare especially when examining fish from wild, because in riverine system where interaction of various pollutants occur and the extension of pollutional level fluctuates and where the system has inherent quality of retrieval. The alterations in histopathological lesions in such ecosystem although detrimental to fish health do not cause death because pollutional level becomes sublethal. This sublethal pollution logically contributed either to alarm reaction or to secondary response of adaptive stress syndrome.

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XENOBIOTIC ACTION ON FISH GONADAL AND INTERRENAL STEROIDOGENESIS

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It is widely known that there are several types of xenobiotics, such as organochlorines, detergents, heavy metals and others which are endocrine disruptors. The functional homeostasis of hormones are very important in the life cycle of a fish, because they are seasonal breeders. Any change in the fine tuning of the steroid hormones leads to disruption of the reproductive efficiency of the fish and consequent depletion in the population in the long run. It has been amply reported that fish gonadal functions are compromised by environmental contaminants (Thomas, 1989, Choudhary *et. al* 1993), reports of xenobiotic action fish interrenals are relatively rare (Bhattacharya and Mondal, 1997). In the absence of formed adrenal glands, the interregnal tissue in the head kidney of fish is of prime importance in the schematic events of synthesis of the stress hormone, cortisol. Fish are constantly exposed in their ambience to a variety of xenobiotics and it ids expected that they would respond to the xenobiotic insult impinged upon them.

During the course of an investigation, adult, healthy, female fresh water murrels were exposed to an organophosphate, metacid 50, an organochlorine, endosulfan and two ubiquitous heavy metal water pollutants, cadmium (Cd) and mercury (Hg). The doses selected were non lethal, of 1/50 LC 50, where no physiological distress was noted and the exposure regimen was continued for 35 days. Samplings were performed at day2, 7, 21 and 35 post treatment.

A decrease in ovarian progesterone (P_4) release was very remarkable in all the treatment schedules, although at 2d Hg exposure there was an enormous increase in P_4. Increasingly, there was no dramatic change in the case of Estradiol (E_2 release. On the other hand, P_4 release from the international elevated and cortisol declined remarkably in almost all the treatments. In contrast to a low plasma P_4 level on 7d Hg, metacid 50 and endosulfan exposure, Cd treatment resulted in a significant increase, while on the 35^{th} day of exposure, Cd treated fish alone showed a reduced hormone profile and in the other cases the level was normal. In respect of E_2 the pesticide treated fish showed a normal leverl while the heavy metals caused a significant depletion. Interestingly, the cortisol level remained more or less at the basal level except metacid-treated fish.

The chain of events indicates clearly the involvement of the synthetic pathway in hormonal dysfunction in fish.. The xenobiotic signal may be mediated directly to affect steroidogenesis of indirectly via the cholinergic pathway regulating the hypothalamic releasing hormones. The pesticides and heavy metals have been found to inhibit the key enzyme of neural transmission, namely, acetylcholinesterase (AchE) and it is also known that inhibition of AchE is directly correlated to both GtH and GnRH release (Ghosh *et al* 1990). It has also been revealed that ther toxicants augment hydroxysteroid dehydrogenase (HSD) activity when the fish are chronically treated with the xenobiotics. It was found by Mondal *et al,* (1997) that there was a significant increase in oocyte mRNA prepared from Hg-treated fish. Moreover the cell free translation product of this mRNA resulted in a very high titre of HSD. Thus it was abundantly clear that the accumulation of P_4 either in the ovary or the interregnal is due to augmentation of HSD synthesis by the xenobiotic insult. It is concluded that apparently safe doses (1/50 LC 50) of xenobiotics, such as organophosphate and and organoochlorine and heavy metals, are potent endocrine disruptors and interferes with reproductive efficiency without manifesting any other physiological response.

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MICROBIAL ASSESSMENT OF WATER QUALITY FOR FISH HEALTH MANAGEMENT

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INTRODUCTION

The three main objectives of assessing water quality of culture system are (i) to know the productivity status of the system (ii) to know the presence of microorganisms pathogenic to fish and prawn, in the culture system. (iii) to know degree of pollution/contamination of water with wastes and chances of transmission of such pathogens of public health significance to humans through fish/ prawn. The details of the above objectives and techniques used for assessment of microbial quality of water are described here.

MICROBIAL POPULATION IN AQUATIC ENVIRONMENT

Microbiota are the primary producers in the aquatic environment and are responsible for approximately 50% of all primary production. They are also the primary consumers. The microbiota that inhabit aquatic environments include bacteria, viruses, fungi, algae etc. and the common habitats include planktonic, sediment, microbial mat and biofilm.

Plankton refers to the microbial communities suspended in the water column. The photoautotrophic Cyanobacteria with algae are called Phytoplankton and suspended heterotrophic bacterial population are called Bacterioplankton and protozoans make up the Zooplankton. Phytoplanktona are the primary producers in the food web using photosynthesis to fix CO_2 into organic matter. The role of bacterioplankton is to mineralize important nutrients contained within organic compounds and convert a portion of the dissolved carbon into biomass, which are taken up both other members in the planktonic food-web.

Microbial populations are observed under natural conditions associated with microbial mats and biofilms. In microbial mats , many microbial groups are laterally compressed into a thin mat of biological activity and found in lakes and estuaries. A biofilm is a layer of organic matter and microorganisms formed by the attachment and proliferation of bacteria on the surface of an object or solid surface like rocks, aquatic plants etc. Biofilms are characterized by the presence of bacterial extracellular polymers, which can create a slimy layer on the solid surface and the bacterial attachment on film may be reversible followed by irreversible attachment. These biofilms can harbor opportunistic pathogens and require high doses of disinfectant for their control. There occurs a great variation of total bacterial population (including photosynthetic bacteria) in natural environment and the numbers may vary between 10^0 and 10^8 organisms/ml. The primary producers present in higher numbers ranging 10^6 to 10^8 /ml along the shallow edges and the number of heterotrophs vary between 10^1 and 10^6/ml. Their number increases in response to higher organic load in the system. Along sewage outflow areas and down stream, the concentration of heterotrophs ranges from 10^4 to 10^9 organisms/ml. In estuaries, which tend to be turbid due to large amount of organic matter brought in by rivers and mixing by tides, the light penetration becomes poor. The number of primary producers ranges from 10^0 to 10^7 organisms/ml. In marine water the heterotrophic population vary considerably with depth with range of 10^1 /ml in oligotrophic zones to 10^8 organisms/ml in zones where organic matter is high (Down *et al.*, 2000). Viruses (bacteriophages) in freshwater environments can be very abundant and can utilize bacteria, cyanobacteria and microalgae as their hosts and affect the population dynamics and community composition in the planktonic environment. Virus induced lysis of bacterioplankton can account for 20-50% of bacterial mortality. However, these bacterial population can not in any way be related to the health status of the aquatic animals in the system. This is more dependant on presence of pathogenic bacteria and their interaction, as described later in this text.

MICROBIAL POLLUTION AND DISEASE

Even though the fish in their culture and natural environment are continually bathed in water suspension containing a variety of microorganisms, both pathogenic and non-pathogenic, they do not all become diseased. Several parameters associated with the fish are directly related to the occurrence of disease upon interaction with appropriate pathogen and environmental factors or conditions. These include the factors that are constantly present (constitutive) such as the fish species, genotypes, age, size, developmental stages, nutritional and reproductive statuses and innate defenses related to immune competence.

Fish and prawn, both in freshwater and marine or brackishwater environment are prone to a variety of disease conditions, both bacterial, viral and fungal origin (Table-2) and most of these are transmitted through water. Common bacterial pathogens like *Vibrio alginolyticus, V.parahaemolyticus, V.anguillarum, V.harveyi, Aeromonas* sp, *Pseudomonas* sp. etc. are common inhabitant of marine and brackishwater environment, where as, *Aeromonas hydrophila, Pseudomonas sp., Vibrio* sp. etc. are commonly isolated from fresh water (Austin and Austin, 1987). Besides these, a number of other microbial pathogens like *Acenetobacter, Micrococcus sp., Cytophaga sp.,Morexella sp., Flexibacter sp.* etc. are also commonly found both in fish, fish surface and in water. Hence aquatic environment severs as a platform both for maintenance, survival and transmission of such pathogens. Mere isolation of any pathogen not necessarily indicate health status of fish or prawn, however it can indicate the concentration or dose of such pathogens in aquatic environment. Isolation of pathogen from diseased fish, their isolation, re-induction of disease in fish and re-isolation of that pathogen, are the steps followed to conclude a pathogen responsible for disease. A variety of cultural, biochemical, immunological and molecular techniques are used for identification of such pathogens from water and fish sample, which are discussed below.

ASSESSMENT MICROBIAL PATHOGENS

Isolation and identification of microbial pathogens present in environmental sample forms the basic step in analysizing their role in pathogenecity. A variety of microbiological, immuonological and molecular techniques are used for detection of pathogens.

1. Microbiological Techniques :

(a) Direct bacterial count : Estimation of total bacterial count using fluorescent/ acridine orange staining, epiflusrescence method and Electronmicroscopy

(b) Culture methods : Used for enumeration of viable bacterial load in the sample. Following methods are commonly used :

(i) Plating method using suitable bacteriological media, by Streak plate, pour plate and membrane filtration techniques

(ii) Most probable number (MPN) method, using tube fermentation

(iii) Detection using Automated microbial identification system

2.Physiological methods : This technique is used to measure microbial activity, by using

(i) enzyme assays like dehydrogenase, phosphatase, protease, amylase, cellulase etc. enzymatic activities and

(ii) by use of radiolabelled tracers (^{3}H, ^{14}C) into cellular macromolecules

3. Immunological techniques : Different immunological techniques are used for detection of pathogen, their components and antibodies, which help in diagnosis. These techniques have gained popularity for detection of a variety of microorganisms present in water or in fish, hence commonly used in diagnostic laboratories. Some of the commonly used immunological techniques are -

(i) Enzyme immuno assay like ELISA, Dot immunoassay etc.

(ii) Flourescent antibody technique

(iii) Protein Electrophoresis (PAGE, 2D-PAGE) with Western Blotting

(iv) Immunocytochemical assays

(v) Immunoprecipitation assays

4. Molecular Techniques (Nucleic acid based methods)

Different nucleic acid based techniques have been developed and applied which has revolutionized the diagnostic techniques. These techniques offer higher specificity, sensitivity and can be applied in such cases where other technique fail to diagnose. Hence these techniques have gained popularity in diagnostic medicine and successfully applied for detection a variety of bacterial and viral pathogens of fish and prawn.

Some of the commonly used techniques are :

(i) Gene probes like DNA and RNA probes, both radiolabelled and non-radiolabelled have been developed for detection of a variety of fish and prawn pathogens. The target DNA in sample fixed onto nylon membrane or nitrocellulose membrane are detected by using hybridization techniques.

(ii) Polymerase chain reaction (PCR) and related techniques like Random amplification of polymorphic DNA (RAPD), Restriction fragment length polymorphism (RFLP) etc., have revolutionized the diagnostic pathology. These techniques have got wide scope of application for detection, differentiation and characterization of cells, species and pathogens at DNA level.

Assessment of aquatic microbial pollution

Methods have been developed to estimate the degree of water pollution and contamination with wastes by estimating indicator organisms present in the system. Research has established the significance of coliform group density as a criterion of the degree of pollution. Fecal streptococci and enterococci also are indicators of fecal pollution. Their detection of fish culture system indicate contamination of water with bacteria of public health significance. This is more important when fish culture system is regularly contaminated with sewage and urban waste and in cases of sewage fed fisheries. The significance of the tests and interpretation of results are well authenticated and thus have been used as a basis of standards of bacteriological quality of water(Eaton *et al.,* 1995).

The heterotrophic plate count may be determined by pour plate, spread plate or membrane filter method. It provides an approximate enumeration of total numbers of viable bacteria that may yield useful information about water quality. Coliform group consists of several genera of bacteria belonging to the family *Enterobacteriaceae*. The standard test for coliform group may be carried out either by the multiple-tube fermentation technique or membrane filter technique or by chromogenic substrate coliform test. The fecal streptococci have been used with fecal coliforms to differentiate human fecal contamination from that of other warm blooded animals. It has been suggested that the ratio of fecal coliform (FC) to fecal streptococci (FS) could provide information about the source of contamination. A ratio of greater than 4 is considered indicative of human fecal contamination, where as a ratio of less than 0.7 is suggestive of fecal contamination from animal sources. The enterococcus group is a subgroup of the fecal streptococci. The multiple tube technique and membrane filter technique are also used for estimation of these groups of bacteria. Techniques for estimation of presence of other species of bacteria like *Salmonella* sp., *Shigella* sp., *Klebsiella* sp., *Pseudomonas aeruginosa* , *P. fluorescens*, *Actinomycetes* etc. Readers are requested to go through the APHA manual on Standard methods for examination of water and waste water for details of these techniques (Eaton *et al*., 1995). Besides these, the techniques already described for detection of pathogenic bacteria in fish or water , can also be used for detection of such bacteria in polluted water.

Similarly most recognized water borne virus disease outbreaks have been caused by sewage contamination of water bodies. Detecting viruses in water through recovery of infectious virus requires three general steps: (a) collection of contaminated water sample from culture system (Sewage fed fisheries), (b) concentrating the virus in water sample, and (c) identifying and estimating the total number of virus in concentrated samples. However, these techniques have their inherent drawbacks, involvement of high cost and lack of suitable methodology. Hence these techniques for estimation of aquatic virus contamination are not regularly employed as used for pathogenic bacteria.

FISH HEALTH MAINTENANCE IN AQUATIC ECOSYSTEM

Maintenance of a quality environment means "Hazard reduction through environmental manipulation". Infectious diseases of cultured fishes are reduced most effectively and efficiently through maintaining a healthy environment through proper management practices. It is far more important and economically beneficial to control diseases of fish through environmental management and these approaches should be included in a health management plan in fish culture.

There will be minimal occurrence of infectious diseases if fish are maintained in a perfectly balanced environment with less or no stressful conditions, as a resulted due to over crowding, poor water quality, variable temperature conditions and poor nutrition. If stressful conditions are minimized, infections will be minimized when they occur, but use of certain drugs, chemicals and antibacterials are often required to prevent and control such infections. Disease prevention emphasizes procedures that prevent infection even through the pathogenic organisms are present in the environment. These procedures are usually employed when fishes / fingerlings are screened, handled, cultured or shipped, during which time the fishes are most vulnerable to injury, trauma or physiological stress. If the protective mucous layer, scale or epithelium are damaged, the underlying tissues are open to water borne pathogenic bacteria and protozoan parasites which become more easily established on fish. Thus exposure of fish to therapeutic levels of antibacterials will aid in wound healing. Besides these, economical and effective vaccination procedures are also employed in routine management of fishery resource.

Table 1. Involvement of various microbial pathogens in diseases of fish, shrimp and prawn and their transmission in aquatic environment.

Disease condition	Involvement of pathogens
I - Fish Diseases :	
1. Exopthalmia (Pop eye condition)	*Aeromonas hydrophila, Edwardsiella ictaluri, Streptococcus spp., Staphylococcus spp.*
2. Hemorrhages in the eye,	*Streptococcus spp., Yersinia ruckeri*
3. Haemorrhages in the Mouth	*Vibrio anguillaraum, V. ordalii, Pseudomonas anguillaseptica*
4. Hemorrhages on body Surface with ulcers	*Aeromonas hydrophila, E.ictaluri, Flexibacter columnaris, Vibrio spp., Pseudomonas spp.,*
5. Surface abscesses with blood filled blisters	*A.hydrophila, Edwardsiella tarda, Renibacterium salmoninarum*
6. Whitish nodules on gills	*Edwardsiella tarda*
7. Fin rot and Fin rot	*A.hydrophila, Mycobacterium spp., Nocardia spp., Pseudomonas spp. Cytophaga spp.*
8. Gas filled hollows in the muscles	*Edwardsiella tarda*
9. Bacterial gill disease	*Cytophaga spp., Flexibacter spp., Flavobacterium spp.*
10. Epzootic Ulcerative Syndrome (EUS)	*Aphanomyces sp., Aeromonas hydrophila*
II Diseases of Shrimp	
1. Bacterial shell disease	*V.alginolyticus, V.parahaemolyticus, Aeromonas sp, Pseudomonas sp.*
2. Septicaemic Vibriosis	*V.alginolyticus,V.parahaemolyticus, V.anguillarum,*
3. Filamentus bacterial disease	*Leucothrix mucor, Flexibacter sp., Cytophaga sp., Flavobacterium sp.*
4. Monodon Baculovirus disease (MBV)	*Monodon baculovirus*
5. White spot Syndrome	*White spot syndrome virus*
Diseases of Freshwater Prawn	
1. Black spot disease	*Vibrio sp., Aeromonas sp., Pseudomonas sp.*
. Vibriosis	*Vibrio alginolyticus, V.anguillarum,*

Table 2. Bacterial population commonly found in freshwater and marine water fishes

	On skin surface of Fish	In Gut of Fish
Freshwater fishes		
	Acinetobacter	*Acinetobacter sp.*
	Aeromonas sp.	*Enterobacter sp.*
	Alcaligens sp.	*Escherichia coli*
	Enterobacter aerogenes	*Klebsiella sp.*
	Escherichia coli	*Proteus sp.*
	Flexibacter sp.	*Aeromonas sp.*
	Micrococcus sp.	*Cytophaga sp.*
	Morexella sp.	*Flexibacter sp.*
	Pseudomonas sp.	*Pseudomonas sp.*
	Vibrio sp.	
Marine fishes		
	Acinetobacter sp.	*Aeromonas sp.*
	Alcaligens sp.	*Pseudomonas sp.*
	Bacillus cerus	*Vibrio sp.*
	Bacillus firms	
	Coryneforms	
	Cytophaga sp.	
	Flexibacter sp.	
	Escherichia coli	
	Lucibacterium sp.	
	Photobacterium sp.	
	Pseudomonas sp.	
	Ps. Marina	
	Vibrio sp.	

