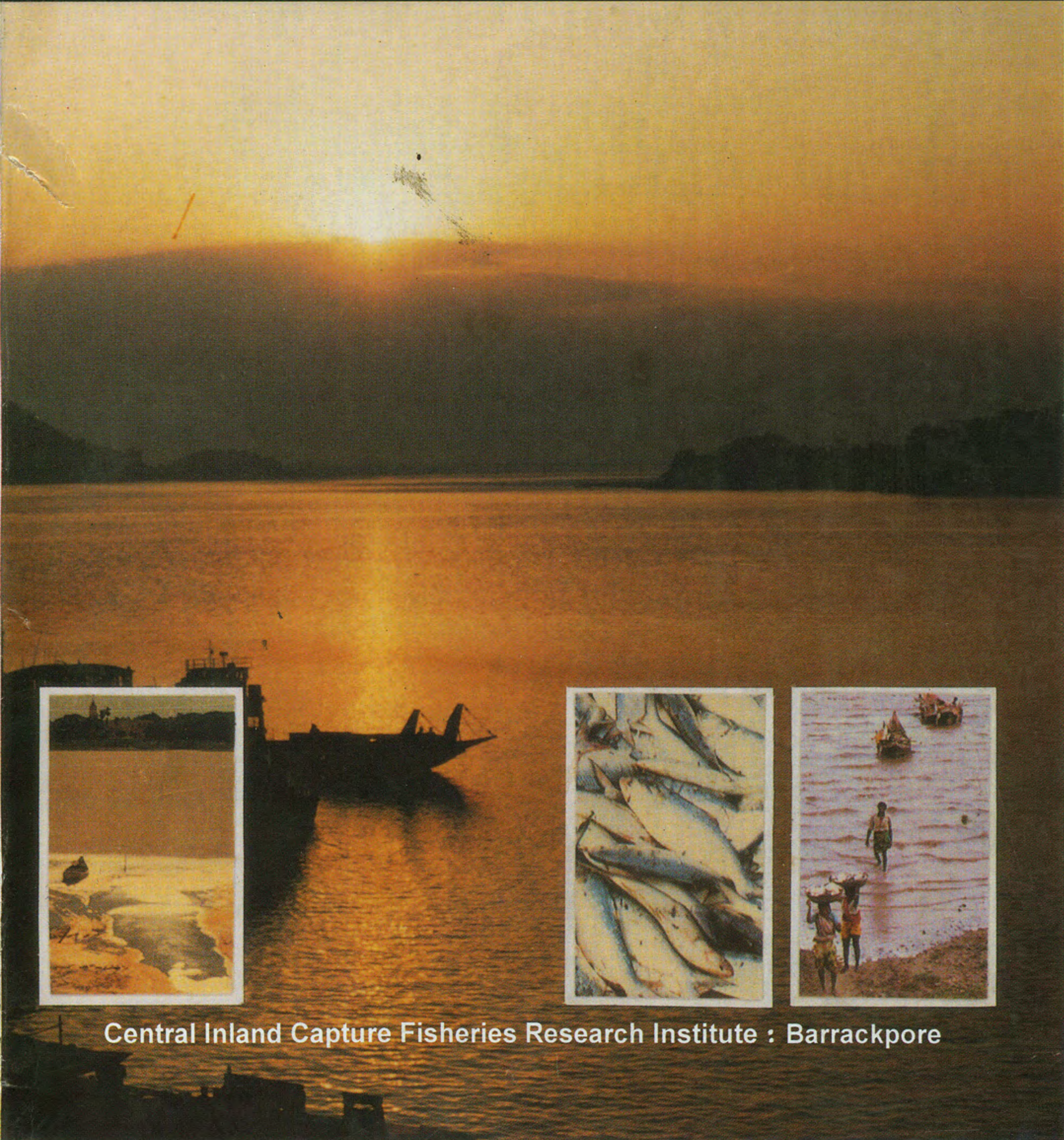
ECOLOGY, FISHERIES & FISH-STOCK ASSESSMENT OF INDIAN RIVERS

Edited by
M. Sinha, M. A. Khan & B. C. Jha



Central Inland Capture Fisheries Research Institute : Barrackpore

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Ecology, Fisheries and Fish Stock Assessment in Indian Rivers

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PREFACE

Indian Council of Agricultural Research (ICAR) sponsors Summer/Winter School for dissimination of the knowledge gained by its Institutes through research to the target groups (university teachers, managers and research scholars). Putting principles into practice is the aim of the ICAR. Against this background, a Summer School on "Ecology, Fisheries and Fish Stock Assessment in Indian Rivers" was allotted to Central Inland Capture Fisheries Research Institute, Barrackpore from July 14 to August 12, 1999. This compendium is a compilation of lectures delivered by experienced resource persons at the said Summer Institute.

Our knowledge on ecology, fisheries and population structures of fishes is inadequate and far from satisfactory. Moreover, the literature on the subject is widely scattered, making its availability difficult for an ordinary research worker. This volume has been constructed to provide a synthesis of available scientific knowledge on rivers and to provide the basis for achieving their scientifically sound and environmentally sensitive management. The book reminds readers of the basis of the management and then describes, the sensitivity of the river systems to environmental perturbations. It further, focuses on the tools and approaches that are available for solving or mitigating particular problems. This publication also provides latest data on ecology, environment and fisheries of rivers Ganga, Godavari, Narmada, Brahmaputra and Mahanadi, collected from their origin to the sea through exploratory survey by CIFRI scientists.

It is expected that this volume will be of immense help to the teachers, researchers and managers by providing them the scattered data within the precinct of a single compendium as well as, the possible mitigational measures for present day constraints of riverine fisheries.

M. Sinha
M. A. Khan
B. C. Jha

*Summer School on **Ecology, Fisheries and***
Fish Stock Assessment in Indian Rivers
CIFRI, Barrackpore 14 July to 12 August 1999

RIVER MANAGEMENT - OBJECTIVES & APPLICATION

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Introduction

Water, which permeates life on Earth, is essential as an enabler and sustainer of plants, animals including human being. Introduction of water management, the rivers in particular, has a long history dated back to very early days of human civilization on this planet. It may not be only coincidental that most of the early human settlements flourished on the banks of rivers or other natural waters. It is not difficult to imagine the historical basis for the utilization of rivers as natural defensive lines or obstacles to protect the settlers in the event of any invasion. In the modern world, however, this is anachronistic. Political boundaries that follow rivers or cross watersheds have become unfortunate historical legacies which has complicated the objectives of river basin resource management. The notion of rivers as boundaries has no relevance in science. A geo-morphologist or a hydrologist views a river as a part of a drainage network, subject to the behaviour of the other elements of the system. In ecology river is the focus of catchment processes rather than a boundary between one system and another. Unfortunately, however, ecologists have been slow to recognise properties in practice, and slower still to consider the properties of entire river system. The ecological integrity of connected rivers is evident in many ways. A river system comprises streams with a shared history of tectonics and marine invasions. The main stream environment is subject to tributary inflows often with distinctive physical, chemical or biological features, but generally with an underlying common character. Fish and other biota may range widely through the water ways of the system, exploiting different resources or the same resources. A river system is, therefore, a logical environmental unit for management. However, given the complexities of larger river systems, the only practical unit for management is a particular river basin which may be regarded as a sub-unit of the larger system.

Rivers have been used by man more than any other type of ecosystem. They have been abstracted from, fished in, boated on, discharged into and many other activities. The rivers remain as an attractive resource to man being considered as a continuously renewable resource, a rapid removal system for unwanted substances, and a valuable store of potential energy. Besides, riverine ecosystem is a real repository of wide variety of plant and animal germ plasm, supplier of one of the best and relatively cheaper form of animal protein in fish and a plethora of other benefits both economic and aesthetic. It is a paradox, however, that the very life-line of human civilization from the very early days has been brutally assaulted for irrational economic gain. This singular factor of economic gain becoming the main motivator of river management has pushed all other aspects into the rear. The immediate fall-out of such developments have manifested in gross impairment of environment quality affecting the production functions and biodiversity adversely. The present status of Ganga river system, the life-line of the densely populated and one of the most fertile basins of the world has badly suffered at the hands of its beneficiaries only. Construction of many dams and check-dams, large scale abstraction of water for various usage, un-planned disposal of wastes and so on have not only affected its water quality or biological production or biodiversity but the ecosystem as a whole wherein the very physical entity of the river has been threatened. The conditions of river Ganga may be compared with river Columbia of North America for which it is said that *a river that died and was reborn as money*. In the backdrops of mounting pressures on riverine ecosystems due to various omission & commission by man in recent years the concept that conservation should hold the key for river management is gaining ground throughout the world. However, conservation needs to be attempted in its totality reflecting geographic, economic, scientific or cultural perspectives.

Objectives & Principles of River Management

The moot point of animated discussion is, as to what should be the ideal purpose and objectives in the management of rivers to achieve the best. Precisely, river management must be attempted with the following broad objectives :

- *Balancing between the interests of various user groups*
- *Optimisation of use of various resources with a sense of rationality*
- *Inclusion of environmental interests and social benefits to the people*

- *Cleaning up of old sins like excessive pollution to maintain essential ecological processes and life support system, to preserve genetic diversity, and to ensure sustainable utilization of species & ecosystems.*

Balancing between users' interests

River management in most of the countries of the world has the domination of one or a handful of users which have exploited the water resources the most. Evidently, holistic approach in river management is seldom followed. In India damming of river channels for irrigation, potable water, industrial use and hydel power generation remain the most predominant interests and as such management of riverine resources primarily revolved round these activities considering all other interests like genetic diversity, fisheries, recreation, aesthetic etc. as secondary. Theoretically, river water must be apportioned when more than one party claims the right to use this limited resource. This is all the more essential to protect the interest of voiceless components of the ecosystem such as landscape, plants, animals and so on. However, it is easier to be said than done in absence of stringent laws and strong political will.

It has been observed that many agencies such as irrigation, hydel, industries, municipality and many more draw water from the riverine sources and generally operate in isolation without any mutual understanding or rationality. Accordingly, more often conflicting signals come to the fore in relation to owning the responsibility of problems inflicted into the system. Obviously, the management of riverine resource for peoples' welfare lacks *overall planning, comprehensive view & integrated approach.* The prevailing situation of river water management is more of an *ad- hocism* than *holistic* or realistic to become sustainable. *It seems that resource managers are most consistent in their inconsistence.*

Optimization of the use of resources

The economic and social growth of any country and the effective utilization of water resource go side by side. Imbalance in either way makes things difficult affecting the progress adversely. This condition has however, shown the emergence of a selected few major interests which often dominate the frame work of river management. The reason is simple and that is to gain the maximum from economic point of view in a shortest possible duration. Optimization of the use of resources in the present day context is to limit the rights of economically weighty and historically important interests to strike a balance between various usage of riverine waters. We are, very often, confronted with a situation where the balancing of various rivers related activities are lop-sided. Compulsions of achieving more in terms of money or jobs, generally, hold the key of river management and in the bargain those values which can not be measured such as biodiversity loss or water quality degradation or impairment of ecosystem are pushed in the background.

This is a fact that the largest percentage of worlds' population live fairly close to water, and have to bear the ongoing developmental activities which affect and manipulate the nature so as to keep the social wheel moving. The real problem is, as how to find an acceptable balance between use and conservation of natural resources of all kinds. It has become a legacy and many a time a necessity to weigh more in favour of economics or financial profits so far as the use of a particular resource is concerned to gain the maximum within a relatively limited time frame than to presume ecological disturbances on a longer perspective. In recent years, however, the concept of sustainable development is beginning to force its way in, at all levels of resource management. But, developing and poor countries with *hand-to- mouth economy* are working as a bulwark towards the sustainable resource utilization and comprehensive planning. The situation is no better in much developing economy also.

Environmental interests

The purpose of resource management should be to try to reach the ideal state i.e. utilization of resources without compromising the natural basis of the system. The World Commission on Environment & Development, 1987 has come out clearly on this concept. The prescription is sustainable development based on control use of resources, cutting back consumption and intensive measures to lessen damages wherever necessary.

There is no doubt that even the renewable resources like rivers have been degraded to the extent that this vital characteristics of renewability has become vulnerable. All over the globe the river courses have increasingly degraded by soil erosion, chemical wastes, irrigation salts, organic overloads, heavy abstraction of water or many man-induced modifications (Fig. 1). Mitigation action plans are also in vogue in many places but they are inadequate to take care off the whole range of ecological processes in a river system, being by and large location specific in nature. The catchment or watershed area of river basins remain the potential sites for various man induced activities and unless the land use pattern in the catchment areas is made rational and environmental friendly nothing tangible can be expected in terms of river management. Evidently, in order to keep the rivers relatively unimpaired so far as the ecological processes and biodiversity are concerned for sustainable use, a comprehensive management planning incorporating all the facets such as physical, chemical, biological, aesthetic, ethnic and so on is a must.

PARTIAL CONTROL

Point source pollution

Civil works

Flow

Predators

Abstraction

Fisheries

RIVER
Conservation/
Management

LITTLE OR NO CONTROL

Climate

Acid deposition

Land use

Diffuse sources of Pollution

Human disturbance

Fig. 1 : Factors affecting river conservation / management

Cleaning-up of *old sins*

Using rivers as a collection sink and transport of waste materials from industry and domestic source is no longer acceptable. An improvement in the prevailing situation is the need of the hour and the same can be attained without actually turning to river management by simply preventing the pollutants from reaching the water course. A diffuse flow of pollutants from agriculture, industry and other sources may become critical in case the discharge rate of the river is somehow reduced or altered, because that would affect the self purifying abilities of the river and as such there must be a reasonable restriction on factors creating such situation.

The most disgusting problems what we face today is large scale alteration of river courses over centuries into hydraulically optimal but ecologically catastrophic stereo-typed canal systems which are often responsible for excessive enrichment of nutrients in the systems. The broad range of natural variations has disappeared resulting into damage of the biotic abundance and the necessary flexibility within the ecosystem. It is essential, therefore, that environmental management must form a part of all the developmental projects related to the riverine resources.

Options for conservation/management

The *conceptual* frame-work for river conservation and management suggests five options viz. *Preservation, Limitation, Mitigation, Restoration* and *Dereliction*. This hypothesis emphasises more on integrated river development and accordingly the management approach would vary as per the needs of different societies, the environmental consequences of attempting to meet those needs, and the relative importance given to cultural aspects also and not only the economic considerations alone. At one end of the spectrum the case is for *preservation* of relatively pristine rivers/streams on the basis of leave-alone policy. In arid regions and tropics where water shortage is common deforestation, catchment erosion, siltation, etc. would figure prominently in the management of rivers, while in industrialized nations acidification, toxic wastes and recreational demands might have to be addressed. The pressure and problems may vary in nature but the principle of catchment management remains the same. In case of rivers of higher order i.e. having less environmental impact *limitation* of catchment development should hold the key in its management. Contrary to that in rivers of lower order more efforts should be on *mitigation* action plans and as such there may be need for river regulations in the areas of water abstraction or acceptability of waste disposal to preserve the micro habitat for better biotic proliferation. As we proceed further to the degraded end of the spectrum the emphasis shifts towards *restoration* of rivers by improving the processes of recovery in relation to water quality, hydrology, aquatic habitat structure and riparian zones. The end of the spectrum marks the end of the tunnel for conservation and in such cases the scenario is of complete *dereliction* due to various activities and as such the only option left is to accept the status quo.

River management in the future

The rapid growth in human population is the greatest strain on the total resource capital. The pressure on aquatic resources in general and the riverine resource in particular are bound to increase many folds as the quality and physical availability of such resources per capita is on the decline. There is a strong link between resource management in general and water management in particular that it seems that we have to have qualified managers in sufficient number to tackle this ticklish issue to avoid total loss of aquatic resources. It would be an exercise in futility if, we expect to solve the river problems in river alone, because most of the problems originate from the river catchments. Evidently, better understanding and effective management of the catchment areas with a sense of rationality in all form of activities hold the keys to tackle the problems related to river management, indirectly. Besides these exploitation of biological resources also requires certain degree of restrain to save the genetic wealth of riverine origin. The golden question is can this be achieved ? The answer is not simple specially in developing countries because their priority differs as compared to well off nations. It can be possible only if, the developed countries are obliged to share their wealth to some extent so that the developing or poor countries can make ecologically correct choices.