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Summer school on ***Methods of assessment of aquatic ecosystem for fish health care***
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BIOINDICATOR APPROACH FOR ASSESSING IMPACT OF ENVIRONMENTAL STRESS ON FISH HEALTH

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INTRODUCTION

Aquatic systems experience some level of chronic and/or sublethal exposure from environmental pollutants which impact these systems through point source or non-point source pathways. While impacts on aquatic systems from point since are relatively straightforward to assess using standard toxicological and ecotoxicological approaches, affects from non-point source are much more difficult to assess and quantify primarily due to multiple stressor effects.

Classical toxicology has been one of the primary approaches by which the effects of environmental pollutants on aquatic organisms have been assessed. A variety of standardized laboratory toxicological studies have been conducted where contaminant dose, for example has been related to responses of individual organisms particularly at the biochemical or physiological levels. These types of controlled lab studies however, provide limited information about how organisms, short of mortality or other survival end points, respond to environmental stressors in their natural environment.

Because of the problems and limitations of laboratory toxicological studies and most other methods which have been used in attempts to evaluate and quantify the effects of environmental stressors on the health of aquatic systems, better field bioassessment approaches are needed which provide an integrated framework for addressing cumulative and/or synergistic environment impacts on the health of aquatic systems. One such method, the bioindicator approach, has proven successful in assessing and evaluating the effects of contaminants and other types of environmental stressors on the health and integrity of key biological components of aquatic systems.

Both rapidly responding exposure biomarkers such as biomolecular and biochemical responses, and slower responses but ecologically relevant bioindicators such as population and community responses are included in this bioindicator assessment methodology.

CONCEPTUAL BASIS OF BIOINDICATORS

Bioindicators can be defined as anthropogenically induced variations in biochemical or physiological components or functions (*i.e.*, biomarkers) that have either statistically correlated or casually linked, in at least a semiquantitative manner to biological effects at one or more of the organisms, population, community or ecosystem levels of biological organization.

A field based bioindicators approach basically involves measuring a selected suite of responses at each of several levels of biological organization from the molecular to community levels for by sentinal organisms in the environment. Biological responses measured with this approach fall along two gradients, one of response time and the other of ecological relevance.

Environmental stressors first effect sub-organismal components such as cells and tissues and, if a stressor continues to be of sufficient duration and magnitude effects at these lower levels will eventually be manifested at increasingly higher levels of biological organization. Responses *eg.,* Biomolecular/biochemical are essentially quick responding and sensitive indicators to environmental stressors but they are generally characterised by low ecological significance. Responses *eg.,* Population level however, display very little response sensitivity but possess high ecological relevance. Ecologically relevant end points are important in the ecological risk assessment process and also in environmental compliance and regulatory assessment. The bioindicator approach, therefore, includes the best of the two features of an environmental health assessment programme, a combination of sensitive and rapidly responding biomarkers and slower responding indicators which have ecological relevance. By using this approach, therefore, we can increase our ability to link or correlate environmental stressors such as contaminants to observed biological effects.

BIOINDICATORS MEASURED

Corresponding to the various levels of biological organization, a suite of bioindicators can be measured at each of these levels as shown in Table 1. Each of the six main levels of responses represent increasing levels of biological organization decreasing levels of response sensitivity to environmental stressors and increasing ecological relevance.

Table 1. Representative bioindicators measured at six major levels of biological organization

Biochemical	Physiological	Histopathology	Individual	Population	Community
MFO enzymes	Creatinine	Necrosis	Growth	Abundance	Richness
Bile metabolites	Transaminase enzymes	Macrophage aggregates	Total body lipid	Size & age distribution	Index biotic integrity
DNA integrity	Cortisol	Parasitic lesions	Organo-indices	Sex ratio	Intolerant species
Stress proteins	Triglycerides	Functional parenchyma	Condition factor	Bioenergetic parameters	Feeding types
Antioxidant enzymes	Steroid hormones	Carcinomas	Gross anomalies	Reproductive integrity	

At the biomolecular/biochemical level, mixed function oxidase enzymes (MFOs) have been used as indicators of exposure to a variety of bile metabolites have been used to reflect exposure to PAH types of compounds.

Measures of DNA integrity have proven to be reliable measure of exposure to genotoxic agents.

Stress proteins have been used widely to indicate non specific response from a variety of environmental stressors.

Antioxidant enzymes are just coming into wide use as indicators of oxidative stress (particularly heavy metals) at cell level.

At the next level of biological organization, a variety of physiological responses have proven valuable for assessing the health of organisms collected from the field including organ dysfunction indicators *viz.,*Creatimine for kidney damage and transanimase enzyme as indicators of liver impairment. Cortisol as a non specific alarm reaction stress indicator. Triglycerides (neutral lipids) as simple bioenergetic indicators to stress at physiological level. Steroid hormones such as female estradiol which reflects reproductive function.

At the next level of organization, structural changes in tissue and organs are measured as various histopathological indicators such as cell necrosis, macrophage aggregates, and incidences of carcinomas and tumors.

At the individual organism level, measures of somatic growth, total body lipid, various organo-somatic indices and identification of several gross anomalies such as gross body lesions, parasites and various pathological conditions (HAI).

Population level indictors typically measured are relative abundance, age and size frequency (indicators of reproductive fitness and recruitment) and various measures of reproductive integrity such as fecundity, egg condition, and age at maturity.

Community level ecologically relevant responses used in bioassessment are species richness, Index of Biotic integrity (IBI) and distribution of trophic feeding types in the community.

This list of bioindictors have been found to have worked best in a variety of aquatic systems (streams, rivers, lakes, estuaries) under a variety of environmental stressors.

CONCLUSION

Thus the primary advantage of this integrated bioindicator approach is that it can provide (1) early warning signals of environmental damage (2) assessment of the integrated effects of a variety of environmental stressors on the health of organisms, populations, and communities, (3) sentinels of potential hazards to human health based on the responses of fish, shellfish to environmental stressors (4) evaluation of the effectiveness of remediation efforts in clean up of contaminated areas and (5) scientifically sound information for addressing ecological and possibly human health risk issues at contaminated sites.

SUGGESTED READING

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METHODS FOR ASSESSMENT OF FISH POPULATION IN INLAND WATER BODIES

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INTRODUCTION

Over the past few decades, natural fish stocks have been placed under considerable and sustained pressure from intense fishing, pollution and other anthropogenic activities associated with inland and water resource development. These activities have resulted in habitat loss and degradation, and consequent decline in distribution and abundance in fish species. Several strategies are being adopted to stabilise the status of the fisheries and prevent them from decline. They include fisheries management, fisheries mitigation and rehabilitation methods. Knowledge about the fish stock size, recruitment and survival rates is essential for taking appropriate decisions pertaining to management options. In the context of management of fisheries, the managers tend to seek appropriate biological advice with regard to the levels of fish stocks and the extent of exploitation in order to suggest suitable strategies. In this context, the assessment of fish populations, recruitment intensity, mortality rates and levels of exploitation etc assumes greater importance.

Various approaches have been suggested for estimation of fish population by utilizing data on catch and effort, tagged recoveries and other biological inputs. We will bow present various method of estimation and discuss them in the proceeding paragraphs with suitable examples.

METHOD BASED ON CATCH AND FISHING EFFORT

Reasonable results can be obtained by considering stock size to be proportional to fishing success (cpue) and eliminating the effect of recruitment by using a short time scale. This type of computation first applied to a population of rats by Leslie and Davis (1939). An improved form was introduced in estimation of fish population by De lury (1947) and refined by Braaten (1969) . The natural

logarithmsof the catch per unit effort $\left(\frac{C_t}{f_t}\right)$ is plotted against the cumulativeeffort (E_t) to the

mid point of each interval $\log\left(\frac{c_t}{f_t}\right) = \log_e (qNo) - qE_t$

This determines a straight line whose slope estimate the catchability (q) of the fish and whose ordinate intercept estimates $\log_e$ q No, where No is the original population.

Any fishing success method implies two rather severe conditions:

i) that there be no appreciable success or deficit of immigration into the stock over emigration out of it, and no recruitment by growth of smaller fish into the catchable size range;

ii) that the catchability of the fish remain constant or at least that it has no sustained trend during the period of the computation.

Derzhavin's biostatistical method

He conceived the idea of applying the observed age structure to catch records available and to calculate the contribution of each year class to each year's catch. By summing the catches removed in future years from the year-classes alive in a given year, he calculated a minimum number of animals alive in the reference year. A figure which was called the utilized stock/virtual population size using marked individuals. (sample censussing)

Marking methodology in estimation of population parameters in an exploited fishery

Marking techniques have been used from centuries for the study of animal populations from Moths to Whales. Towards the beginning of 20th century these methods started playing important role in the study of movements and migration of fish and formed the basis for estimating the total population size. During the post quarter of a century tagging experiments have been extensively employed for measuring growth of individual fish and mortality rates caused by fishing and natural environmental factors. The scope and application of marking methods were further extended by the researchers for studying the prey-predation relationship and swimming velocities of fish species. Useful experiments were first conducted by Peterson towards the beginning of the 20th century, by tagging marine fish named plaice and he devised basic and simple methods for estimating various population parameters. The use of these methods stimulated considerable research into the development of more efficient experimental procedures and associated statistical techniques of estimation. These methods were based on the presumption that the tagging or marking of fish satisfies certain basic assumptions such as :

i) After the release of tagging individuals they mixes with the untagged fish and both types of animals are equally liable to capture i.e. the catchability coefficient is same for tagged and untagged fish.

ii) The fish and the sampling effort is randomly distributed.

iii) Population of tagged individuals in the sample is same as in the total population.

iv) Size of the population does not change during the period of investigation i. e., no recruitment or immigration from outside take place.

v) Survival rate is constant over the experimental period.
The success of estimation methods depend on the efficiency of the tags and their application. It has to be ensured that the efficiency of tagging is such that the following features of the models are satisfied.

i) There should not be any initial tagging mortality.
ii) Complete reporting of tags should be ensured through various measures.

iii) The loss of tags between rèlease and last recapture should be minimum.

iv) Tagging should not force any extra mortality

v) The catchability for tagged and untagged specimens should be same. ie., tagged should not make the fish more vulnerable to gear as compared to untagged fish.

vi) Tags should not affect the growth, physiology, behaviour and survival of the tagged fish. i.e. without any detrimental effect upon swimming stanu.. or buoyancy regulation.

METHODS OF ESTIMATION

For simplicity in presentation of various methods, the experiments are grouped into two main categories.

i) Estimation of parameters from a single tagging experiment.

ii) Estimation of parameters from a multiple tagging experiments.

In (i) tagging is done only on one occasion extending to a limited period of time and recaptures are made thereafter. The recaptures so obtained may be grouped in the following three ways.

i) Sample is taken on one occasion only and marked recaptures are recorded (single recapture)

Suppose a population of unknown size N has M marked individuals and U = N-M unmarked. A random sample of size n from the population yields m marked and u = n-m unmarked. Assuming marked and unmarked are equally represented in the sample, we can write:

$$\hat{N} = \frac{M.n}{m}$$

which leads to the well known Peterson estimate -

$$\frac{m}{n} = \frac{M}{N}$$

ii) Samples are taken from the population on number of occasions and the numbers bearing tags are recorded in each sample.

Here let m_i be the marked fish out of n_i in the i-th sample and Y_i be the ratio of m_i and n_i

(i.e $y_i = \frac{m}{n}$); then the estimates of survival rate can be obtained as ;

$$S = \frac{X}{\left(\sum y_i + X - y_k\right)}$$

[*Robson and Chapman* (1961)]

$$Where\ X = \sum_{i=1}^{k} (i-1)\, y_i$$

$$S = \frac{\sum_{i=2}^{k} y_i}{\sum_{i=1}^{k-1} y_i} \qquad [Jackson\,(1939)]$$

$$S = \frac{\sum_{i=2}^{k} y_i}{\sum_{i=1}^{k-1} y_i} \qquad [Heincke\,(1913)]$$

Jackson estimate $S = \frac{238}{339} = 0.70$

Table 1 .Estimation of survival rate from a single tagging experiment with captures on discrete occasions. (Hypothetical example)

i	1	2	3	4	5	6
m_i	12	14	2	4	4	3
n_i	1000	1500	400	1000	1200	1600
y_i	120	93	53	40	33	19

Robson and Chapman estimate $S = \frac{546}{358 + 546 - 19} = 0.62$

Heincke estimate $S = \frac{238}{358} = 0.66$

iii) Tagged individuals are recaptured continuously as in commercial fishery and are grouped according to successive time periods.

Here, we may assume that n_i be the number of tagged fish recaptured during the i-th period after tagging. If the tag recaptures are grouped in this fashion, then under the assumption that the decline in the numbers of tagged individuals can be expected to approximate to an exponential curve, estimate of mortality rate may be calculated by the regression equation.

F, M & X are losses due to fishing mortality, natural mortality and extra losses due to loss of

$$\log n_i = -Z'Ti + \log\left(\frac{FNo}{Z'}\right) + \log\left(l - e^{-ZT}\right) \; where \; Z' = F + M + X$$

tags, deaths due to tagging and migration out of the area. No. is the total no. of fish tagged.

The above equation may be written in the simple form as ;

$$\log n_i = bi + a \ where \ b = slope = Z'T$$

(T= time duration of each interval. T=1 if groupings are done yearly)

It is desirable to check the validity of linear relationship by plotting the actual data. Any departure from linearity will suggest that the assumption of constant mortality is violated. Secondly, since the variance will be roughly universally proportional to the numbers returned in each interval, it will rapidly increase in the later intervals. To minimise this effect more weightage to earlier points are given while fitting an eye fit line.

Chapman (1961) has suggested another method of estimating F and M for such type of grouped recaptures. He provides the estimates of F and M as follows;

where n= no. of fish recaptured, N, total no. of tagged fish effectively released and t is the time at which

$$\hat{F} = \frac{n(n-1)}{N\sum t_i}, n \geq 2$$

$$\hat{M} = \frac{(N-n)(n-1)}{N\sum t_i}, n \geq 2$$

recaptures occur in the sample.

Table 2. Recaptures by month from 6539 tagged fish effectively liberated

Code No. (X_i) regression	Days since tagging	Number returned	log (n_i) = (Y_i)	Beverton & Holt Method
-	0	501	-	$\sum xy = 34.373$
1	10	270	5.598	$\sum x^2 = 60$
2	20	133	4.890	b=-0.5729, a=5.8848
3	30	177	5.176	ie Z'T = 0.5729
4	40	55	4.007	Z' = 20.805
5	50	96	4.564	F'T = 0.073
6	60	17	2.833	F = 2.664, M = 18.114
7	70	27	3.296	
8	80	2	0.693	
9	90	4	1.386	

$$Chapman(1961)\hat{F}_e = 4.3833$$

$$\hat{M}_e = 17.79$$

$$\hat{Z} = 22.1733$$

Multiple Tagging

In this class individuals are tagged on more than one occasion and sampled for recaptures on more than one occasion. Multiple tagging leads to the possibility of recapturing and releasing the same individuals on more than one occasion. These recaptures may be classified in three different ways.;

i) Recaptures are classified with reference to all the occasions on which it has been previously tagged and released

ii) Recaptures are classified with reference only to the occasion on which they were first released. (Robson Method)

iii) Recaptures are classified with reference only to the occasion on which they were last released. (Jolly-Seber Method)

The numbers released on any occasion have also been classified by different , authors in different ways. Robson method takes into account the Individuals that are newly tagged and released on each occasion. Jolly -Seber method takes care of the total number of tagged individuals released on each occasion. (i.e., newly tagged + previously tagged)

Jolly -Seber Method

Let n_i be the number offish sampled on i-th occasion m_i of them bear tags.