It would also be necessary in future to develop an understanding that the riverine resources, be it physical or biological cannot be exploited according to technical/economic criteria alone, rather on the basis of a long term sustainable development and utilization of resources. This is a kind of presupposing the knowledge that resources are limited and that nature has its level of tolerance, even though perspectives may be long by the human scale.

In view of the growing stresses and declining resources more importance have to be attached to ecological management and evaluation in contrast to the traditional mode of resource management and exploitations. It is true that production of more value added products is like a lubricant which makes the wheels of society go round,but it is also the fact that economic time frame is far too short as compared to ecological response time and the natures' level of tolerance. A good dose of coercion is essential, in the form of legislation and a rational planning to restrain market forces putting undue stress on resources.

Strategies for effective river conservation / management

- The Application of Theoretical Ecology to River Conservation*: biogeographic theory to stream colonisation, nutrient spiralling in river channels, floodplains and riparian zones, the resilience of stream to external disturbances and community structure are the topics of theoretical ecology beneficial in effective river conservation/management.*

- Increased Research Efforts*: The attitude that all environmental problems can be solved at one stroke by short term, low budget research projects needs immediate change with the introduction of broad based research efforts.*

- Studies on Habitat Requirements of Riverine Biota*: management of many important species failed to achieve desired result in absence of adequate knowledge on their habitat requirements. It is necessary, therefore, to know the ecologically sustainable habitat requirements.*

- Taxonomic Work*: Adequate taxonomic feed back is essential for the conservation and management of riverine biodiversity as well as potential harvestable crop.*

- National and International Coordination*: Better and effective liaisoning is a must between developmental, NGOs and research organisations, nationally and internationally, for optimum results.*

- Improved Procedures for Environmental Assessment: Introduction of EIA before the initiation of any developmental projects in or near the rivers must be made mandatory.

- ***Adaptive Management in River-modification Schemes***: Even unwanted interferences on rivers can be used as case studies for future advantages (e.g. reservoir releases, river abstraction)

- ***Long-term Monitoring***: Long term ecological studies on riverine variability are a must to formulate lasting conservation/management packages.

- ***Public Awareness & Participation***: River basins are rarely uninhabited. People's participation is a must to achieve the goal of effective river management/conservation because they use or abuse it the most.

Conclusion

The field of stream ecology and its management is in exponential phase since last few decades as per the studies carried-out so far. It has thoroughly emancipated from the status of fishery ecology and related limnology to a highly interdisciplinary area of enquiry. The thrust of the work in running waters has continued to be three- pronged viz. Fisheries, water quality, and general ecology. The last decade has been more productive for the latter than the first two. Effective integration of these three would be the goal for river management in future. Transfer of appropriate technologies in clandestine manner with the in-put of scientifically sound feed-back on ecological variables obtained from applied aquatic research including water quality standards may dominate the management of riverine ecosystem in the distant future. This would be a compulsion in the face of increasing demands for food from aquatic sources and to harvest the same on sustainable basis. This situation would be more critical in the third world countries to ensure food security for its growing population in geometrical progression. Besides this more thrust on the conservation of aquatic germ plasm or biodiversity would be the focal point of river management in future in order to exploit sustainable bio-production for human welfare.

The common property approach practiced in case of fisheries of Indian rivers is a further constraint in proper management of riverine fisheries. It is restricted to harvesting of the resource with little attention paid for its conservation/management. No state wants to spend money on development/management of the riverine fishery which is inter-state in nature. Under these circumstances, for sustainable development of riverine resources there is an urgent need for establishing a central organisation (*National Riverine Fisheries Authority*), which should be responsible for development of riverine fisheries resource of the nation. This would automatically help in river management also as sound ecological health of rivers is a must for good fishery.

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CHEMICAL CHARACTERISTICS OF RIVERINE ECOSYSTEM - AN OVERVIEW

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Introduction

Throughout man's history, he has settled around rivers and lakes, to fulfill of his need for drinking water, fishing, recreation and for transportation. In India, all major rivers such as Ganga, Jamuna, Godavari, Narmada, Sindhu and Cauveri are most sacred to Indians, since they are the lifeline of important agricultural and other economic activities. The Ganga river basin is well developed with regard to communication, industrilisation and urbanisation. But increased anthropogenic pressure during last few decades has adversely affected many river water, both in terms of quality and quantity. Deforestation of catchment areas, leading to increased silt load in the river and increased water abstraction for irrigation, industrial and other purposes coupled with huge discharge of industrial and municipal effluents have resulted in deterioration of water quality in many rivers. In general, the headwater stretch of a river influence the downstream stretches through its discharges, sediment and organic loads, waters and soil quality and biota. Much more significant in recent past, the damming of almost all rivers has been done inducing environmental stress evoking wide protests from ecologists and environmental activists.

Riverine resources

India has fourteen major rivers each having catchment area of 20,000 sq. kms and above, while it has forty four medium rivers with catchment areas between 2000 sq. km and 20,000 sq. km. It has also small rivers (about 55) with 2000 sq. kms catchment areas which generally originate from coastal mountains. The major river basins form about 83-84 percent of the total drainage area and alongwith the medium river basins account for 91 percent of the total drainage of the country. Indian rivers may be classified into two groups:

i) The Himalayan group
ii) The Deccan group (Peninsular)

All the Himalayan rivers including the Ganges, the Brahmaputra, the Sindh and their tributaries, put together, has a total length of 8047 km. They are perennial since they receive water from ice melts of Himalayas.

The Deccan rivers are generally rainfed and fluctuate in volume. A large number of them are seasonal.

Chemical characteristics

The chemical characteristics of a river generally depends on the climate, topography, bottom sediments and catchment areas on which the river originates and passes on.

Most of the rivers originate from mighty hills or mountains where there is no human habitat, the water quality of the river at the hilly stretch may be considered to be pollution free and pure. Nutrient level is generally low, water reaction may be near neutral, BOD nil or negligible, oxygen plentiful, water temperature is low. Due to fast current, development of zooplankton and phytoplankton organisms may be poor. Fish growth and production in these hilly stretch may be less due to low temperature and poor nutrient status.

When the river enters plain, it receives nutrients from the catchment areas and become nutrient rich and productive. Temperature, dissolved oxygen, water reaction, and nutrient levels are generally conducive for higher productivity of the river in the plain. However dense human population in this zone may create pollution problem. Generally the river has tremendous self purifying capacity to abate pollutional stress. But, if the quantum of industrial and municipal discharges are very high in a river particularly in untreated form. the water quality is deteriorated and the river become polluted causing severe stress on aquatic organisms besides health problems.

In the estuarine region, the physico-chemical characteristics of the river changes tremendously depending on zonal location. In estuarine stretch the river may be divided into three regions based on salinity and biotic communities.

1. Freshwater zone (2) gradient zone or transition zone and (3) marine zone or lower estuarine zone.

We may discuss the chemical characteristics of river Ganga which is the most important river in India, as an example of a typical river.

Soil characteristics of Ganga

Texture

From origin to Haridwar, the Ganga river bed contains 98-99.8% sand, retaining the original Ustorthents character. From Haridwar to Patna, the texture is sandy soil with 79 to 99.7% sand. From Sultanpur to Uluberia the bottom sediment is more or less loamy in texture (31-79% sand 12-60% silt and 5-30% clay). The estuarine belt has the typical newer alluvial soil. Lower zone of Hooghly estuary and adjacent Sundarban estuaries contain high percent of clay forming 11-36% of the bed soil. From Nabadwip to Sagar Island the riverine bed has silty loam texture.

The aquatic productivity of Ganga in upper and middle stretch from origin to Patna is generally poor due to sandy bed.

Soil pH

The entire Ganga riverine system had near neutral to slightly alkaline soil reaction with pH ranging between 6.5 and 8.9. Soil reaction was occasionally acidic in the hilly stretch near Tehri, while it was neutral or slightly alkaline in the upper to middle stretch upto Farakka. From Farakka downwards the soil reaction is slightly alkaline, which is, in general, conducive for aquatic productivity.