T_i = number offish released on i-th occasion (newly tagged + previously tagged)

r_i = the total no. offish recaptured during the experiment that were last released in the i-th sampling occasion

q_i = the no. of fish last liberated before the i-th occasion which are not captured on the i-th occasion but which are captured after the i-th occasion.

I_i = the no. of tagged individuals in the population immediately prior to the taking of the i-th sample.

I_i-m_i = tagged fish in the waterbody prior to i-th occasion.

q_i of I_i -m_i are captured after the i-th occasion

r_i out of T_i are captured during the experiment

Then by simple proportional theory

$$\frac{q_i}{I_i - m_i} = \frac{r_i}{T_i}$$

$$or \quad I_i = m_i + \frac{q_i T_i}{r_i}$$

Then the estimate of S_i, the probability of survival of a fish from the end of i-th sampling to the beginning of (i+ 1)th of sampling is given by

$$\hat{S}_{i/i+1} = \frac{I_{i+1}}{I_i - m_i + T_i} = \frac{r_i (T_{i+1} q_{i+1} + r_{i+1} m_{i+1})}{r_{i+1} T (q_i + r_i)}$$

The above equation is equivalent to the ratio of the number of tagged fish prior to the (i+ 1) th sampling, to the number of tagged fish in the population immediately after the i-th sampling. It therefore provides an estimate of the survival rate between two sampling provides, but does not take account of any mortality that might occur during the sampling period itself.

Robson's method

This method deals with the general situation in which recaptures are classified according to the occasion in which they were first released. Following the previous analogue, we may say that

$$\frac{q_i'}{I_i} = \frac{r_i'}{T_i'}$$

$$or \quad I_i = \frac{q_i' T_i'}{r_i'}$$

$$\hat{S}_{i/i+1} = \frac{I_{i+1}}{I_i + T_i}$$

$$\hat{S}_{i/i+1} = \frac{T_{i+1}' q_{i+1}' r_i'}{T_i (q_i' + r_i') r_{i+1}'}$$

The values of q_i', r_i' & T_i' will not necessarily have the same numerical values as Jolly and Seber's T_i, r_i and q_i. It estimates the probability of survival of an individual from the end of one sampling occasion to the end and not the beginning of the next sampling occasion.

Example: Estimation of survival rate

Table 3. Jolly -Seber Method

i	Number tagged (T_i)	2	3	4	5	6	r_i
1	1000	60	32	21	13	3	129
2	2060		124	82	49	12	267
3	1656			149	89	22	260
4	1252				188	46	234
5	2339					193	193
	m_i	60	156	252	339	276	1083

Value of q

1	2	3	4	5
0	69	180	188	83

Value of S

$S_{1/2} = 0.59$ $S_{2/3} = 0.50$ $S_{3/4} = 0.45$ $S_{4/5} = 0.60$

Table 4. Robson Method

i	Number tagged(T_i)	2	3	4	r_i
1	1000	60	36	27	123
2	2000		120	90	210
3	1500			135	135
	m_i	60	156	252	468

Value of q

1	2	3
0	63	177

Value of S

$S_{1/2} = 0.60$ $S_{2/3} = 0.50$

Estimation of population size :

Let N_i be the total fish present in the waterbody at the i-th sampling

$$N_i = \frac{n_i q_i T_i}{m_i r_i} + n_i \quad \text{(Jolly - Seber method)}$$

$$N_i = \frac{n_i q_i T_i}{m_i r_i} \quad \text{(Robson method)}$$

Table 5. Jolly – Seber method

Basic data calculation for table 3

	T_i	q_i	r_i	m_i	I_i	n_i	N_i=n:I_i/m_i
1	1000	0	129	-	-	-	-
2	2060	69	267	60	592	16000	157867
3	1656	180	260	156	1302	10000	83462
4	1252	188	234	252	1258	7000	34944
5	2339	83	193	339	1395	5000	21822

Table 6. Robson method

	T_i	q_i	r_i	I_i'	n_i	N_i	m_i
1	1000	0	123	0	16000	-	0
2	2000	63	210	600	10000	16000	60
3	1500	117	135	1300	7000	83333	156

Use of Multi – stage sampling in estimation of fish population in small stream and rivers

A common, although generally unrecognised use of multistage sampling designs in freshwater fisheries research is for estimation of the total number of fish in small streams. Here, these are two stages of sampling. At the first stage, one selects a sample of stream reactions, usually of equal length. Within any selected stream section, some population estimation techniques must frequently a removal method estimator based on electro-fishing is used to estimate the total number of fish present.

Four estimates of total fish population have been derived under different sampling........

N = total no. of primary units
n = total no. of primary units in the sample
Y_i = total in primary unit i estimated as
M_i = size of the primary unit i
M_o = total size of all primary units
$P_i = M_i / M_i$ ponds of selecting the jth unit in a .... draw when length are selected by PPS with replesent

$$SRS = \hat{Y} = \frac{N}{M} \sum_{i}^{N} \hat{y}_i \qquad ....(1)$$

PPS with replesent

$$\hat{Y} = \frac{1}{n} \sum^{n} \frac{\hat{y}_i}{p_i} \qquad ....(3)$$

$$SRS\ ratio = \hat{Y} = M_o \frac{\sum^{n} \hat{Y}_i}{\sum^{n} M_i} \qquad ....(2)$$

Relative performances of the three above sampled procedure will depend primarily on the following conditions

1) The no. of primary unit data selected, n, and the size of the sampling unimous, N.

2) The degree to which primary unit totals are proportioanl to primary unit sizes masured roughly by the correaltion between Y_i and M_i.
3) The range of sizes of primary units in the sampling variance , and

4) Survey cost associated with electro-fishing within selected primary units.

The formulae (1) will be appropriate if the primary units of uneqaual size are selected by SRS but one does not imply an auxillary variable. When primary unit totals are highly correlated with primary unit sizes first stage variance will be large for this design as the individual primary unit totals will be very different form the average primary unit total. In estimate (2) auxillary variable M_i may dramatically increase precision of estimation over equation (1) when a (primary unit total are proportion to primary unit size and b the variation in primary unit totals increases in proportion to primary unit size. The estimate at (3) will perform best when Y_{ir} proportional to M_i.

CONCLUSION

It may be concluded that these methods can be applied in different situation depending upon the information available. However it may be mentioned that the population estimation with Tag and Recapture methods give fairly reasonable results if the assumption are followed during the experiments.

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STATISTICAL METHODS FOR INTERPRETING DATA ON ENVIRONMENTAL STRESSORS AND ITS IMPACT ON FISH HEALTH

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INTRODUCTION

The change in the environment will affect the various parameters connected with the fish health. The parameters may be assessed qualitatively or quantitatively. When the parameters are measured quantitatively we need some tools to compile and compare the impact on fish health. There are various statistical tools for this purpose. Some of them are discussed for understanding the environmental stress on fish.

Measure of central tendency

When a mass of data is presented either in raw form or in the form of a frequency distribution, no general idea of the data under study could be obtained. So, we need to summarise the information contained in the data. The summarisation is done by using certain descriptive measures, which will determine certain features of the data. One of such characteristics is central tendency.

Very often we find a tendency in the data to cluster around a central value. If length measurement of fish from a culture pond is taken the length seems to concentrate around a certain length. This is apparent from Table 1, where the figures seem to concentrate about a point between 22 and 23 cm. In such case it is possible to use a single value to represent the whole set of data. Such a representative or typical value of a variable is called a measure of central tendency or an average.

Table 1. length of 20 fish caught from a pond

Sl No.	Length (cm)	Sl.No.	Length (cm)
1	22.2	11	22.0
2	23.7	12	23.7
3	21.7	13	23.4
4	22.3	14	22.8
5	24.1	15	21.4
6	24.5	16	22.9
7	22.4	17	22.2
8	23.8	18	23.0
9	22.7	19	22.6
10	22.5	20	22.4

The idea of average is a familiar one. When we say the length of fish in one pond is more than than the length of the fish of the second pond, it does not mean that the length of every fish in first pond is more than the length of every fish in the second pond. All that we mean is that the average length of fishes of pond one is more than the average length of the fishes of the second pond.

There are many types of averages. But we will discuss only one measure namely *arithmetic mean.*

Arithmetic mean

The arithmetic mean (or simply mean), of a variable is obtained by dividing the sum of its given values by their number. If the variable is denoted by x and if n values of x are given - $x_1, x_2, \ldots\ldots, x_n$, then the arithmatic mean of x is

$$\bar{x} = x_i/n$$

Example 1: For the data in Table 1 the arithmetic mean is

(22.2+23.7+…………22.4)/20 = 456.3/20=22.815 cm

When we have a frequency table, the formula may be expressed in the form:

$$\bar{x} = x_i f_i / n,$$

where x_i is the value of x in the i-th class, f_i is the corresponding frequency and $f_i = n$.

Measure of dispersion

The average of a variable gives a general idea as to the whole set of its values. It is clear, however, that a variable to be really variable, its given values will not be all equal to the average. In some cases they may lie very near the average, but in others may be widely scattered about it.Two sets of data may not be identical even though they have the same measures of central tendencies. For the following three sets of data

(i) 60,60,60,60,60
(ii) 30,50,85,75,60
(iii) 10,60,90,90,50

the means are the same, namely 60, but the observations differ in their scatter around the mean in the three sets.

In order to give a proper idea about the overall nature of the given values of a variable, it is necessary, besides mentioning the average value, to state how scattered the given values are about the average. Mainly three different measures are used to determine this feature of a variable, which is called dispersion. These are (1) range, (2) mean deviation and (3) standard deviation.

Range

The simplest measure of dispersion of a variable is its range, which is defined as the difference between the hightest and lowest given values.

Mean deviation

The arithmetic mean of the absolute deviations from a chosen average value 'A' is referred to as mean deviation about A. Denoting the mean deviation by MD_A ,we have thus,

$$MD_A = |x_i - A|/n$$

Standard deviation

The positive square root of the arithmetic mean of the squares of the deviations from the mean is called standard deviation. Symbolically,

$$S.D. = \sqrt{\Sigma(x_i - \bar{x})^2/n}$$

This can also be written as

$$S.D. = \sqrt{(\Sigma x_i^2/n - \bar{x}^2)}$$

For grouped data the standard deviation is given by

$$S.D. = \sqrt{\Sigma f_i(x_i - \bar{x})^2/n}$$

This becomes on simplification

$$S.D. = \sqrt{(\Sigma f_i x_i^2/n - \bar{x}^2)}$$

Measures of relative dispersion

The above mentioned measures of dispersion are expressed in the same units as belong to single variable. But problem may be encountered to compare the dispersion in different variables having different units of measurement. For example, to compare the dispersion of a set of heights (cm), with a set of weights (kg), the measure of dispersion has to be made free from the units. For this purpose the simplest procedure is to express a measure of dispersion as a percentage of a measure of central tendency. The most commonly used measure of this type is the coefficient of variation (CV), which is the standard deviation expressed as percentage of the arithmetic mean. In symbols,

$CV = 100\ s/\bar{x}$. where s= standard deviation, x = arithmetic mean

Besides the above-mentioned use, such measures serve another purpose. The coefficient of variation will give the true picture of the relative accuracy. It may be useful even when we want to compare sets of data expressed in the same units but having widely different means.

Comparison of two means

The problem here is to examine it two population means are equal or not. The problem may, however, assume two distinct forms. In one case, the two quantities are the means of the same random variable for two different populations. In the other, they are the means of two different random variables for the same population.

Let the random variable x have the means μ_1 and μ_2 in two different situations (like the races, two universities, two factories, two machines or two batches of workers of the same factory, and so on). We want to see whether μ_1 and μ_2 may be taken to be equal, on the basis of a random $x_{11}, x_{12}, \ldots x_{1n}$ from the probability distribution of x for the first situation and independent random sample $x_{21}, x_{22}, \ldots, x_{2n}$ from the probability distribution of x for the second situation.

We shall assume that in each situation the probability distribution of x is of the normal type. In order to avoid complications in the test procedure, we shall make the further assumption that the two distribution have a common (though unknown) variance, say σ^2. (This assumption of homoscedasticity or of equality of variances.).

The proper test-criterion for our null hypothesis, viz.H_o: $\mu_1 = \mu_2$ is then

$$t = \frac{\bar{x}_1 - \bar{x}_2}{s'\sqrt{(1/n_1 + 1/n_2)}}$$

where $\bar{x}_1$ = mean of the first sample = $\Sigma x_{1i}/ n_1$

$\bar{x}_2$ = mean of the second sample = $\Sigma x_{2i}/ n_2$

and s'^2=pooled sample variance =

$$\{\Sigma (x_{1i} - \bar{x}_1)^2 + \Sigma (x_{2i} - \bar{x}_2)^2\}/(n_1+n_2-2)$$

$$=[\{\Sigma x_{1i}^2 - (\Sigma x_{1i})^2/ n_1\} + \{\Sigma x_{2i}^2 - (\Sigma x_{2i})^2/ n_2\}]/(n_1+n_2-2)$$

This test criterion has, under H_0, the t-distribution with d.f.= n_1+n_2-2. As such , if we denote by $t_{\alpha, n1+n2-2}$

the upper point of this distribution and by t_0 the observed value of t, then our procedure will be as follows:

One will reject H_0, if and only if $t_0 > t_{\alpha, n1+n2-2}$ or $t_0 < -t_{\alpha, n1+n2-2}$ or $|t| > t_{\alpha/2, n1+n2-2}$, according as the alternative hypothesis is H_1: $\mu_1 > \mu_2$ or H: $\mu_1 < \mu_2$ or H: $\mu_1 \neq \mu_2$ This test procedure has been called Fisher's t-test.

Comparison of k means

Sometimes we require to test for the equality of means of k univariate normal distributions supposed to have the same (though unknown) variance.

Let the variable x have the normal distribution with mean μ_i and variance σ^2 (the same for each i) in the ith situation. Our null hypothesis is

$$H_0: \mu_1 = \mu_2 = \ldots\ldots\ldots\ldots\ldots = \mu_k,$$

which is to be tested against all alternatives on the basis of k random samples of sizes n_1 , n_2 , ... n_k taken from these distributions. We shall assume that $n_i \geq 2$ for at least one i. the jth observation in the ith sample will be denoted by x_{ij} ($i = 1,2,\ldots\ldots, k$; $j = 1,2,\ldots\ldots, n_i$).

Further , let

$$\bar{x}_i = \sum_{j=1}^{n_i} x_{ij} / n_i$$

= mean of the ith sample

and

$$\bar{x} = \sum_{i=1}^{k} \sum_{j=1}^{n_i} x_{ij} / \sum_{i=1}^{k} n_i$$

$$= \sum_{i=1}^{k} n_i \, \bar{x}_i \, / \, n, \qquad where \; n = \sum_{i=1}^{k} n_i$$

= grand mean

Now we have

$$\sum_i \sum_j (x_{ij} - \bar{x})^2 = \sum_i \sum_j \{(\bar{x}_i - \bar{x}) + (x_{ij} - \bar{x}_i)\}^2$$

$$= \sum_i n_i (\bar{x}_i - \bar{x})^2 + \sum_i \sum_j (x_{ij} - \bar{x}_i)^2$$

The L.H.S. is the sum of squares (SS) of the deviation of observations from the grand mean and is called the *'total SS'*. As to the R.H.S., the first component represents the weighted sum of squares of deviations of the sample means from the grand mean and is called the '*SS* between groups (or samples)'. On the other hand, the second component is the sum of squares of deviations of the observations from the respective samples means and so is called the '*SS* within groups'. Hence the above equation may be put in the form total $SS = SS$ between groups + SS within groups

$$= SSB + SSW$$

It can be shown that

$$E(SSB) = (k-1)\sigma^2 + \sum_1 n_i (\mu_i - \overline{\mu})^2$$

and

$$S(SSW) = (n-k)\sigma^2$$

where $\overline{\mu} = \sum_i n_i \ \mu_i \ / n.$

Hence if we call SSB/(k-1) and SSW/ (n-k) the 'mean square between groups' (MSB) and the mean square within groups' (MSW), respectively, then

$$E(MSB) = \sigma^2 + \frac{1}{k-1}\sum_i n_i (\mu_i - \overline{\mu})^2$$

and $E(MSW) = \sigma^2$

Thus the expected value of MSW is σ^2 irrespective of the validity or otherwise of H_o, while MSB has the expectation σ^2 if H_o holds and otherwise its expectation is greater than σ^2. It seems, therefore, that a comparison of MSB and MSW should provide us with a test for H_o. The test - criterion is

$$F = MSB/MSW$$

which is, under H_o, distributed as F with df = (k-1, n - k). H_o is rejected if and only if F_o the observed value of the criterion, exceeds $F_{\alpha\,:\,k-1,\,n-k}$.

The process of splitting the total SS into independent components like SSB and SSW, which can be attributed to different sources of variation, is called *analysis of variance*. The technique has numerous applications and here we have discussed one of the simplest. The whole procedure is generally exhibited in a tabular form.