Free calcium carbonate

The content varied widely depending on zonal location and season. Free calcium carbonate content from Tehri to Kannauj was 0.8 to 10%, from Kanpur to Patna was 0.25 to 8.5%, and low content was found between Sultanpur to Farakka. In general, the content was high during summer and monsoon periods, while lower content was recorded during winter. However, the Hooghly estuary was rich in calcium Carbonate. (4.0 to 17.5%).

Organic carbon

Organic carbon content in the bottom soil was very low (0.04-0.18%) in the upper stretch of Ganga upto Kannauj indicating little river pollution. From Kanpur to Patna, inspite of sandy texture, the organic carbon content was higher (0.02 to 0.35%).

From Sultanpur onwards the content tend to increase which was maximum in the lower estuarine stretch (1.41%). Marked increase in organic carbon content from Dhulian onwards appears to be due to location of agricultural fields by the side of the river.

Total nitrogen

The total nitrogen content was very low (0.003 to 0.084%) in the upper and middle stretch of the river, while it was moderately high (0.042 to 0.092%) in the estuarine region, indicating that the latter is more productive compared to freshwater riverine region.

Available phosphate

The available phosphate content in bottom sediment of upper stretch between Tehri and Kannauj was very low (Tr to 0.05 mg/100g), while moderate contents (Tr. to 3.9 mg/100g) were noted in the middle and lower riverine stretch upto Katwa. In the estuarine zone, the content was significantly high ranging between 1.4 and 16.1 mg/100 g, which indicated that the estuarine region was much more productive than the upper, middle and lower riverine stretch of Ganga river.

Sp. conductivity

Sp. conductivity was low (0.09 to 0.92 millimhos/cm) in the stretch from Deoprayag to Patna. From Sultanpur to Uluberia, the conductivity was 0.05 to 1.02 millimhos/cm. In estuarine region the conductance increases gradually as one proceed towards marine region and maximum value (8.0 millimhos/cm) was noted at Frazerganj.

Water quality of the Ganga

Temperature

In upper stretch of Ganga temperature ranged between 9.5 °C and 20 °C during winter and summer respectively. The temperature of middle freshwater stretch as well as estuarine stretch ranged between 16.0 and 33 °C. Thus, the water temperature of both riverine and estuarine systems may be considered as conducive for fish growth, excepting the upper stretch.

Transparency

In general, the transparency was maximum during winter and summer, while it was minimum during monsoon. Zonewise, maximum transparency was noted in upper stretch between Tehri and Haridwar, followed by medium values in middle stretch, while lower values were noted in estuarine zone due to tidal effect.

Dissolved oxygen

DO was generally adequate in the Ganga riverine system which is very conducive for aquatic habitat. DO content was relatively high (7.6 to 11.2 mg/l) in upper stretch between Tehri and Rishikesh. Minimum DO content was noted at Kanpur (5.0 ppm), Dalmau (4.9 ppm), Buxar (3.4 ppm), Varanasi (4.5 ppm) and Munger (4.8 ppm) during summer or monsoon. However, DO content was fairly high in all stretches during winter. Since DO content above 5 ppm is desirable in a natural water body, the contents at Buxar, Varanasi, Dalmau and Munger indicated that the aquatic animals at these places may be under strain, presumbly due to industrial and municipal effluents during summer. In Hooghly estuary the DO content was generally more than 5 ppm in the main channel, although at the outfall region the content may be lower indicating pollutional stress in the out-fall zone.

pH

The water reaction of the Ganga river was slightly alkaline, which is conducive for aquatic productivity. In upper stretch (Tehri to Kannauj) pH ranged between 7.6 and 8.6, while pH ranged from 7.0 to 9.2 in Kanpur to Patna stretch. From Sultanpur to Uluberia pH fluctuated between 7.3 and 8.3, but pH ranged between 7.4 and 8.5 in the estuarine region. In estuarine region, the diurnal fluctuation of pH was very low, which is very conducive for aquatic habitat.

Total alkalinity

Total alkalinity was slightly low (48 ppm) at upper stretch (Tehri) which increased gradually to 208 ppm at Kannauj. Total alkalinity content ranged between 92 to 236 ppm in the middle stretch and 95 to 174 ppm in the estuarine stretch. The lower estuarine zone having alkalinity content between 95 and 160 ppm was found to be very productive. In Ganga river system, the total alkalinity was minimum during monsoon or post monsoon, while the maximum content was recorded during winter or pre-summer.

Free CO_2

Free CO_2 was present in the upper stretch (Tehri to Haridwar) and also in the lower stretch (Dhulian to Frezerganj) including Sundarban estuaries. However, free CO_2 content was generally absent in the middle stretch (Farukhabad to Farakka) presumably due to its utilisation by aquatic plant organisms during photosynthesis.

Chloride

Chloride content was maximum during summer and minimum during monsoon and postmonsoon. Chloride content ranged between 4.0 and 45.5 ppm in the riverine stretch between Tehri and Uluberia. Moderately high contents were noted at Mirzapur (45.5 ppm), Varanasi (43.8 ppm), Ghajipur (43.8 ppm) and Buxar (43.8 ppm) during Summer presumably due to municipal and industrial pollution. The freshwater stretch of Hooghly estuary from Nabadwip to Uluberia had 4.0 to 22.0 ppm chloride content. But the chloride content increases tremendously as one proceed towards Frazerganj (18000 ppm) in lower estuary.

Sp. Conductivity

Sp. conductivity increased gradually as one proceed from Tehri (120-180 µmhos/cm) to Buxar (510-730 µmhos/cm). From Sultanpur (244-301) to Farakka (188-240 µmhos) the value was slightly low, which slowed a slight increasing trend from Dhulian (110-247 µmhos/cm) to Uluberia (110-380 µmhos/cm). From Roychalk the conductivity increased steadily as one proceed towards Frazerganj (15000-31800 µmhos/cm).

Phosphate

Phosphate content was trace in the upper stretch from Tehri to Farukhabad. In the middle stretch of Ganga higher phosphate content was recorded at Kanpur (0.5-2.5 ppm), Allahabad (Tr.-0.8 ppm), Varanasi (tr-1.05 ppm) and Buxar (Tr-0.4 ppm) during summer presumably due to impact of municipal and industrial pollution. In lower stretch (Sultanpur to Uluberia) maximum content of the nutrient was recorded during monsoon (0.08 ppm to 0.16 ppm), indicating that fertile agricultural catchment areas supply the nutrient during monsoon flooding. Phosphate content was low in the lower estuary indicating that the nutrient is allochthonous in nature.

Nitrate

The Ganga receives maximum quantum of nitrate during monsoon months from its nutrient rich catchments areas in U. P., Bihar and West Bengal through flood water. Thus maximum nitrate was recorded during monsoon in river Ganga. The downstream of Haridwar receives huge nitrogen from the catchment areas or industrial discharge from many molasses, sugar, fertilizer units. In Hooghly estuary, higher nitrate content was found in the freshwater zone compared to marine zone indicating that nitrate is allochthonous in the system.

Silicate

Silicate content in Ganga river varied significantly both seasonally and zone wise.

In upper stretch (Tehri to Anupsahar) the content was maximum (5.4-8.6 ppm) during winter and minimum (Tr) during summer. In middle stretch maximum (11.2-14.4 ppm) silicate was found during summer and minimum (0.6-2.7 ppm) during winter. From Sultanpur to Uluberia the silicate content showed less seasonal fluctuation and the contents (5.6-12.4 ppm) were in general conducive for growth of diatoms. Minimum silicate content was recorded in lower estuary.

Calcium

Calcium content in upper stretch of Ganga was slightly low (7.1-14.2 ppm) at Tehri which showed a slight increasing trend as one proceed downswards upto Buxar (31.3-43.3 ppm). From Sultanpur to Uluberia calcium content was moderate (8.0-32.0 ppm), but in lower estuary at Frazerganj the content was significantly high (240-681.4 ppm).

Magnesium

Magnesium content was fairly high in upper stretch of Ganga between Tehri to Kannauj (42.8-76.1 ppm). The content showed an declining trend in the middle stretch and lower stretch from Kanpur to Farakka. In the estuarine region the content showed an increasing trend and maximum content was found at Frazerganj (108-863.1 ppm) in marine region of Hooghly estuary.

Calcium and magnesium contents were in general, minimum during post monsoon and maximum during winter or pre summer.

Primary production

Primary production in Ganga varied significantly depending upon climate, transparency, turbulance and nutrient contents. Gross primary production in the upper stretch (Tehri to Kanauj) ranged between 20.8 and 202.5 mgC/m^3/hr, middle stretch (Kanpur to Patna) between 15 and 632.8 mgC/m^3/hr and lower stretch (Sultanpur to Katwa) between 33.3 and 142.0 mgC/m^3/hr the maximum being recorded during summer and minimum during rainy season. In Hooghly estuarine system gross primary production ranged between 20.8 and 137.5 mg C/m^3/hr, the minimum being noted during rainy season and maximum during winter. Marine region of the estuary was more productive compared to freshwater and gradient zones, presumably due to higher nutrient level and more transparency.

Chemical characteristics of Narmada river

Both Tapti and Narmada are the oldest rivers in the world, due to their flow through the mountainous system which form part of the Godwana Plate. They are geologically 150 million years older than river Ganges.

Transparency was very high in Narmada from origin to Sisodara, but transparency was lower in estuarine region from Bhadbhut to sea face. The water reaction was slightly acidic at sources (pH 6.4) but it was slightly alkaline afterwards (pH 7.4-8.2) which is conducive for aquatic habitat.

Dissolved oxygen content (5.0-10 ppm) was conducive for aquatic life from origin to Sisodara. The estuarine region had slightly low content particularly at the outfall region. DO content was reduced at Amarkantak, Manot, Jabbalpur and Ankeleswar due to organic pollution.

Free CO_2 was frequently absent in the riverine zone presumably due to its absorption by aquatic weeds during winter and summer. Total alkalinity ranged between 80 and 208 ppm which is conducive for fish health.

Total hardness ranged between 28.0 and 380 ppm, the minimum was at the origin and the maximum was at Bheraghat during summer. Hardness was minimum during monsoon and maximum during summer. Magnesium content ranged between 8.0 and 208 ppm, while calcium content was 20 to 184 ppm in the freshwater region. Both calcium and magnesium content showed steep increase in the lower estuary of Narmada.

Chloride content was less than 10 ppm in the riverine zone from origin to Sisodara, but it showed steep increasing trends as one proceed towards marine zone from gradient zone of Narmada estuary.

In Narmada the phosphate content was very poor in the riverine stretch between origin and Sisodara. However, the points receiving municipal effluents had slightly higher contents.

The nitrate content was low (0.05-0.12 ppm) presumably due to its absorption by aquatic macrophyte in the river during winter. In Summer, the nitrate content was slightly more (0.1-0.3 ppm) in the stretch between Sandia and Mola. Total nitrogen content ranged between 0.13 and 0.23 ppm in winter in the stretch Sandia to Mola.

The silicate content was fairly high during winter in the stretch Sandia to Mola which ranged between 13.8 and 19.4 ppm.

Biological oxygen demand (BOD_5) was very low (0.2-0.8 ppm) indicating that the river was in general free from industrial pollution. However from Amarkantak to Bheraghat, the BOD values occasionally cross the safe limit (5 ppm), indicating that the upstream stretch may be slightly polluted during winter and summer months.

Primary production of Narmada

The primary production by aquatic weeds was significantly high in Narmada compared to photosynthesis by phytoplankton during winter and summer in the stretch Sandia to Mola. Primary production was generally low during monsoon and postmonsoon period and maximum during May. Gross primary production generally ranged from 0.868 to 2.925 $gC/m^2/day$ in the stretch origin to Hoshangabad and net production ranged between 0.864 and 2.397 $gC/m^2/day$. Primary production (gross) in the estuarine region ranged between 25.0 and 208.3 $mgC/m^3/hr$.

Soil characteristics of Narmada for the stretch Sandia to Mola

Narmada bed sediment contains 92-96% sand, 1-3% silt and 3-6% clay indicating that the bottom deposit is sandy and rocky. Organic carbon (0.12-0.54%), total nitrogen (0.011-0.06%), free calcium carbonate (2.0-6.0%) and available phosphate (0.4-2.0 mg/100 g) contents were low to medium in this stretch, which indicated almost no pollution in this river. However, in the estuarine region (Bharbhut to sea face) the bottom soil texture is loam or clay loam. In the estuarine region the nutrient contents (organic carbon, N, PO_4 etc) were higher in bottom soil compared to those in freshwater riverine stretch.

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ECOLOGICAL SIGNIFICANCE OF RIVER CONTINUUM – CONCEPTUAL FRAMEWORK

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Rivers as a resource

River can be defined as a large body of water constrained in a channel (Rao, 1979). However, rivers, as resource, are viewed in terms of their entire watersheds, rather than just in terms of actual body of water flowing in channels. After Leopold and Maddock (1953), both rivers and the landscapes upon which they flow have been considered as systems in several senses of the word. This is mainly due to the dynamic interrelationship of factors affecting stream flow, sediment transport, stream channels, and the enclosing canyons. The hydraulic functions of a river are closely linked with the catchment and the channel, which together constitute its hydraulic geometry. It is empirically shown that water depth, width, and velocity are functions of the load transported by the river. Thus, one could predict, for example, the effects of changes in load supplied by side streams upon the entire geometry of the system. This clearly shows that any river stretch cannot be considered in isolation while trying to understand its hydraulic geometry. The same is true with the physico-chemical characteristics of water, soil and the suspended particles in a river. Thus, the environment in which the riverine communities live is influenced by a number of natural and man-made variables all along the course of a river, its catchment, tributaries and associated lakes.

Since rivers are used for multiple purposes, there is bound to be conflict in its use among individuals, groups of individuals, states of a country and between countries. There is also inter-sectoral conflicts in water allocation for irrigation, power generation, navigation, fisheries, recreation and so on. Dovetailing these opposing interests in the river use is very a difficult task often involving compromise on social, political and environmental issues. This underscores the need for an integrated approach in riverine resources development, which links the management of rivers with that of other water bodies associated with it as river continuum. The need for such an approach is suggested in this paper.

The River Continuum Concept

By virtue of the inter-disciplinary character of the running-water ecology, there have been important interactions among biologists, stream ecologists, hydrologists, geomorphologists, and terrestrial botanists during the last two decades, resulting in a greater level of understanding of the synergistic effects of various temporal and spatial parameters of both terrestrial and aquatic realms. A significant outcome of this approach has been the emergence of River Continuum Concept (RCC), which was initially proposed by Vannote *et al.* (1980). RCC stipulates that headwaters to mouth, the physical variables within a river system present a continuous gradient of physical conditions. This gradient elicits a series of responses within the constituent populations resulting in a continuum of biotic adjustments and consistent patterns of loading, transport, utilization and storage of organic matter. Based on the energy equilibrium theory, the structural and functional characteristics of stream communities are adapted to conform to the most probable conditions of channel pattern and flow.

Spatial components of river continuum

The spatial components of river continuum are the catchment, the channel (including creeks, rivulets streams tributaries and the mainstream and the distributaries), floodplain wetlands (including oxbow lakes), and the estuary (Fig 1). Rivers are classified on number of ways depending on various criteria *viz.*, flood *rivers, reservoir rivers, tropical forest rivers, savanna rivers, desert rivers* and *tundra rivers* (Table 1) with numerous further sub divisions. The two major zones of a river are *rhithron* and *potamon* stretches. Rhithron is defined as the region extending from the source to the point where mean monthly temperature rises up to 20 ^{0}C, oxygen concentration always high, flow is fast, turbulent, bed composed of rock stones or gravel with occasional sandy or silty reaches. Rhithron is further classified into morphological types such as riffles, (low gradient riffles, rapids, and cascades) and pools. This zone has alternate patches of pools and riffles due to changes in gradient. The productivity of rhithron is often expressed in terms of pool-riffle ratio. Potamon is the region where mean monthly temperature rises to over 20 ^{0}C, oxygen deficit may occur, flow is slow and the bed is mainly sandy or muddy. The potamon stretch consists of braided or meanderine forms. In flood rivers, there are two major components of potamon *viz*., the channel and the floodplain.