Analysis of Variance table

Source of Variation	d.f.	Sum of squares	Mean square	F Observed	F Tabulated 5% 1%
Between treatments	k-1	SSB	MSB=SSB/(k-1)	MSB/MSW	
Within treatments	n-k	SSW	MSW=SSW/(n-k)		
Total	n-1	SST			

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ROLE OF EXTENTION IN CONSERVATION OF AQUATIC ENVIRONMENT FOR MAINTENANCE OF OPTIMUM FISH HEALTH AND PRODUCTION.

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INTRODUCTION

Fish, an excellent source of animal protein, is one of the staple items of diet for the country's sizeable population. Hence, maximum sustained yield of fish from natural waters and assurance of recurring, bountiful harvest of fish without depleting the resources and wastage of fishing effort are necessary for the nation. Unfortunately, apart from fish health hazards, destruction of fish habitat by alteration of river systems, increased water abstraction, over fishing of important fishes, pollution of fishery waters, land development and domestication of species have been going on indiscriminately. These anthropogenic induced alterations along with fish mortality due to disease outbreak have, naturally, been showing qualitative and quantitative changes in population structures as indicated in decline of fisheries in different ecosystems.

All these factors lead to the strong requirement of judicious exploitation of commercially important fish species, protection of the stocks from any sort of stress including pollution and fish health hazard, for improvement of the fishery and conservation of the aquatic environment *vis-a-vis* rich fish resources of the country.

RESOURCES

Fortunately, India is endowed with rich and diverse inland water resources in the form of rivers, canals, estuaries, lagoons, backwaters, brackish water impoundments, mangroves, floodplain wetlands, upland lakes, swamps and man-made reservoirs, tanks and ponds. A well conceived, rational strategy of harnessing them can substantially improve the fish production and help reducing the animal protein gap in our diet. Out ecosystems are well known for their mega diversity of biological wealth, harbouring over 12% of the shell and fin fishes known. Many of them are acclaimed for qualities such as fast growth rate, hardiness and flavour and are considered as delicacies. Conservation of the country's rich germplasm is our bounden duty to posterity. Again, unlike agriculture, fisheries does not consume water and make serious demands on the water budget. On the other hand, it helps to improve the quality of natural waters. With a catchment area of over 3.12 million km^2, country's 14 large, 48 medium and innumerable small rivers carrying a surface runoff of 167.23 million ha through their drift exhibit a kaleidoscopic variety of environments such as the cold streams of the uplands, fast and slow moving stretches in the plains, floodplain lakes, deep pools, placid backwaters and estuaries. development and rational exploitation of our capture fisheries resources are challenging tasks, unlike culture fisheries where ecosystem manipulation and production monitoring are easy. Large open waters, spread among varied geoclimatic conditions, exhibit diverse ecodynamics and hence no uniform guideline can be formulated for their management.

Definition of conservation

Conservation is broadly defined as management of human use of the biosphere, so that it may yield the greatest sustainable benefit to present generation while maintaining its potential to meet the needs and aspirations of future generations. Conservation embraces preservation, maintenance, sustainable utilization and restoration of the natural environment.

Need for conservation

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

ROLE OF EXTENSION IN FISH CONSERVATION

Extension is a system which is used as an instrument to bring about a desirable change, be it sociological or technological. It is a multidimensional system with interrelationship, linkage and transactions between and among internal and external domain. It aims at causing planed change or progress in the target field as per the greater sociological and economic changes designed by the political will of the people. In view of its crucial role, the fish conservation programme planning development also has to include the extension component as an integral part.

The role of fisheries extension is much beyond mere dissemination of information. Extension has a central role to play in the process of transfer of ideas in relation to its components like research, clients and support. This role becomes even more important when it comes to the question of influencing of resource poor fish farmer/fishermen who constitute a sizeable number in the country towards adoption of conservation meaasures. Right from generation of fish conservation programmes and fish health care, the extension system has to provide feed-back to the research system about the characteristics of the target group, their needs, interest, enterprise and above all their resource constraints. Taking clue from such information, the research system should be engaged in the development of technology *vis-a-vis* conservation plan in close association with the extension system as well as client system. The fish conservation programme, thus generated will be tailor made to the conditions of the clientele. The extension system has to translate fish conservation measures into the form of messages mostly on the information on management of aquatic environment, fish health care, restriction on catch size of fish understandable to the target group and organise a strategy, so that they are disseminated through the utilization of appropriate media. As the target groups operate under resource constraints and become victim of under-employment while adopting conservation measures. Various support provisions are to be made available to them, so that they can actually adopt the practices. In doing so, another very vital requirement on the part of extension system is to organise the members around functional group, so that the bargaining power of the members is increased and common property resources can be pooled and utilized in more efficient manner. The final outcome of this process should be adoption of practices by the members of the target groups. For success of fish conservation programme for maintaince of optimum fish health and production; extension system not only depend upon its capability in safe-guarding fish germplasm resources through adoption of conservation measures, but also expedite its ability to provide relevant technological base to protect fish health to various categories of fish farmers/fishing population operating under divergent resource endowments and aqua-ecological characteristics.

Strategy for effective communication

The present strategy towards conservation of aquatic environment *vis-a-vis* monitoring of fish health management in the country calls for rapid dissemination of information to the clientele in mass scale direction and bringing the gap between research system and target groups in the field. The strategy for communication of information on conservation measures to the target group is to be treated henceforth as one of the essential inputs to overall activity in the intended fishery development programmes.

Types of information

Ideally information system for conservation of aquatic environment for maintenance of fish health and production should cover :

1. Information on local natural resources and biodiversity
2. Information on direct abstraction to potable supply
3. Information on food for human consumptions derived from the inland water
4. Information on industrial abstraction
5. Information on crop irrigational abstraction
6. Information on livestock water use
7. Information on local industries and nature of its effluents
8. Information on domestic sewage discharge
9. Information on chemicals in use in aquaculture
10. Information on chemicals in use in agriculture
11. Information on status of local deforestation
12. Information on disease outbreak
13. Information on fish mortality

14. Information on impact fish disease in public health

15. Information on conservation measures

16.Information on socio-economic status of the fishermen population

17. Information pertaining to existing facilities and infrastructure

18. Information on use of gears and mesh size

19. Information on close seasons

20. Information on non-fishing zones and seasons

21. Information on alternative jobs for clientele when involved during conservation programme

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

COMMUNICATION PLANNING

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

Face to face oral strategy

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

Case Studies

The case studies may come from all the areas of extension activities of the inland fisheries development *vis-a-vis* protection measures of the aquatic ecosystems.

The case studies may be on achievement/activities of individuals worker and experience of fishermen. The information can be compiled to give up to date data.

Circulation

Information on protection measures towards fish and fisheries conservation could be widely circulated in the form of circular letter, hand-out, leaflet, pamphlet, mimeograph etc.

Joint field visit

Joint field visits of researcher and extension worker will enable them to understand about success of the conservation programmes of fish and 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

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

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 than the process put to use.

Local participation is not the only new criteria by which the management of aquatic environment 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.

Inland aquatic environment *vis-a-vis* conservation 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 prioritise 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 protecting fish in aquatic ecosystems and should work, within a time frame, towards an ideal (even if it may not be wholly achievable) condition.

People's participation

Encouraging people's participation in the management of aquatic ecosystem conservation 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 management of aquatic environment. 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 phase of participation;

iv) the proportion of those potentially affected who really participate in such schemes;

v) the representativeness and accountability of the leader and the local organisation 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 socially feasible action but towards development itself. Development, welfare and problem-solving were, in the past, activities that families, kinfolk and communities talked. But with development and welfare increasingly and unfortunately, often exclusively becoming government responsibilities, or at best, agency functions, the question of who participate in whose activity becomes very relevant.

Generally speaking it is the Government/Development agencies only who now-a-days do something for the beneficiaries, whether this involves transferring technology or building infrastructure, or whatever other tasks. The Non Governmental Organisations must take initiative in this regard, so that participation of clientele increases.

Leadership in conservation movement

The village motivators play a key role in establishing good participation of the members of the target group in the activities of fish and fisheries conservation. They have a major responsibility in explaining conservation of aquatic environment programmes and in setting up good systems of dialogue, so that the members of the target group get full opportunity to express their opinions freely. There is no doubt that the village motivators have been helping this process enormously because they have been able to gain confidence of the members of the target group as they live in the same village and thus, they have succeeded in establishing that the fish conservation programme in the country has genuine reason to be helped.

It has been intended that the village motivators should identify a small core of villagers who would represent the whole range of different village groups. These villagers are known as facilitators and their role will be seen as ensuring good lines of communication between fish farmer/fishermen and extension personnel involved in fish conservation programme. In general, much of the communication with villagers is on an informal level, although there is also regular programme of group meetings, field days, training sessions etc. The people's participation programmes have demonstrated that participation in the fish conservation programme is possible only when the members of the target group are able to pool their efforts and resources in pursuit of objectives and goals they set for themselves. The most efficient means of achieving this objective are small, democratic and informal groups of 8 to 15 like minded people. All the programmes on conservations aiming at ecological restoration for maintanace of optimum fish health and socio-economic development would have better chances of success if people visualise these as their own activity. The fish conservation movement necessarily involves both individual and group actions. In fact, participatory approaches are indispensable for successful programmes on conservation of environment *vis-à-vis* fish production..

CONCLUSION

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

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ECONOMIC IMPACT OF ENVIRONMENTAL DEGRADATION VIS-À-VIS FISHERIES

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INTRODUCTION

Environment is the nature's endowment, which provides us the life support systems. It sustains our very existence, therefore, is considered as a special asset in economics. The assessment of economic impacts of environmental degradation would require to quantify the extractions from nature and the addition of wastes or residuals. The exercise of measurement or quantification of these variables in physical terms may be carried with the help of primary and secondary information, but to evaluate or assign them some monetary value is the subject matter of environmental economics including economics of environmental degradation. In India, studies related to environmental economics are very few particularly on aquatic environment. Since, aqua-resources form the habitat of fishes, the study primarily deals with environmental degradation in context of water pollution. To evaluate the economic impact of environmental degradation vis-à-vis fisheries, the pre-requisites may be i) major sources of water pollution; ii) environment management system (EMS); iii) Laws for water pollution prevention; iv) conceptual approach for addressing the aquatic environmental impacts; v) assessment of ecosystem health; and vi) social and economic evaluation including economics of environmental degradation. These aspects are briefly addressed in the present lecture alongwith summary of the concepts, methods and techniques used in environmental economics.

Major sources of aquatic environment degradation

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

a) Domestic waste

Urban municipal solid waste generation in India is estimated to increase from 48 to 3000 million tonnes per annum during 1997 to 2047 (Uberoi, 1999). It means over 62 times increase in waste generation. As per estimates, if present methods of waste disposal continue, the area under landfill sites would increase seven times. To recover and recycle such huge volumes of domestic wastes there is urgent need to plan strategies and to implement them the earliest.

b) Industrial waste

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

c) Agricultural runoff

Agricultural activities are one of the primary causes of environmental degradation through water pollution. The problem became more pronounced in developing countries like India, where agriculture is the major enterprise. Excessive use of fertilizer resulted in eutrophication in many aquatic habitats. In addition groundwater may also become contaminated with fertilizers and pesticides.

Environment Management System

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

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

Laws for Water Pollution Prevention

a) River Boards Act, 1956

According to this act River Boards have been established to regulate and develop inter-state rivers and river valleys. The act entrusts the River Boards with functions of i) conservation, control and optimum utilisation of water resources of inter-state rivers; ii) promotion and operation of schemes for irrigation, water supply, drainage, flood control, afforestation and navigation; iii) control of soil erosion and prevention of pollution of waters of inter-state river (s). The boards require knowledge on several technical and other aspects to prescribe the standards and give consents. Although, they are following ISI standards as a rule of thumb, but they have to make independent individual judgement based on situation for granting consent orders.

b) Water (prevention and control of pollution) Cess Act, 1977

The act authorizes Water Boards and local authority to levy and collect cess on water consumed by persons engaged in certain industries, with a view to augment their resources.

c) Water (prevention and control of pollution) Act, 1974 amended as Act of 1979

The act defines the water pollution, sewage effluents, sewer, industrial effluents, stream, etc. It enacted to establish Central and State Water Boards. The functions of Central Boards are primarily advisory and supervisory, while of State water Boards these are more comprehensive.

Conceptual approach for addressing the aquatic environmental impacts

To provide a basis for addressing aquatic (surface water) environment impacts, a six step or six -activity model is suggested for the planning and conduction of impact studies (Canter, 1996). This model is flexible and can be adapted to various project types by modification, as needed, to enable the addressing of specific concerns of specific projects in unique locations. This model is mainly related to river systems, the principles could also be applied to the examination of impacts on lakes, estuaries, coastal zones, and the ocean. The six generic steps involved are :

1. Identification of the types and quantities of water pollutants to be introduced, water quantities to be withdrawn, or other impact-causing factors related to the development project.

2. Description of the environmental setting in terms of river, lake, or estuarine flow patterns; water quality characteristics; existing or historical pollution problems; pertinent meteorological factors (examples are precipitation, evaporation, and temperature); relationships to area ground water resources; existing point and non point sources of pollution; and pollution loading and existing water withdrawals.

3. Promulgation of relevant laws, regulations, or criteria related to water quality and/or water usage, and any relevant agreements between states, countries, or other entities related to relevant transnational waters.

4. Conduction of impact prediction activities, including the use of mass balances in terms of water quantity and/ or pollutant loading changes, mathematical models for relevant pollutant types (conservative, non-conservative, bacterial, nutrient, and thermal), aquatic ecosystems model to account for floral and faunal changes and nutrient-pollutant cycling or qualitative predictions based on case studies and professional judgement.

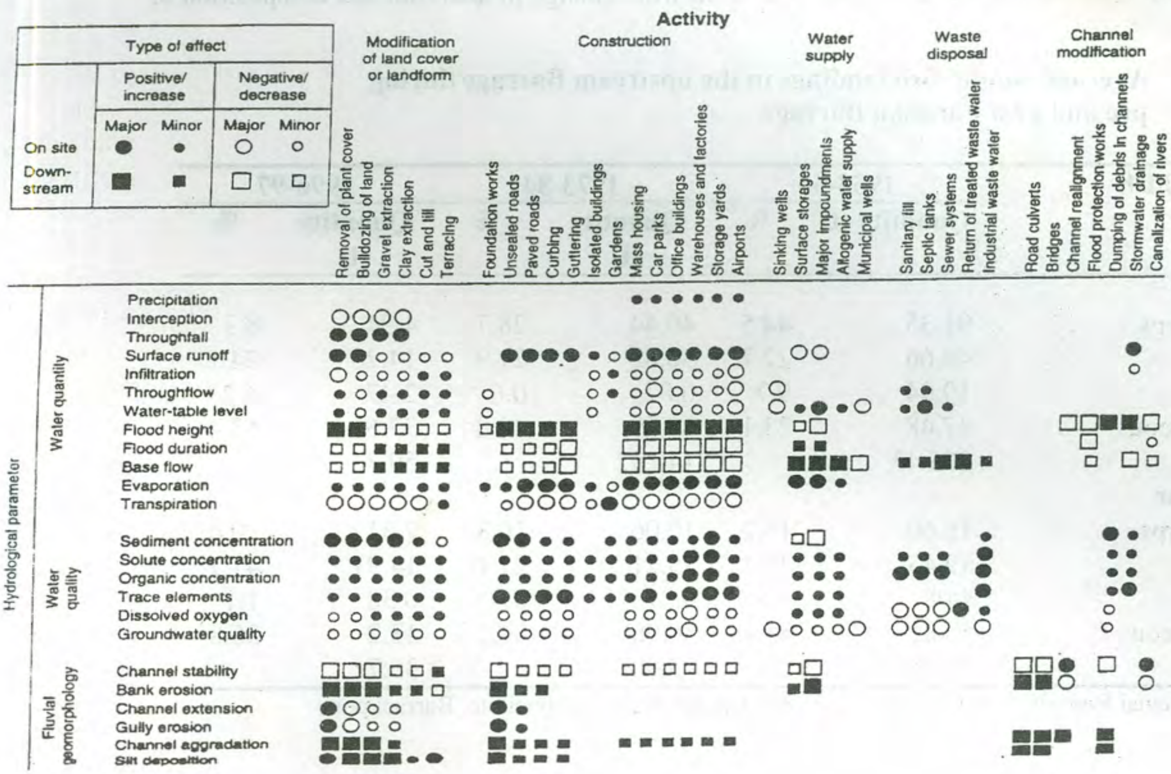
5. Use of pertinent information from step 3, along with professional judgement and public input, to assess the significance of anticipated beneficial and detrimental impacts; and

6. Identification, development and incorporation of appropriate mitigation measures for the adverse impacts.

The fundamental step is identification of potential impacts. Several methods have been developed as aids for identifying generic impacts, one of the approach makes use of simple interaction matrix, represented in Figure 1. It displays an impact matrix, which depicts various land use changes and their consequences on selected hydrological parameters. The careful examination indicates both the positive and negative effects either at sites of land use change or downstream.