Table 1. Classification of rivers

Type	Characteristics
Classification 1	
Reservoir rivers	Have extensive lakes, swamps, or flood plains near the headwaters resulting in the gradual release of flood waters and sustained flow with only slight variations of rate.
Flood rivers	Have extreme annual fluctuations in water level from sever flood to sometimes complete desiccation during dry season
Classification II	
Tropical forest rivers	Have many characteristics of reservoir rivers in that the variation of flow are evened out by the retention of water in the flooded forest. Low pH, low alkalinity, low silt load
Savanna rivers	May be either of sand bank type which frequently cease to flow or even dry out seasonally depending on the form of the basin. pH rarely extreme, slightly acidic to alkaline, conductivity reasonably high
Desert rivers	Receive no tributaries in their dry land course, tend to conform to flood-type. Greatly increased alkalinity and conductivity due to evaporation and end up as salt marsh or lake
Tundra rivers	Drain arctic and sub-arctic zones, flow regimes dependent on winter freezing. Poor ionic contents as the lands on which they flow are denuded of top soil during glaciation

Distribution of communities in a river continuum

The producer and consumer communities characteristic of a given river reach become established in harmony with the dynamic physical conditions of the channel. In a natural stream system, biological communities can be characterized as forming a temporal continuum of synchronized species replacements. This continuous species replacement facilitates to distribute the utilization of energy inputs over time. Two definite tendencies are discernible according to the basic tenets of RCC *viz.*, (1) the tendency for efficient use of energy inputs through resource partitioning (food, substrata, *etc.*) and (2) the tendency for a uniform rate of energy processing throughout the year. The biological system moves towards a balance between these two opposing tendencies. The RCC proposes that biological communities developed in natural streams assume processing strategies involving minimum energy loss. Downstream communities are fashioned to capitalize on upstream processing inefficiencies. Both the upstream inefficiency (leakage) and the downstream adjustment seem predictable. Thus, the river continuum concept provides a framework for integrating predictable and observable biological features of the system.

Role of invertebrates

Under the RCC concept, the invertebrates are selected as a group that can be used to analyse basic patterns of running-water ecosystem structure and functions. This view links the invertebrate associations along the continuum, from small headwater streams to large rivers, to the basic nutrient pools that also shift along that continuum. A key part of the RCC is the notion that the organic resources available to invertebrates along the continuum reflect primarily the inputs and influences of the landscapes (terrestrial biomes) through which the waters flow. In the headwaters, major carbon inputs are from the riparian zone. In the mid- sized rivers, associated with reduced bank shading but reasonable water clarity, internal primary production becomes a more dominant source of carbon compounds. In the larger rivers of the lower basin the accumulated loading from the tributary network, and periodically inundated floodplain, become the major carbon sources. The relationship between detrital and algal food resources and the invertebrate functional feeding groups that use these resources is also a major basis of RCC. Because detritus is such an important energy source in stream ecosystem dynamics, it is clear that micro-organisms play a pivotal role in the processing of organic carbon in running waters.

Biological gradient in a river continuum

From headwaters to downstream extent, the physical variables within a stream system present a continuous gradient of conditions including width, depth, velocity, flow volume and temperature. In order to develop a biological analogue to the physical system, the biological organization in rivers should conform structurally and functionally to kinetic energy dissipation patterns of the physical system. Biotic communities do adjust rapidly to any changes in the redistribution of use of kinetic energy by the physical system. Based on consideration of stream size, some broad characteristics of lotic communities which can be roughly grouped into headwaters (order 1-3), medium sized streams(4-6) and large rivers (>6) Fig 2.

Heterotrophic and autotrophic regimes over the gradient

Many headwater streams are influenced strongly by the riparian vegetation which reduces autotrophic production by shading and contribute large amounts of allochthonous detritus. As stream size increases, the reduced importance of terrestrial organic input coincides with enhanced significance of autochthonous primary production and organic transport from upstream. This transition from headwater (dependent on terrestrial inputs) to medium sized rivers (relying on algal or rooted vascular plant production) is thought to be generally reflected by a change in the ratio of gross primary productivity to community respiration (P/R) (Fig. 2). The zone through which the stream shifts from heterotrophic to autotrophic is primarily dependent upon the degree of shading (Minshall, 1978).

Large rivers receive quantities of fine particulate organic matter from upstream processing of dead leaves and woody debris. The effect of riparian vegetation is insignificant, but primary production may often be limited by depth and turbidity. Such light attenuated systems would be characterized by P/R <1. Stream of lower order entering mid-sized or larger rivers have localized effects of varying magnitude depending upon the volume and nature of the inputs. Morphological behaviour adaptations of running water invertebrates reflect shifts in types and locations of food resources with stream size.

Functional groups in a river continuum

The general functional groups in a river continuum are shredders, collectors, scrappers (grazers) and predators whose relative dominance (as biomass) are depictded in Fig 2. Shredders utilize coarse particulate organic matter (COPM >1 mm) such as leaf litter, with a significant dependence on the associated microbial biomass. Collectors filter from transport, or gather from the sedimens, fine and ultra fine particulate organic matter (FPOM- 50 m to 1 mm ; UPOM - 0.5 to 50 m). Like shredders, collectors depend on the microbial biomass associated with the particles (primarily on the surface) and products of microbial metabolism for their nutrition. Scrappers are adapted primarily for shearing attached algae from the surface. The dominance of scrappers follows shifts in primary production being maximized in mid-sized rivers with P/R >1. Shredders are considered to be co-dominant with collectors in the headwaters reflecting the importance of riparian zone- CPOM and FPOM-UPOM derived from it. With increasing stream size, and a general reduction in detrital particle size, collectors should increase in importance and dominate the macroinvertebrate assemblage of large rivers.

Man-made habitat modifications

Anthropogenic stresses in the riverine ecosystem have a direct bearing on the status of sediment, composition of biotic communities and the overall biological production functions. These can be broadly grouped into five major categories *viz.*, water abstraction, sedimentation, river training, dams, and effluxion of waste water. Water abstraction for various purposes such as irrigation, drinking water and industrial use affects the depth, velocity and discharge rate at the lower stretches. Dams and other hydraulic structures built across river stretches have a similar impact, apart from obstructing movements of organisms. Effect of pollution due to waste discharge are also far reaching. In the context of river continuum, sedimentation and river training merit special mention.

Sedimentation

Erosion of top soil in the catchment area is the main man-made factor that leads to increased sediment load in rivers. Vegetative cover on the slopes acts as an adherent of top soil during the surface runoff. Removal of forest cover in the slopes for logging, grazing of cattle or for urban needs make the soil susceptible to erosion, thus adding to the sediment load in the river.

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

The rate of suspended load transport has a relation to the vertical distribution of the concentration of sediment particles at the column of water. It is apparent that the suspended load concentration decreases from the bed towards the water surface and that the mixing process must therefore result in the upward movement of suspended particles for transport. Thus, the transport of bed load, suspended load and the wash load are dependent mainly on the velocity and gradient. Increase in sediment rate, generally triggered by the poor environment management at the catch ment (mainly deforestation)or the rhithron stretch can lead to channel modification all along the river course affecting the biotic communities. This emphasizes the need to treat the river as a continuum from catchment to the mouth.

River training

With constantly changing velocities and volumes of flow, rivers are bound to have different quantum of energy at different times. This, in turn, results in bank erosion. Main purpose of river training is to allow the movement of bed and suspended load without damaging the banks. Protection of banks becomes necessary to control floods to safeguard towns, roads, railways, *etc.* to facilitate construction of hydraulic structures and to facilitate navigation. The common methods followed in river training are construction of guide banks, spurs (groynes) and river revetments. The guide banks and spurs are essentially the devices to nudge the stream flow to a desired channel, whereas the river revetments smoothen the banks by masonry or other structures to prevent the river from excoriating its banks. Rivers are linear systems which serve to drain the water falling on the continental masses towards the oceans. This transfer involves the kinetic energy dissipation inherent in water and the morphology of the channel plays a role to even out the loss of energy along the river course. The hydraulic processes arising from this loss act in a predictable manner within the river channel. Thus, the river bank modifications and other training at one stretch of river may lead to catstrophic changes downstream.

Integrated riverine resources management

The approach to rational watershed management under the river continuum concept leads us to an integrated riverine resources management involving inter-dependence of water, land and the people. Obviously, various developmenatl activities all along the river continuum need to be streamlined on an integrated manner. This involves both on channel and off channel components (Table 2).

Table 2. On-channel and off-channel components of integrated riverine management

On-channel components	Off-channel components
Water allocation for various sectors; Water quality standards; Sedimentation levels; River training; Channel flow in relation to environmnet, navigational, fisheries and recreational requirements; Hydraulic structures in relation to fish migration; and Habitat changes due impoundment.	Catchment conservation; Soil erosion; and Irrigation canals.

Conditions on land are directly dependent on the behaviour of stream flow and the accumulation of ground water. River basins are large and complex watersheds and the basin projects may involve watershed protection, their impoundment and management. This necessitates a basin-wise approach in planning storage reservoirs, industries, crops, and programmes on health and education.

Conclusion

The river continuum concept provides a basic framework for integrating predictable and observable biological features of flowing water systems with the physical geomorphic environment. The model, based on the concept of dynamic equilibrium for biological communities, suggests that community structure and functions adjust to changes in certain geomorphic, physical, and biotic variables. This paves the way for an integrated, holistic approach in riverine resource management.

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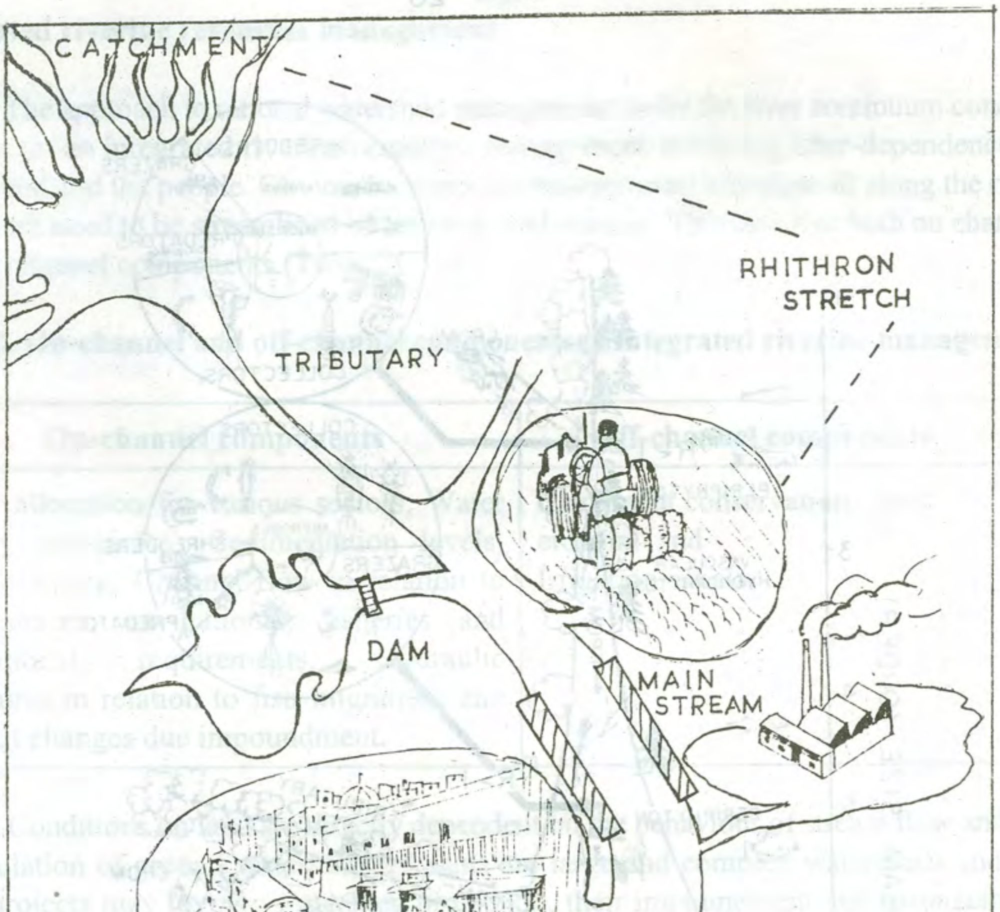

Fig. 1 Components of a river continuum

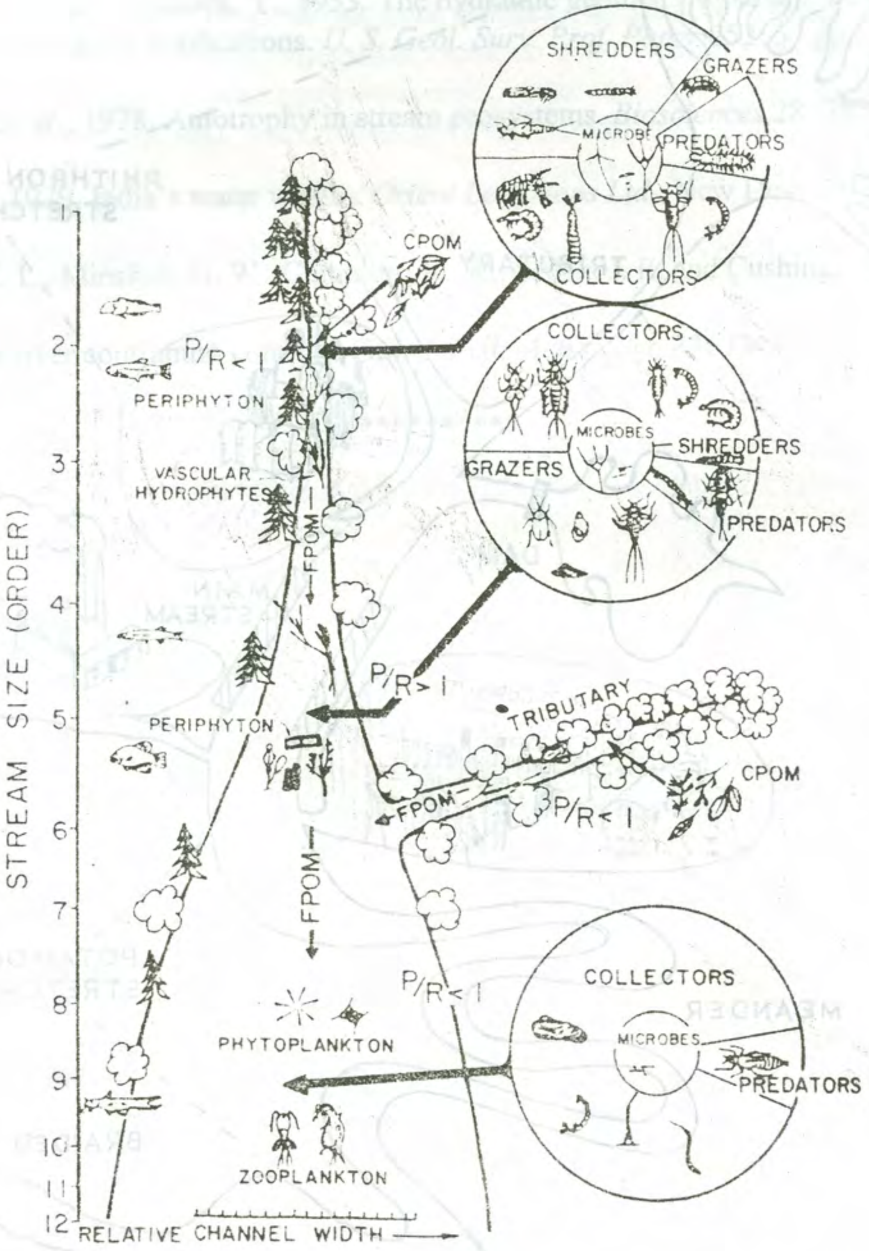

Fig. 2 Diagrammatic representation of river continuum concept
(After Vannote *et al.*, 1980)

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ENERGY DYNAMICS IN THE MANAGEMENT OF RIVEVERINE SYSTEMS

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Introduction

The energy source for all living organisms is sun, a vast incandescent sphere of gas, which release energy by the nuclear transformation of hydrogen to helium. The light energy emitted from the sun is pulsating field of electromagnetic force, spreading from its source at speed of $3.0x10^8$ m sec^{-1} in the form of endless series of waves, the individuals being referred to as wavelength. The radiation emitted from the sun, vary between wavelengths 1A° to 1,35,000 A°. Only a small fraction of energy radiated in the wavelength range 3,800 A° to 7,800 A° (visible spectrum) is useful for various transformation processes on the earth. As much as 95 to 99% of this energy is lost and only 1 to 5% is captured by photosynthetic organisms, converted to chemical energy and stored by them as energy rich organic compounds for the use of different consumers. The living organisms in any aquatic system are inter linked with one another by energy chains and are arranged according to their mode of obtaining energy. The primary energy fixed by the producers flows to the other consumers and thus measurement of rate of conversion of solar energy into chemical energy gives a measure of potential energy resource in the system.