Assessment of Ecosystem Health

Figure 1. Impacts of land use and changes on selected hydrological parameters



2. Aquatic- ecosystem key variable weights

Rivers		Lakes	
Variables	Weights	Variables	Weights
sh Species Association	30	1.Total Dissolved Solids	30
nuosity Index	20	2. Spring Flooding Index	20
otal Dissolved Solids	20	3. Mean Depth	15
urbidity	10	4. Chemical Type	15
hemical Type	10	5. Turbidity	15
enthic Diversity	10	6. Shoreline Development Index	5
		7. Total Fish Standing Crop	b
		8. Sport Fish Standing Crop	b

ts for stream/river variables may be reassigned based on knowledge of local area or other erations. A paired comparison technique may be used to adjust weights

data are available, weights may be reassigned or the fish data may be used solely to determine t quality. A paired comparison technique may be used to adjust weights

e: Canter (1996) p. 391

onstruction of Farakka barrage on river Ganga and its impact on fisheries of Ganga River n is one of the most important examples of impact environmental change on fisheries. The e fish catch composition during pre and post Farakka period in up and down stream are nted in tables 3 and 4. The impact is evident from change in quantum and composition of atch.

3. Average annual fish landings in the upstream Barrage during pre and post Farakka Barrage

Fish	1958-66		1973-84		1996-97	
	Quantity (t)	%	Quantity (t)	%	Quantity (t)	%
abad						
Carps	91.35	44.5	40.44	28.7	4.94	8.3
h	46.66	22.7	30.82	21.9	14.28	24.1
	19.94	9.7	0.87	0.6	2.47	4.2
llaneous	47.48	23.1	68.79	48.8	37.61	63.4
	205.43		140.92		59.3	
alpur						
Carps	16.60	18.2	10.06	10.8	7.31	20.4
h	19.43	21.4	25.21	27.1	14.91	41.7
	4.08	4.5	0.87	0.9	0.38	1.1
llaneous	50.82	55.9	56.96	61.2	13.2	36.8
	90.95		93.90		35.7	

: Annual Reports, Central Inland Capture Fisheries Research Institute, Barrackpore

Table 4. Average annual fish landings in the Hooghly estuary during pre and post Farraka Barrage

Fish	Pre-Farakka Barrage				Post- Farakka Barrage			
	1960-63		1966-75		1984-95		1997-200	
	Quantity (t)	%	Quantity (t)	%	Quantity (t)	%	Quantity (t)	
Hilsa	743.9	23.22	1457.1	15.37	2336.6	5.39	9576.9	15.6
Mullets	39.5	1.23	30.8	0.32	18.2	0.04	37.5	0.06
Thread fin	74.4	2.32	63.9	0.67	296.7	0.68	524.4	0.86
Perch	45.9	1.43	24.5	0.26	49.9	0.12	130.3	0.21
Sciaenids	118.9	3.71	203.7	2.15	4327.7	9.99	8102.2	13.2
Catfish	152.5	4.76	109.6	1.16	992.9	2.29	1653.9	2.71
Other clupeids	136.2	4.25	437.8	4.62	4081.6	9.42	12345.7	20.2
Ribbon fish	83.1	2.59	454	4.79	12835.5	29.61	4184	6.86
Bombay duck	797.1	24.88	2067.9	21.81	5301	12.23	9950.7	16.3
Pomfret		0.00	71.6	0.76	866.3	2.00	45.8	0.08
Prawn	574.1	17.92	1338.3	14.11	2939.3	6.78	3573.6	5.86
Other	438.4	13.68	3222.3	33.99	9295.7	21.45	10906	17.8
Total	3204		9481.5		43341.4		61031	

Source: Annual Reports, central Inland Capture Fisheries research institute, Barrackpore

Social and economic evaluation

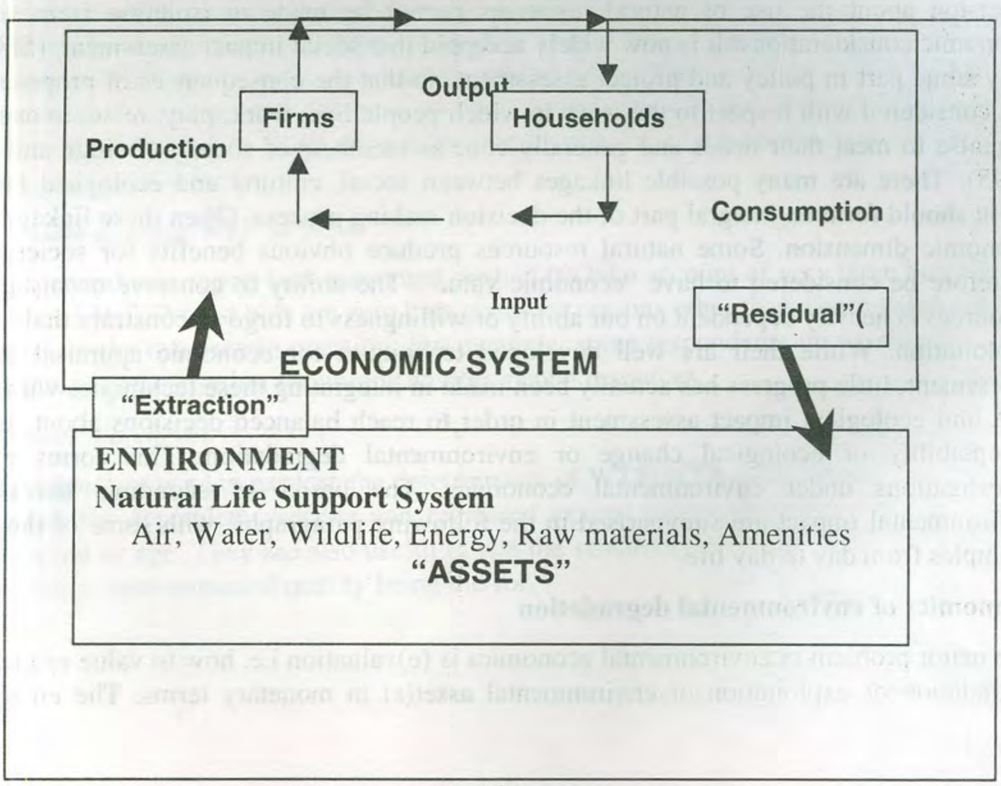
Decision about the use of natural resources cannot be made in isolation from social and economic considerations. It is now widely accepted that social impact assessment (SIA) should play some part in policy and project assessment, so that the consequences of proposed actions are considered with respect to the ways in which people live, work, play, relate to one another, organise to meet their needs and generally cope as members of society (Burdge and Vanclay, 1995). There are many possible linkages between social, cultural and ecological factors and these should form an integral part of the decision making process. Often these linkages have an economic dimension. Some natural resources produce obvious benefits for society and can therefore be considered to have "economic value". The ability to conserve or sustain natural resources is heavily dependent on our ability or willingness to forgo or constrain their economic exploitation. While their are well developed techniques for economic appraisal and social assessment, little progress has actually been made in integrating these techniques with those for EIA and ecological impact assessment in order to reach balanced decisions about the overall acceptability of ecological change or environmental degradation. This forms a part of investigations under environmental economics. The basics of economic assessment of environmental impact are summarised in the following paragraphs, with some of the practical examples from day to day life.

Economics of environmental degradation

The major problem in environmental economics is (e)valuation i.e. how to value or measure the degradation or exploitation of environmental asset(s) in monetary terms. The emergence of sustainable development as fundamental imperative of any economy has made this valuation process a pivotal point. India is in no way an exception. A nation is said to have sustainable development, if it enables to satisfy its requirements (social, economic and others) without jeopardizing or compromising with the interests of future generations. The relation between an economic system and environment is depicted in Figure 2. It indicated the extraction of natural resources from environment and adding the residual or waste material into it. Therefore, the valuation of environmental degradation should be from viewpoint of benefits extracted from environment and losses due to residuals or waste disposal into it.

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

Fig. 2. Interaction of economic system and environment



Valuation of environmental degradation

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

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

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

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

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

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

Method of valuation

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

Techniques of valuation

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

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

b) **Indirect approach**: evaluates the preferences indirectly based on the inferences from actual individual behaviour in relation to environmental goods and services. These are of two-type i) Surrogate and ii) conventional market type. The surrogate market techniques included Household production function (Travel cost and averting behaviour) and Hedonic pricing

(Property and labour market), while conventional market techniques are of three types: Dose-response, Replacement cost and Opportunity cost.

One method each from direct (Contingent valuation) and indirect (Replacement cost) approach are briefly discussed below

Contingent valuation method

The contingent valuation method (CVM) is one of the techniques that can be used to estimate economic values for commodities that cannot be traded conventionally in markets. Davis (1963) proposed the method. CVM works by directly soliciting from a sample of "consumers" their willingness to pay (WTP) for, or accept (WTA) a "change in the level of environmental service flows in a carefully structured hypothetical market" (Hanley and Spash 1993). Briefly, CVM can be undertaken in six stages outlined below.

Set up a hypothetical market

To set up the hypothetical market for environmental goods, environmental economist must be aware of i) environmental assets expected to be affected in the degradation process, ii) the people likely to be affected due to degradation, iii) extent of impact due to degradation across different sectors of people likely to be affected, iv) socio-economic status of this populace, and v) their willingness to pay for or accept (compensation) the degraded environment. Based on these primary data, specify reasons for payment/acceptance of compensation and frame the provision rule, to go about the bidding for valuation of the changes in hypothetical market.

Obtain "bids" for environmental goods or services

Carry out survey, usually through face-to –face interview, by telephone or by mail. WTP may be derived through bidding (higher and higher amounts are suggested to respondents until their maximum WTP is reached), as a closed –ended referendum in which a yes/no reply is sought for a single recommended payment, as open ended question in which responded are asked to specify their maximum WTP or as a "payment card" in which respondents are able to choose from a range of values.

Calculate average WTP or WTA

As a general rule report both mean and median (to take account of very large bids) and exclude "protest bids". Protest bids are zero bids given for reasons other than a zero value actually being placed on the resource in question. For example, some respondents might refuse to accept any amount of compensation for unique environmental resources.

Estimate bid curves

Bid curves are used to explore the determinants of WTP/WTA bids. WTP/WTA amount can be used as the dependent variable and regressed against independent variables such as income, education or age. They are also useful to test the sensitivity of WTP amounts to changes in the amount of environmental quality being bid for.

Aggregate data

This is the process whereby mean bids derived from a population sample (the sample mean) are converted to a total value figure for the whole population. For example, the sample mean may be multiplied by number of households in the population.

Evaluate exercise

CVM exercise should be evaluated to establish how successful the application of CVM has been. The results should be considered in the light of whether a high proportion of protest bids was received, or respondents appeared to understand the hypothetical market or they had direct experience of the environmental assets in question.

Replacement cost

This method of evaluating the economic impact of environmental degradation is common for the eco-systems that are damaged or destroyed and are to be replaced. The cost of replacement can be estimated for some ecosystems or habitat types, and varies according to ecosystems and their specific condition. This technique is still in developmental or experimental stage and it is difficult to estimate how much it will cost to achieve a desired end result. The figure 3 shows the process of replacement of the damage to the ecosystem (Jones and Pease, 1996). It depicts that natural recovery of an ecosystem may take a long time, so, for active restoration efforts may be undertaken which require expenditure in the form of replacement cost. The area A is allocated to active restoration, while area A+B allocated to natural recovery. In 1985, GOI set up Central Ganga Authority for planning and execution of a time bound programme to prevent river Ganga from pollution, better known as GANGA ACTION PLAN. It is one of the examples of such activities. The categories and distribution of these schemes in Gangatic states are given in Table 5. The total budget of the plan at Rs 259.27 crores can be considered as the replacement cost for restoration of riverine habitat.

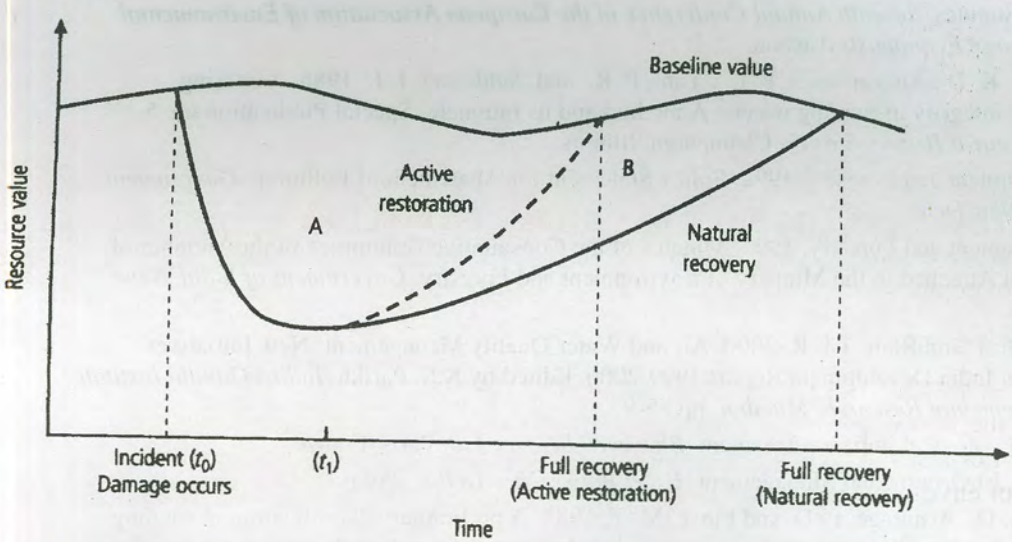


Figure 3. The role of restoration recovery and replace ment cost

Table 5. Distribution of schemes and replacement cost under Ganga Action Plan

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

Figures in parentheses represent the number of sanctioned schemes

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Summer School on ***Methods of assessment of aquatic ecosystem for fish health care***
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Farmer Participatory Research as a Tool in Fish Health Management

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India has the longest history in aquaculture and this technology appears to have been invented by the farmers of the eastern part of the country. Food habits of the people is influenced by the available resources. Rice and fish being the common diet of people, it appears that the area was rich in fishery resources and rice fields also contributed substantially for fish production in the past. The declining catch from the natural environment could also be one of the reasons for the invention of fish culture techniques by the farmers of this region. In Bangladesh, there are evidences to demonstrate clearly the impact of pesticide usage and the decline in the rice field fishery. There has also been tremendous loss of production due to the epidemic diseases like EUS in the freshwater sector and the White spot syndrome virus disease in the marine sector. There are estimations available on the direct loss of fish due to diseases from culture ponds, but losses occurring in the open waters through the direct impact of disease as well as their effect on biodiversity are not known. Evidences indicate that EUS has caused heavy damage to smaller carps, other weed fishes, air breathing fishes etc., which have been mainly providing food to the poor people who are largely dependent on open water fishing. It should be noted here that most species affected in open water bodies are also nutritionally rich (Table 1).

Farmer Participatory Research has been tried since almost a decade to address varieties of agricultural problems, including fish health issues. In this paper an effort has been made to share the experiences of using this tool to address some of the fish health issues in Bangladesh and India.

GENESIS OF FARMER PARTICIPATORY RESEARCH

Green revolution was largely accomplished by using the system of Training and Visit Extension approach, wherein training and visiting of demonstration plots by the trained farmers formed the key components. Affluent farmers derived the benefit to some degree through this system. They were able to adopt the packages given by the institutions and obtain appreciable amount of production owing to the ability of those farmers to provide the inputs. This approach made the farmers as passive recipients of technology and the process almost left out completely the resource poor farmers, who constitute bulk of the farming community. As an alternative to this system, new forms of information dissemination strategies begun to emerge in the last decade and among them "Farming Systems Research and Extension " became popular. However, here again, instead of allowing farmers to innovate using the resources available to them, researchers used farmers field only as an experimental plot with farmers acting as doers/observers using the resources provided by the extension agencies. Since the system again proved to be defective, farmer participatory research has come in to practice as an improvement to the FSRE system and the new approach has been found to be useful to carryout both **Research through Extension and Extension through Research.** In this approach, there is no standard package of technology to adopt, but there are baskets of options to adapt and adopt. Results / observations available from various sources are compiled and they are subjected to further adaptations at the farmers level based on the resources available with the farmers. The results / observations from the research organizations are only used as reference by farmers to experiment the new technological options or potential pathway to find solutions to the problems and thereby evolve farm specific practices which would best suit them. Social issues are given equal or even more consideration than the plant / animal biology. With the emphasis being laid on giving principles instead of the process/ recipes, the results obtained using this approach in different parts of the world have shown better sustainability under different circumstances.

INTEGRATED PEST MANAGEMENT

The first successful application of farmer participatory research in Asia was made on a large scale in developing the Integrated Pest Management Strategies for paddy crop in Indonesia by the FAO project. The results of the project have demonstrated that farmers are confident and competent in carrying out research to solve their farming problems. Commonsense and curiosity being the foundation stones for any research investigation, abundance of these qualities with farmers did result in the evolution of a number of crop varieties, until last century, when the scientific community took almost complete control of research. Using these historical facts and recognizing every individual innovation capability, FAO – IPM project took advantage of igniting those basic qualities possessed farmers to solve their field problems, initially in pest management without using the pesticide and promoting rice – fish wherever, it was possible. The concept of trying out field as a laboratory, use of class rooms without walls, use of facilitators in place of teachers, self discovery process, etc., are used as guiding principles in farmer field schools.

Farmer Field Schools not only provide an opportunity to solve their field based agricultural problems, but also create an opportunity for them to solve several other sociological problems that might be confronting farmers owing to its group based learning approach used.

PROCESS

Each school would generally consist of a maximum of 25 - 30 farmers of almost the same economic strata. Farmers meet together in these farmer field schools once a week or in two weeks time, based on the planning they make early in the season. With the help of a trained facilitator, farmers make plan for a rice crop season / other crops in regard to the issues they like to learn, which would help them to address the field problems. These learning sessions, which would last from 2-3 hours to half a day will involve field observations, discussions on the observations and making collective decisions in regard to the management issues like water condition in the field, fish growth, level of pests and beneficiary insects, etc. Based on the observations and discussions, farmers arrive at decisions on the management strategies to be adopted in the upcoming weeks.

Pesticide usage is rampant in paddy fields for the control of pests and diseases. Farmers have been taught generally only about the harmful insects with less focus on beneficial ones. Nature has created both pests and beneficial insects to maintain balance in the ecosystem. However, as a result of the application of pesticides, they not only kill the harmful insects , but also several of the beneficial insects. This results in the resurgence of harmful insects in a short span of time. This has been leading to the continued usage of pesticide for the control of pests by the farmers. As stated earlier, extensive usage of pesticides has also resulted in the destruction of several fish species. Rice field fishes, which once met most of the food requirements of rural people are becoming rare. The decline of fish species under the natural environment has been largely attributed to the usage of pesticides. In addition, bioaccumulation of pesticides has been causing serous health concerns too. Impact of endosulfan on the health of people is becoming visible in some states like Kerala. This pesticide is not only used widely in various agricultural crops, but also in fish ponds for killing fishes. In Bangladesh, it is popularly called as Indian oil as it is imported from India and widely used on various crops.

IMPACT OF ECOLOGY BASED LEARNING SESSIONS

Following the Indonesian model, Farmer Field Schools / Participatory Action Research Groups were established in different parts of Bangladesh. Farmers made observations by themselves on the management of the paddy fields without the usage of pesticides by maintaining paddy fields with and without pesticides. These simple experiments along with other supplementary observations set to understand the process of controlling pests by natural enemies helped farmers to understand the interaction between beneficial and harmful insects in the rice fields. Farmers were able to eliminate the usage of pesticides through these simple experiments and observations. Results of more than a decade long work with more than 200,000 families have demonstrated that more than 90% of the farmers have stopped using pesticide completely, after going through the learning sessions. Experiences indicate that each group of farmers have to be worked with at least for 2- 3 rice crop seasons to achieve good success and sustainability (Table 2)

FISH AS AN INCENTIVE IN ELIMINATING PESTICIDE USAGE

About 20% of the available land located in low lying areas have been found to be suitable for rice fish cultivation. These paddy fields have been brought under rice-fish through these ecology based learning sessions (Table 3). Fish is an attractive commodity for farmers in several areas where water is abundant. Introduction of fish in paddy fields through the simple modifications of fields like raising dikes, construction of canals around paddy fields, fish refuge / ditch etc., for the fish to take shelter during low water season are completed early in the season. These canals and ditches covered an area of 4-10% of the paddy field. Fish were grown in all the three crop seasons – Amon, Aus and Boro. The usage of fish in the paddy field not only prevented farmers from using pesticides in the paddy field, but increased paddy yield by 8-10% and the farm income by 30-50% (Table 4) . Production of fish have varied from 300 –1200 kg / ha. During Amon season, with high depth of water, fish were grown to marketable size in 4-5 months time. While some farmers would market them at this stage or stock in fish pond, others would either continue culture in the boro season if there is adequate amount of water in the ditch/paddy field. During boro season, water being scarce, farmers largely depend on the bore well water. Hence, farmers generally undertake fish seed production with species like common carp, tilapia and silver barb and nurse the seed to fingerling size in paddy fields (fig 1 and 2). Experiments have shown that water hyacinth roots with common carp eggs are directly placed in paddy fields and the recovery of fry (3 - 4%) has been found to be economical. Use of paddy fields for nursing of fry is becoming common and it has been suggested that paddy fields can be effectively used for nursing of fish seed. The income derived by such nursing activities have been quite impressive and women have been actively involved in fish breeding and nursing activities Table 5).

EMERGENCE OF COMMUNITY RICE-FISH FARMING

As the land holdings of farmers is small with floods being common in low lying areas, particularly during monsoon, community fish farming has emerged as an alternative. In this system, farmers holding land in a given area would join together, stock fish collectively, allow fish to move in the entire area without boundaries, harvest fish jointly and share the production based on the collective decision arrived before starting the activity. However, paddy cultivation will still continue as an individual activity, but everyone would abide to the rule of non-usage of pesticide. Community fish farming has created much better bondage between the members of the communities. However, to maintain that community cohesiveness, good leader is necessary and through the community participation such leaders are elected. Elected leaders are provided with adequate knowledge on leadership qualities.

Community rice-fish farming has contributed to increase the rice field area suitable for fish farming and in some areas, even up to 40% of the total paddy cultivated area could be brought under rice-fish cultivation.

SUSTAINABILITY STUDIES

Studies conducted on the sustainability of rice fish cultivation, non-usage of pesticide and the usage of dikes around paddy fields for growing vegetables, etc have shown that among the various activities rice-fish is the most sustained activities by the farmers. Dike crop was given up in many areas since labour required was too high and the returns obtained were not commensurate with the amount of effort. Among other factors, in areas where there was more poverty, less job opportunities, participation of women in training activities, etc were found to sustain the activities better. Conservativeness, alternate job opportunities, poor quality of facilitation, etc., led to the resurgence of pesticide usage by farmers once the project activities were withdrawn from the area.

IMPACT OF UNIFIED EXTENSION APPROACH ON THE ADOPTION OF RICE-FISH SYSTEM

One of the important steps that has been suggested to increase fish culture by many agencies is the adoption of unified extension system. In most countries, there are separate Departments to look after the activities of agriculture, forestry, fisheries, veterinary sciences, etc with each Department looking from its own perspective without understanding the complexity of the farming systems and the amount of time available with farmers. Under the unified extension system, extension agent acts only as a facilitator, facilitating the process of learning through the self discovery process. Facilitators receive constant back up support from the technical team. Through this new approach, it has been found that the adoption of new technologies evolved is much faster and sustainability is greater. Specialists in the subject area appear only when there are special problems. Through a number of projects this unified extension system has been tried extensively in Bangladesh by different NGOs.

The above approaches used in the farmer participatory research have demonstrated that it is possible to reduce /eliminate the pesticide usage and safeguard the health of fish and people. In India, the amount of pesticide usage is on increase with a consumption of about 50,464 tonnes during 2000-01 as against 43,381 tonnes during the previous year. Considerable amount of this pesticide is used in the paddy fields and this usage is affecting the biodiversity in rice fields. Any efforts to reduce / eliminate the usage of pesticides would help both environment and farmers.

EPIZOOTIC ULCERATIVE SYNDROME (EUS)

The EUS disease which was first recorded in Japan in 1970s took more than a decade to notice in India and in the early years of its occurrence (during mid 80s), it caused heavy damage to fish culture systems. Several theories were floated on the causative agent ranging from chemical pollutants to virus. However, concerted efforts of a few researchers, finally demonstrated that the causative agent is fungus – *Aphanomyces invadans*. The damage caused by the disease being very destructive in several of the Southeast Asian countries, efforts were made by some of researchers in developing preventive or curative measures on an isolated basis. However, there were no easily available solution to the problems.

In Bangladesh, EUS continues to be one of the major problems encountered in carp farms and open water bodies. Participatory action research groups (PARG) constituted as part of an EU funded project to test the suitability of "farmer participatory research" to enhance productivity, undertook a study covering three winter seasons to address the problems of EUS. This disease was identified as the number one problem encountered by fish farmers. Other problems identified in the fisheries sector included poor growth of fish, oxygen deficiency, etc. Based on the literature review and discussion with a number of experts in the area, it was decided to explore alternate possibilities to find solutions using the resources available with the farmers. Prior to experimentation, learning sessions were organized with every group of farmers and discussed the causes of disease and the existing status of knowledge. With each group consisting of 25–30 members, the number of farmers owning fish ponds varied from 5-15 in each group. Those farmers owning ponds agreed upon to set up experimentation using different materials available / easily accessible to them. The experimental protocols were developed in consultation with farmers. It was agreed that excepting the cost of knowledge, which would be provided free, all other input costs will be borne by farmers themselves. Altogether 315 farmers took part in the study during the first year.

Farmers chose four different treatments, namely salt, lime, a combination of salt and lime and ash. The dosage rate was decided based on the available closely related information – salt and lime was applied at 1 kg / decimal (40 m^2) as the primary dose , while the combination treatment had a 50% mix of the two. In the case of ash, it was applied at 3 kg / decimal as the first dose based on the results available in regard to its action as compared to lime (Table 6). The outbreak of disease generally occurs when the temperature reaches to the lowest level during winter season. Based on the temperature data available, a fortnight prior to the lowering of temperature, treatments were commenced. Following the basal dose application as suggested above, farmers agreed to apply the dose at half the initial dose every fortnight until the end of the cold season. Farmers sampled fish every fortnight and observed their growth and health, while the water qualities were based on visual observations. All farmers were not able to maintain the protocol of applications of the purchased inputs like salt and lime or even ash. When they did not see disease, farmers stopped the application of treatment. There was no distress situation noticed during the culture period, resulting in the harvest of fish and sale in most cases. At the end of the season, farmers met together and analysed the results of adopting one or the other treatments and the benefits noticed in terms of disease prevention, cure, increased profitability and increased production, etc. Among the different treatments tried, the best results were noticed with the application of salt and lime followed by the application of ash and the combination treatment. In most places, farmers were happy with the application of ash as it was a non-purchased input. The results also showed that the production of fish could be increased by 15-20% using ash for treating ponds. Among the various risk factors tested for their influence on EUS, presence of silver barb was found to be the main causative factor, while the application of lime had a protective effect in preventing the disease.

Following the completion of trials, farmers shared their findings with other fellow farmers of the village. These sharing occasions created an atmosphere of scientific events and were witnessed by the researchers of the Research Institutes and Professors from the Bangladesh Agricultural University. Farmers were able to make comparisons between different treatments and arrive at the decision on the best treatment suited to them. Measurements of the overall attitude of farmers indicated that 67% of farmers were happy with the results, 20% of the farmers offered no comments and expressed their desire to try for themselves, 7% of the farmers were confused with the results and indicated that they can't decide on which treatment is really good and 8% of the farmers were unhappy (Table 7).

During 1999 and 2000, the experiment was continued with the new group of farmers and the sustainability aspects of farmers who adopted the treatment in the previous years was also followed closely. Studies showed that majority of farmers continued the treatment, but by using largely either ash or lime. Experimental results in the subsequent years indicated that placing Neem twigs with leaves in ponds or keeping the pond in green condition through regular fertilization were also found to give good results in terms of preventing the appearance of disease.

Based on the above results, simple options for farmers like the application of lime prior to the onset of cold season, application of ash or keeping the pond green were suggested as the potential easy options that could be tried by other interested farmers based on their convenience and necessity .

MANAGEMENT OF WHITE SPOT SYNDROME VIRUS DISEASE

Global shrimp industry faced a setback due to the incidence of white spot virus disease. Like in EUS, though it took some time to decide on the causative agent, research studies have now clearly demonstrated that the white spot disease is caused by virus. However, with no solution to contain the virus problem, the industry is continuing to face series of problems. A farmer participatory research carried out in Karnataka with a group of cooperating farmers, in a collaborative project between the scientists from UK and the Mangalore Fisheries College disease group (Mohan, personal communication) have been able to identify clearly the risk and protective factors. The research conducted was conducted in partnership with 77 farmers using various improved techniques to detect the presence or absence of virus with PCR, water quality analysis, etc. The study demonstrated that by following some of the good management practices, it is possible to grow healthy shrimp. Removal of silt , use of bleaching powder , proper usage of manure , application of appropriate lime and quantity, use of less DAP , use of vitamin C , use of Neem seed cake, etc have all been found to protect the shrimp from the disease. Like wise, there were also a number of risk factors associated with the occurrence of disease like the presence of white spots , colour of shrimp, frequent mortality of shrimp, presence of large number of birds , crabs , etc were found to be associated with the disease. The study conducted by stationing of staff to work closely with the farmers and gathering information on a regular basis on various farm management practices yielded rich amount of information. While such a change in the working approach not only increased the confidence of farmers among the scientific group, it also increased the quality of information obtained from farmers. The results of the study have shown to be a good example from the fisheries sector to demonstrate the usefulness of farmer participatory research. A series of publications are expected to emerge based on these studies and those interested to know more details should contact Dr. C.V.Mohan at the College of Fisheries in Mangalore. .

Shrimp industry has been benefiting the poor substantially. Unfortunately , excepting few studies carried out by Dr. Krishnan in CIBA , there is paucity of information on this issue of who is benefiting from the industry. In general , in the eyes of public, the industry is being identified with few corporate houses and as a result there is a perception that the industry is benefiting mostly rich in the society because of the heavy capital requirement. Field observations indicate that , Shrimp/Prawn farming are powerful tools to improve the livelihoods of people in a short span of time. Unfortunately , due to the poor support to the farmers to help them in gaining knowledge on the management aspects of the system through self discovery process , in many cases , farmers have been pushed into poverty cycle.

CONCLUSION

There are some issues that should be considered by all of us to bring changes in the fisheries sector to meet the fish requirement of the population through igniting blue revolution process throughout the country through FPR.

Defining research agenda

- None denies the necessity of working closely with the farming community. However, when it comes to defining the research agenda and developing program of activities, these necessities are not translated into actions because of various constraints, which are due to both academic and social pressures. The method of evaluation adopted by the scientific bureaucracy and the scientific journals have also been identified as the other causative factors for **poor partnership with the farming community and poor targeting of the poor**. Farmers and farming systems in developing countries being totally different from the developed countries, there is a need to evolve different **approaches to cater to the needs of the resource poor farmers by the resource poor scientists** working in these environments.

Resource Allocation for FPR

- Farmers of Andhra Pradesh have been innovative in many areas including aquaculture. Sometime ago, there was a discussion with the farmers of that state about fish production and consumption in different parts of the country with a view to help them in developing market plans. When the data on per hectare production and per capita consumption were presented, farmers were not able to agree with both the figures. We all are aware that fish production and consumption varies from place to place based on a number of parameters and they need to be estimated based on such parameters and correlated to prepare development plans. There are some efforts in estimating production of fish from capture and culture fisheries, though far from satisfactory, the data provides some idea for making development plans. However, there is paucity of information in regard to the actual consumption of fish, excepting a recent study carried out in four different states by the CICFRI and the College of Fisheries, Mangalore . The study demonstrated large variations in consumption pattern not only between states , but also between different wealth class of people (Pradeep Katiha and Ramachandra Bhatta, Personal Communication).

Estimates based on the ratio of total production and population would not give correct picture. To draw an example from Cambodia, the per capita consumption of fish has been found to be as high as 70 kg/person/year with a minimum being, even in the drought prone districts about 30kg/person/year. However, the national average based on the total production and total population was 13kg/person/year. When they started noticing this large disparity, a number of field investigations were carried out by different agencies and the results indicated that the production levels recorded are actually much lower than the production levels reported. Rice field fishery production, which is largely carried out as the family scale fishing was never recorded, but bulk of the consumption in rural areas continues to be derived from the rice field fishery. As a result of the recent efforts made in the estimation of fish catch, Cambodia has been placed as the fourth largest producer of fish from the freshwater sector in the world. Owing to these important information generation, the sector has been able to secure proper place in the national economy and obtain good international support since the fishery is so much important in the livelihood of people.

Similar may the situation in India and most estimates are currently based on the ratio of total production and total population and there is a need to estimate the actual production and consumption requirement based on the ground level survey. These results should be used to develop local plans and the national fisheries plan should emerge based on these realistic data. The Indian Fisheries Contribution to the GDP is estimated to be around 1.3 %, while its contribution to Agriculture GDP is 4.38%. The allocation of resources to this fast developing sector is considered to be small based on the growth rate as compared to agriculture. Looking at the overall situation, in terms of allocation of research support, Indian agriculture sector, though it contributes to 29% of the total GDP, only 0.3% of the total GDP is allocated for research as against in USA wherein agriculture is reported to contribute to only 2% of the GDP, but receives an allocation of funds, which amounts to 2.8% of the GDP. In It is likely that Indian Government will also allocate more funds to research based on the recent recommendations of the parliamentary committee. There is an opportunity to examine the role of farmer participatory research in enhancing agricultural productivity and obtain the required amount of funding for this new emerging area covering both research and extension. **Farmer participatory research is not a substitute to laboratory based research** and should be used as a complimentary activity , to strengthen laboratory based investigations.

Supply – demand Gap

- It is estimated that with the increasing population, increasing wealth and increasing knowledge on the health benefits of fish, the demand for fish is expected to increase by at least 3-4 folds from the current level by 2020. The per capita consumption of fish on an all India basis is expected to increase to a minimum of 30 kg/person /year , while for those fish is the basic diet , consumption might even go up to 70-80 Kg/person/year, if India becomes a developed nation as predicted. To meet this huge fish requirement of the large population, there has to be well thought out national and regional plans, not only to sustain the productivity level of the existing water bodies, but also to bring available water resources under aquaculture and introduce aquaculture in to the newer areas by understanding the existing farming systems. To accomplish this gigantic task, farmer participatory research would be an useful tool.

Fish Health and organic aquaculture

- With the increasing intensification, various chemicals are used in aquaculture with an assumption that they would contribute to increase in productivity or to solve some of the ecological problems of the pond. With the increasing globalisation of the fishery trade, Indian fisheries products have to compete with other countries. Consumers in both the internal and external markets are becoming health conscious and as a result demand for fishery products , which are organic in nature would be increasing . Hence, organic aquaculture would emerge as an important sector in aquaculture and research in to this area is necessary . Recent rejection of several of the consignments owing to the contamination with some of the banned antibiotics is a good example to explore new ways of sustainable organic aquaculture systems. To enlighten farmers on the possibility of growing healthy aquaculture crop without the usage of harmful materials, farmer participatory research can prove as an effective tool.

There are a number of Governmental and Non-Governmental agencies actively pursuing farmer participatory research to address varied farming problems. There is a good opportunity to use this tool in the fisheries sector to increase fish productivity without damaging the environment. The management bodies of the organizations have to understand the scope and limitations of the system and provide required support to the scientists in bringing changes through FPR.

Table 1. VITAMIN A, CALCIUM AND IRON CONTENT IN FISH

FISH SPECIES	PER 100 g RAW, EDIBLE PARTS		
	Vitamin A, µg	Calcium, mg	Iron, mg
SIS			
Mola (Amblypharyngodon mola)	1960 ± 214	1071 ± 41	7 ± 4
Dhela (Rohtee cotio)	937	1.260	-
Darkina (Esomus danricus)	1457	-	-
Chanda (Chanda sp.)	341	1.162	-
Puti (Puntiius sp.)	37 ± 16	1059 ± 161	-
Kaski (Corica soborna)	93 ± 8	-	-
LARGE FISH, ADULT			
Hilsa (Hilsa ilisha)	69	126	3
Silver carp (Hypophthalmichthys molotrix)	17	268	-
Rui (Labeo rohita)	27	317	-
LARGE FISH, WHOLE JUVENILE FISH including organs and bones			
Silver carp (H. molitrix)	13 ± 3	-	-
Tilapia (Oreochromis niloticus)	19 ± 15	-	5

SIS: Small indigenous fish species; - missing value; Source : NAGA , ICLARM, Supplement to the July-December, 1997 issue. Pp.13-15

Table 2: PERCENTAGE OF FARMERS STOPPED USING PESTICIDES AFTER TRAINING

SEASON	MALES %	FEMALES %
Amon 94	92.42	0
Amon 95	96.2	
Boro 95	88.0	
Amon 96	95.5	
Boro 96	91.2	
Amon 97	95.2	
Boro 97	94.4	
Amon 98	90	
Boro 98	91.92	
Amon 99	94	
Boro 99	89.42	

Table. 3. ADOPTION RATE OF RICE FISH AMONG TRAINED FARMERS

SEASON	MALES %	FEMALES %
Amon 93	20.21	8.44
Boro 94	18.77	12.31
Amon 94	22.3	11.31
Boro 95	16.57	10.44
Amon 95	20.93	6.31
Boro 96	16.51	8.97
Amon 96	16.22	6.94
Boro 97	18.24	13.25
Amon 97	15.99	8.84
Boro 98	21.73	21
Amon 98	17.42	25.58
Boro 99	22	25
Amon 99	25.16	17.94

Table 4 : ADOPTION RATES OF FISH SEED PRODUCTION AMONG TOTAL NUMBERS OF FARMERS TRAINED – ONLY BORO SEASON

Targets: Males 5%, Females 30%

SEASON	MALES %	FEMALES %
Boro 94	5.58	9.06
Boro 95	4.67	8.5
Boro 96	8.45	5.41
Boro 97	7.24	9.09
Boro 98	12.9	23.66
Boro 99	16	22

Table 5: ADDITIONAL INCOME FROM RICE FISH CULTIVATON (in Taka/farmer)

SEASON	MALES	FEMALES
Amon 93	717.56	295.43
Boro 94	684	124.28
Amon 94	1533.39	639.12
Boro 95	528.7	511.7
Amon 95	768.11	616.12
Boro 96	434.97	147.20
Amon 96	390.26	325.08
Boro 97	520.05	458.58
Amon 97	1032.41	916.69
Boro 98	987.12	575.91
Amon 98	615.00	543.14
Boro 99	394	486.00

Table 6: RESULTS OBTAINED WITH DIFFERENT TREATMENTS IN CONTROLLING EUS

TREATMENT	NUMBER OF PONDS[1]	UNAFFECTED PONDS[2]	AFFECTED PONDS[3]
Salt	64 (20.32)	63 (98.44)	1 (1.56)
Lime	76 (24.13)	74 (97.37)	2 (2.63)
Salt + Lime	53 (16.83)	47 (88.68)	6 (11.32)
Ash	63 (20.00)	58 (92.06)	5 (7.94)
Control	59 (18.71)	22 (37.29)	37 (62.71)

1. Figures in parentheses indicate percentages.
2. The numbers include small number of ponds that were affected by the disease and recovered from the disease following the continued adoption of the respective treatments (10, 11, 16 and 15 ponds were affected under salt, lime, salt +lime and ash treatments, respectively)
3. No recovery from the disease was observed in these ponds

Table 7: ATTITUDE OF FARMERS TOWARDS EUS TREATMENT

ATTITUDE	PERCENTAGE
HAPPY	67
CANNOT DECIDE	7
NO COMMENTS	20
UNHAPPY	6

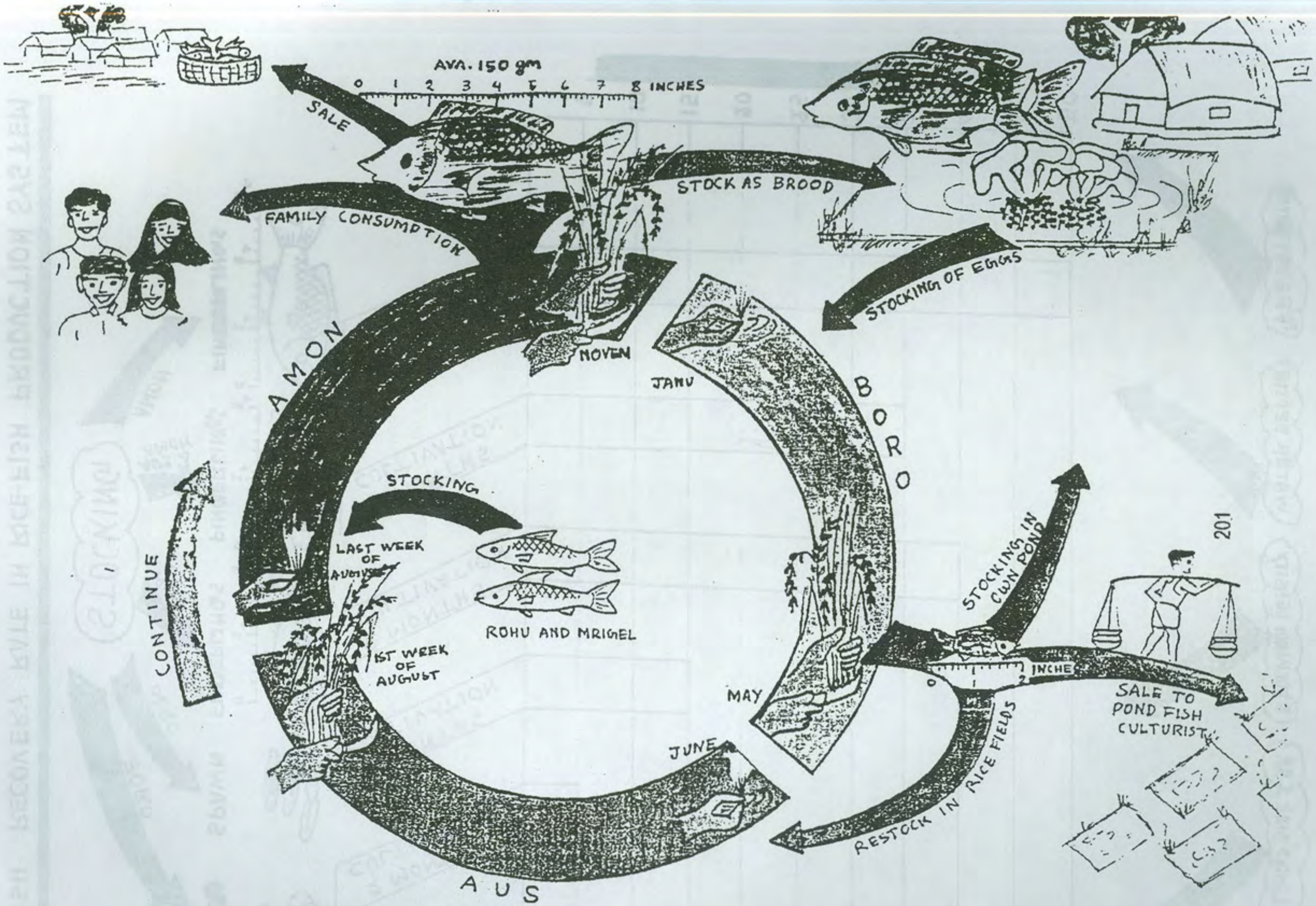

Fig 1 YEAR ROUND FISH AND FISH SEED. PRODUCTION FLOW IN RICE FIELDS

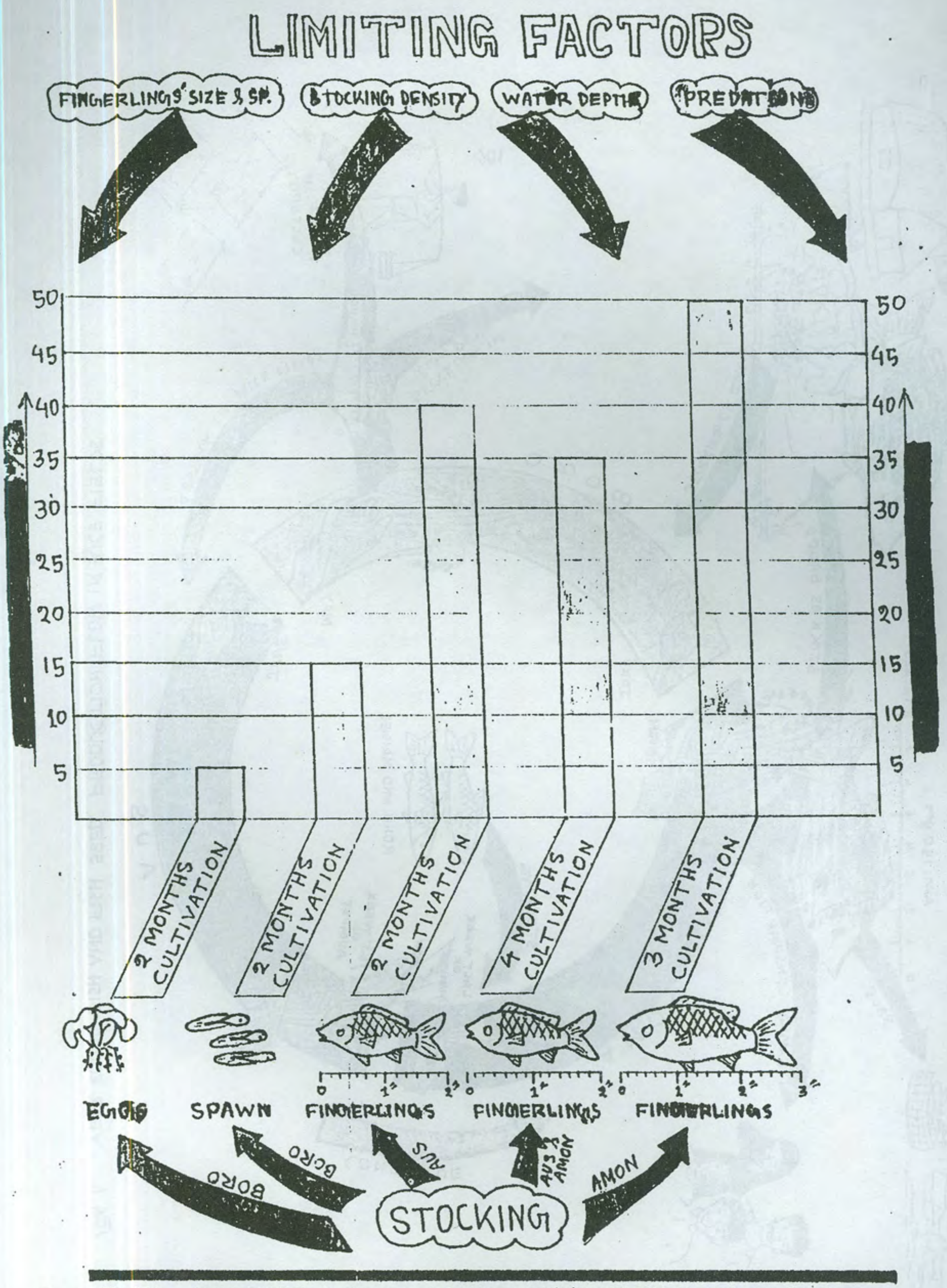

Fig. 2 FISH RECOVERY RATE IN RICE-FISH PRODUCTION SYSTEM

Summer School on *Methods of assessment*
Of aquatic ecosystem for fish health care
18 July to 16 August 2002

Energy Dynamics and Estimation of fish Production Potential of Aquatic Ecosystems in relation to Fish Health

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INTRODUCTION

The energy source to power any aquatic ecosystem is Sun, a vast incandescent sphere of gas, which releases energy by nuclear transmutation of Hydrogen to Helium as pulsating field of electromagnetic waves. The radiation emitted from the sun vary in wave length between 1A° to 1,35,000 A° but only a small fraction of this radiation, in the wave length range of 3,800 A° to 7,800 A° (visible spectrum), is useful for various transformation processes within the system. The energy enters the aquatic system through photosynthetic fixation of solar energy by producers, in the form of energy rich organic compounds, undergoes various transformations in passing from one compartment to the other and finally leaves the system in the form of heat. The whole functioning of the ecosystem depends on two basic principles (i) fixation of solar energy into chemical energy by producers and (ii) transformation of this energy through a series of organisms at different trophic levels before leaving the system as heat of respiration. This fixation and transfer of energy takes place according to the fundamental laws of thermo dynamics which state that energy can neither be created nor be destroyed but it can change from one form to the other and whenever there is any dissipation of energy tremendous amount is lost. The quantitative estimation of the energy involved in the above two processes tells the whole story of the aquatic ecosystems.

Patterns of energy utilization in lakes, reservoirs, beels, rivers etc. have been studied by various workers. The present communication gives a complete background of the energy dynamics of aquatic ecosystems (in general), evaluation of fish production potential from energy flow models and the relation of energy flow studies with fish health.

ENERGY TRANSFORMATION THROUGH PRIMARY PRODUCTION

Assessment of rate of conversion of kinetic energy of sun into potential chemical energy of food by chlorophyll bearing producers gives a dependable parameter to evaluate the production potential of an aquatic ecosystem. The process of energy transformation, known as photosynthesis, can be represented by the basic equation.

$$6CO_2 + 6\,H_2O \xrightarrow[709\text{ cal.}]{\text{Solar Energy}} C_6H_{12}O_6 + 6\,O_2$$

or in a more general way

$$nCO_2 + n\,(H.donor) \xrightarrow[\text{Energy}]{\text{Light}} (CH_2O)n + n.\ \text{oxidized donor}$$

The above process of reduction of carbon dioxide to carbohydrate or oxidation of water to oxygen is endergonic in nature requiring large amount of energy and consequently plants can store large amount of energy through photosynthesis in the form of energy rich organic compounds like proteins, fat, and carbohydrates. The efficiency of energy transformation may be written as

$$\frac{\lambda 1}{\lambda 0} \times 100$$

Where λ1 = energy fixed by producers &
λ 0 = Light energy penetrating he water surface.

From the photosynthetic equation the energy required to liberate one mg of oxygen comes to 3.68 calories and thus the energy fixed by producers can be easily estimated from the amount of oxygen liberated. In reservoirs and rivers the energy transformation at producer level is mainly by phytoplankton where as in beels most of the energy is fixed by growing macrophytes.

The light energy available on water surface, its transformation into chemical energy by producers and efficiency in different aquatic ecosystems like reservoirs, rivers and beels have been shown in figure-1. In reservoirs the light energy available ranged from 17,20,000 to 21,50,000 $calm^{-2}day^{-1}$ of which 2428 to 11,696 $calm^{-2}day^{-1}$ was fixed by producers with an efficiency of 0.126 to 0.682 %. In rivers out of 18,36,500 to 18,67,000 $calm^{-2}day^{-1}$ light energy 4,312 to 7590 $calm^{-2}day^{-1}$ was fixed by producers with an efficiency of 0.23 to 0.40%. On the other hand in beels, where aquatic macrophytes were the main producers, the available light energy was in the range of 18,55,000 to 19,65,000 out of which 37,456 to 63,600 was transformed by producers with photosynthetic efficiency in the range of 2.0 to 3.97 %. Thus the available light energy did not vary much in three types of aquatic systems but considerable difference was observed in respect of rate of energy transformation as well as efficiency, the minimum being in rivers and maximum in beels. As this potential energy fixed by producers flows to consumers at different trophic levels it can be said that among the three types of aquatic ecosystems beels have maximum production potential.

In addition to the autochthonous source of energy fixed by producers lot of energy enters the aquatic system through allochthonous sources, in the form of organic influx and thus

Total energy Available in the System	=	Allochthonous source	+	Autochthonous Source (energy fixed by producers)

Pathways of Energy Utilization (Flow of Energy from Producers to Consumers)

The energy fixed by producers flows to consumers at different trophic levels therefore proper understanding of patterns and extent of utilization of this energy in aquatic ecosystems helps in formulating management measures for stock manipulation and conservation of the resources. The general pathways of utilization of energy in aquatic systems have been shown in figure-2. As shown in the figure there are generally two main routes through which energy is utilized in the system and the producer energy flows to consumers. The first one involves grazing of green organisms (producers) directly by plant feeders or herbivores which are inturn taken by predators and so on. This path is known as grazing chain. All the energy fixed by producers is not utilized directly by consumers and the utilized energy is deposited at the bottom after the death of the organisms. The organic detrital deposits are consumed by organisms feeding on them (detritus feeders) which may again be taken by predators. This path of energy utilization is known as detritus chain. The two pathways are shown below :

Energy at Producer Level → Herbivores → Predators → Grazing chain

Energy at Producer Level → Dead organic matter (Detritus complex) → Detritus feeders → Predators → Detritus chain

In some ecosystems grazing chain predominates while in many others most of the energy flows through detritus chain. Functionally the distinction between the two pathways is very important as there is a time lag between direct utilization of energy by grazers and their ultimate utilization through detritus chain.

Evaluation of Fish Production Potential

According to the second law of thermodynamics when ever there is dissipation of energy tremendous amount is lost. This law is very applicable in aquatic ecosystem as the energy fixed by producers in passing from one trophic level to the other undergoes various transformations. It has been established by a number of studies that in passing from one trophic level to the other almost 90% of the energy is lost. Many workers applied the energy flow concept for calculating the fish production potential of aquatic systems and they felt that in natural systems which have wide range of fish spectrum belonging to various trophic levels the energy at fish level can be taken as 1% of gross or 0.5% of net energy fixed by producers. The fish production potential of a number of reservoirs, lakes, beels and rivers in India has been estimated by taking 0.5% of the net energy fixed by producers as energy available at fish level. The fish production potential estimated by this method was in the range of 55.0 to 265.5 kgha^{-1}yr^{-1} (66,000 – 3,18,600 kcal ha^{-1}yr^{-1}) in reservoirs, 100.0 – 175.0 kgha^{-1}yr^{-1} (1,20,000 – 2,10,228 kcal ha^{-1}yr^{-1}) in Ganga river between Allahabad and Patna and 647.5 to 1283.5 kgha^{-1}yr^{-1} (7,65,000 to 15,40,200 kcal ha^{-1}yr^{-1}) in beels.

Extent of energy utilization in Aquatic ecosystems

The extent of energy utilization and conversion efficiencies in different water bodies have been shown in table-1. The light energy available on the water surface ranged from 6278 to 7847 kcal $ha^{-1}yr^{-1}x\ 10^6$ in reservoirs, 6807 to 6814 kcal $ha^{-1}yr^{-1}x\ 10^6$ in Ganga between Allahabd and Patna and 6753 to 7154 kcal $ha^{-1}yr^{-1}x\ 10^6$ in different beels. Against this available light energy 0.202 to 0.682 % was fixed by producers in reservoirs, 0.154 to 0.271 % in Ganga river and 1.64 to 3.151% in beels . The actual fish production and hence energy output as fish varied considerably in different water bodies depending on the mode of utilization of energy. In some of the reservoirs, in which studies have been made, it was in the range of 4.0 to 103.2 $kgha^{-1}yr^{-1}$ (4800 to 1,23,840 $kcalha^{-1}yr^{-1}$). In river Ganga fish production was in the range of 15.4 to 25.2 $kgha^{-1}yr^{-1}$ (18,520 to 30,228 k calha-1yr-1) while in beels it ranged from 43.0 to 576.7 $kgha^{-1}yr^{-1}$ (51,600 – 6,92,028 $kcalha^{-1}yr^{-1}$). A comparison of fish production potential to actual energy harvest or primary energy fixed by producers to fish showed that in reservoirs 7.2 to 38.8 % of the potential or 0.034 to 0.335 % of primary energy was actually being harvested. In Ganga almost 8.8 to 25.2 % of potential (0.099 to 0.283 % of primary energy) was obtained as fish while in beels, which showed high production potential the actual energy harvest was 6.7 to 50.0 % of the potential or 0.046 to 0.417 % of the primary energy.

It has been found that nearer the useful end product (fish) stands to the first link in the food chain the higher is the yield from the water mass as the loss of energy is much higher if the chain is longer. Accordingly if the water body has the dominance of primary consumers (either herbivores or detritivores) the efficiency of conversion and the energy harvest will be higher. Reservoirs which are dominated by primary consumers either herbivores (Govind Sagar) or detritivores (Bhanisagar, Aliyar and Bachhra) and where 70% of the energy out put is contributed by them have shown better conversion efficiencies either from potential to fish or primary energy to fish. On the other hand reservoirs which are dominated by tertiary consumers (Nagarjun sagar) have shown poor conversion efficiencies due to greater loss of energy. In Ganga, which is dominated by miscellaneous and catfishes, the conversion efficiency is low. In beel ecosystems, where maximum energy fixation is by macrophytes and the main pathway of energy utilization is through detritus chain maximum conversion efficiency has been observed in which 70 to 80 % of energy output is contributed by detritus feeders. On the other hand beels which are dominated by catfishes and the contribution of detritus feeders is less than 20% have shown poor conversion efficiencies either from primary energy to fish (0.046 %) or potential to fish (6.7 %).

The pattern of energy utilization and conversion efficiencies thus give a tool for the further management norms to be adopted. Poor conversion efficiency clearly reflect poor management and greater loss of potential energy. The energy dynamics do take into consideration fishes at various trophic levels but this approach has disadvantage that many fishes are omnivorous and thus can not be assigned to a particular trophic level. More over the feeding habit of the animal do change with the availability of the food.

Thus one has to be very cautious while grouping the consumers at various trophic levels. It has been established by many workers that the most important single channel of energy flow leading to fish production is through organic detritus complex.

Environment, Energy dynamics and fish health

In a healthy ecosystem both the processes of energy fixation by producers (potential energy resource) and its ultimate utilization by consumers at different levels is fast and balanced. Any deterioration in the environment e.g. discharge of sewage and industrial effluents and subsequent loading of organic matter results in sever decline of oxygen which ultimately affects the whole production process and metabolic activities of the fishes. Similarly the discharge of hazardous chemicals like heavy metals and pesticides and their subsequent accumulation by fishes not only affects their health but also hampers the consumption process and the utilization of energy by them. The whole energy fixation and utilization processes are directly related with the environment and health of the fish. Thus the need of the hour is to keep the environment clean and maintain proper healthy fish for the most effective utilization of energy and to get better energy return from the system.

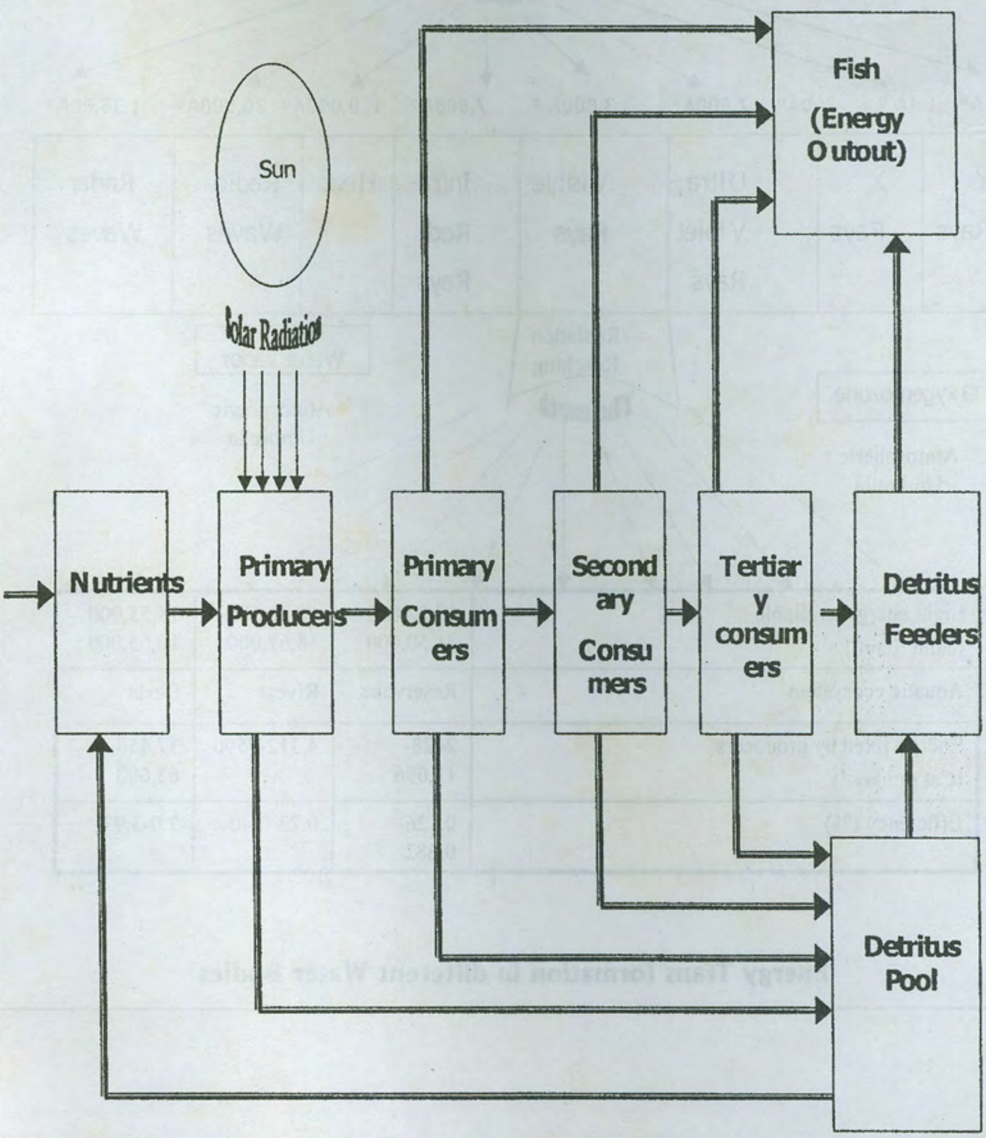
Acknowledgement

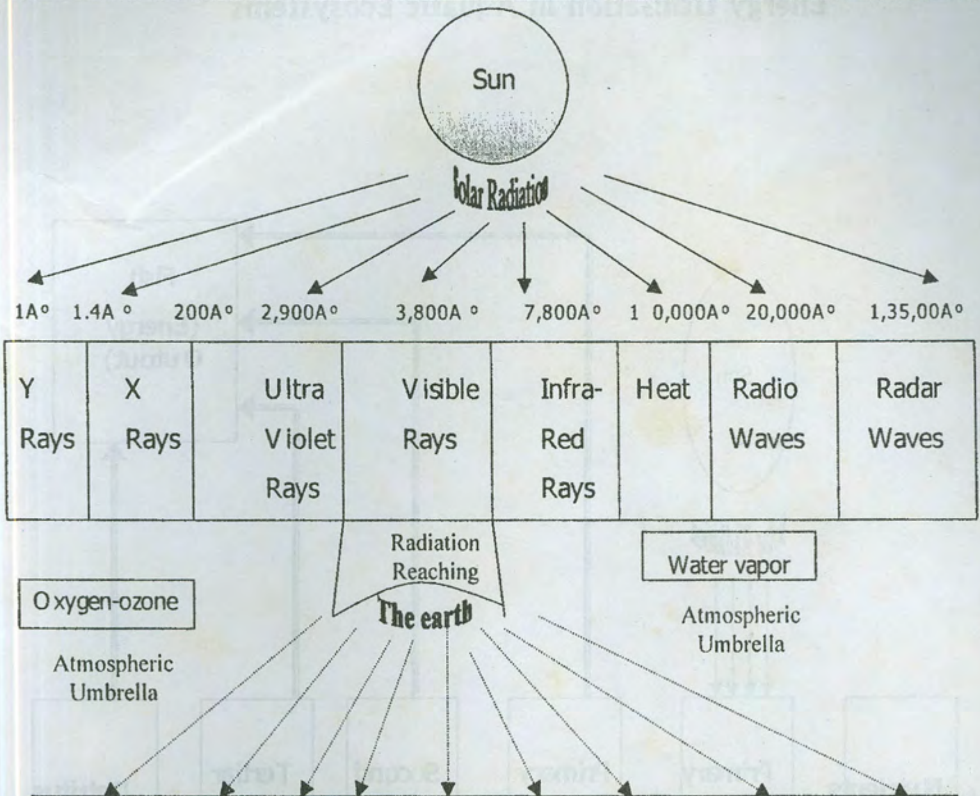
The author is grateful to Dr. V. V. Sugunan, Director, CICFRI, Barrackpore for giving opportunity to deliver lecture and exchange views with the learned gathering.

Energy utilization of different aquatic ecosystems

Parameters		Reservoirs	River (Ganga) [Patna-Allahabad	Beels
Visible radiant energy (K cal $ha^{-1}yr^{-1}$ x 10^6)		6278 – 7847	6807 – 6814	6753-7154
Autotrohic energy fixed by producers (K cal $ha^{-1}yr^{-1}$ x 10^4)		1390 – 4937	1050 – 1872	11,200-21,780
Photosynthetic efficiency		0.202 – 0.682	0.154 – 0.271	1.64-3.151
Fish Production potential	Kg$ha^{-1}yr^{-1}$	55.0 – 265.5	100 – 175.0	637.5-1283.5
	K cal $ha^{-1}yr^{-1}$	66,000 – 3,18,600	1,20,000–2,10,228	7,65,000-15,40,200
Actual Fish production	Kg$ha^{-1}yr^{-1}$	4.0 – 103.2	15.4 – 25.2	43.0-576.7
	K cal $ha^{-1}yr^{-1}$	4,800 – 1,23,840	18,520 – 30,228	51,600-6,92,028
Conversion efficiency	Potential to fish (%)	7.2 – 38.8	8.8 – 25.2	6.7-50.0
	Primary fixed energy to fish (%)	0.034 – 0.335	0.099 – 0.283	0.046-0.417

Energy Utilisation in Aquatic Ecosystems





	Reservoirs	Rivers	Beels
Light energy available (calm^{-2}day^{-1})	17,20,000-21,50,000	18,36,500-18,67,000	18,55,000 – 19,65,000
Aquatic ecosystem	Reservoirs	Rivers	Beels
Energy fixed by producers (Cal m^{-2}day^{-1})	2428-11,696	4,312-7590	37,456-63,600
Efficiency (%)	0.126-0.682	0.23-0.40	2.0-3.97

Energy Trans formation in different Water Bodies