The studies on energy dynamics of an aquatic ecosystem mainly concentrate on two points:

(1) Qualitative assessment of synthesis of organic matter that is transformation of solar energy into chemical energy by producers ;

(2) The pathways of energy transformation that is flow of energy from producer level to consumer at various levels.

The energy dynamics of lakes, reservoirs, beels and other static water bodies have been studied by several workers but practically no information is available on the flow of energy from the solar radiation to the end product (fish) in rivers.

Energy transformation through primary production

Measurement of rate of conversion of kinetic radiant energy of sun into potential chemical energy of food by chlorophyll bearing organisms gives a dependable parameter to assess the productivity potential of an aquatic ecosystem. The process of energy transformation is known as photosynthesis and is represented by the basic equation.

or in a more general way

$$nCO_2 + n(H.donor) \xrightarrow[energy]{light} (CH_2O)_n + n.oxidised\ donor$$

The above redox process, in which water is oxidised to oxygen and carbondioxide is reduced to carbohydrate is endergonic in nature requiring large amount of energy (approximately 112 Kcal of energy permole of CO_2 reduced or permole of O_2 produced) and consequently producers can store large amount of energy as energy rich organic compounds through the above process of transformation. The efficiency of energy transformation may be written as:

The energy required to liberate one mg of oxygen through algal photosynthesis is 3.68 cal and thus energy fixed by producers can easily be calculated from the amount of oxygen liberated during photosynthesis. The total amount of energy fixed by chlorophyll bearing organisms per unit area per unit time is referred to as gross primary production. A part of this energy is used by producer organisms for their own metabolic activities and lost as heat of respiration and the remaining is stored by them. Thus

Gross energy fixed by producers = Net energy stored + Energy lost as respiration

Solar energy available on the water surface and its transformation to chemical energy by producers in different riverine systems has been presented in Table 1. Light energy varied from 18,10,000 to 18,70,000 cal$m^{-2}d^{-1}$ between Allahabad to upper Assam and thus there is not much difference in the available light energy but considerable variations were observed in the rate of conversion into chemical energy by producers being minimum 1752 calm^{-2}d^{-1} in river. Jia Bharali and maximum 5060 calm^{-2}d^{-1} in Ganga at Allahabad. The efficiency of energy transformation (photosynthetic efficiency) ranged between 0.095 to 0.271% in different rivers. In stagnant water bodies the efficiency is comparatively higher than riverine systems but the energy converted and stored at first trophic level is sufficient to sustain the consumers in the system. Apart from the autotrophic source of energy rivers receive large amount of energy through allochthonous source and thus:

Total energy available = Autochthnous source + Allochthonous input of energy
(energy fixed by producers)

Pathways of energy transformation (flow of energy from producers to consumers)

The energy fixed by producer flows to consumers at different trophic levels, therefore, proper understanding of the energy dynamics of the riverine system helps in formulating stock manipulation and conservation of the resource. There are two main routes through which the energy is utilized in the system and the producer energy flows to the consumers. The first one involves grazing of green organisms (producers) directly by plant feeders or herbivores which are in-turn taken up by predators and so on. This path of energy flow is commonly known as grazing chain. All the energy fixed by producers is not always directly utilized by consumers and in the absence of plant feeders the unutilized energy is deposited at the bottom after the death of the organisms. These organic detrital deposits are consumed by organisms feeding on them (detritus feeders) which may again be taken up by predators. The second path of flow of energy through dead organic matter or detritus complex is known as detritus chain. The two pathways are shown below:

$$\left.\begin{array}{l}\textit{Energy at}\\ \textit{producer}\\ \textit{level}\end{array}\right\} \begin{array}{l} \rightarrow \textit{Herbivores}\rightarrow\textit{Pr edators}\rightarrow\textit{Grazing chain}\\ \\ \rightarrow\textit{Dead organic matter}\rightarrow\textit{Detritus feeders}\rightarrow\textit{Predators}\rightarrow\textit{Detritus chain}\\ \quad\textit{(Detritus complex)}\end{array}$$

In most of the 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 that through detritus chain. The pattern of energy utilization in two river systems Ganga and Brahamputra and changes over the years have been shown in Table 2 and 3.

Energy flow model of Ganga at Allahabad indicates that out of 18,520 Kcal $ha^{-1}y^{-1}$ of energy output as fish (1989-93), 11,088 Kcal (60.0%) was contributed by miscellaneous species and 4,752 Kcal (25.6%) by tertiary consumers. The contribution of herbivores, detritivores and secondary consumers were 576 Kcal (3.1%), 1692 Kcal (9.1%) and 432 Kcal (2.2%) respectively. Similarly at Patna out of 30,228 Kcal $ha^{-1}y^{-1}$ of energy output the miscellaneous species contributed 20,544 Kcal (68.0%) and tertiary consumers 5952 Kcal (19.7%). The contribution of herbivores detritivores and secondary consumers being of very low order (4.0, 3.2, 5.1% respectively). The main pathway of energy flow in the system was through grazing chain and the majority of available energy in Ganga was utilized by miscellaneous species and tertiary consumers. The pattern of energy utilization in Ganga during earlier years was totally different than what it was during 1989-93. In Allahabad during 1972-78 energy output as fish was much better and out of 25,524 $Kcalha^{-1}y^{-1}$ the miscellaneous species contributed 10,632 Kcal (41.6%) and tertiary consumers 5,892 Kcal (23.1%) while the contribution of detritivores was 6,744 Kcal (26.4%), herbivores 1,356 Kcal (5.3%) and secondary consumers 900 Kcal (3.6%). In Patna out of 86,940 Kcal $ha^{-1}y^{-1}$ of energy output the contribution of miscellaneous species and tertiary consumers were 39,060 Kcal (44.9%) and 17,940 Kcal (20.6%) whereas that by herbivores, detritivores and secondary consumers were 17,844 Kcal (20.5%), 8,674 Kcal (10.0%) and 3,420 Kcal (4.0%) respectively. These observations clearly show that there has been considerable change in the pattern of energy utilization in river Ganga in both the stretches with remarkable increase in the contribution of miscellaneous species and severe decline in the contribution of other species. The miscellaneous and tertiary consumers together contributed around 64% in the earlier years but their contribution has increased to 87%. The change in the pattern of energy utilization in the river system has resulted in considerable loss of energy in passing from primary to fish level.

In river Brahamputra the pattern of energy utilization has also shown remarkable variations, Table 3. During 1973-79 the total energy output as fish was on average 2,36,316 $Kcald^{-1}$ contributed by miscellaneous species 65,928 Kcal (27.9%), tertiary consumers 64,656 Kcal (27.3%), herbivores 55,992 Kcal (23.7%), detritivores 31,296 Kcal (13.2%) and secondary consumers 18,444 Kcal (7.9%). The flow of energy was both by grazing and detritus chain with substantial contribution by herbivores and detritivores (36.9%). But the pattern has changed over the years and during 1966-98 the contribution of miscellaneous species has gone upto 57.3% in the total energy output of 1,64,808 $Kcald^{-1}$. The contribution of tertiary consumers and secondary consumers were 32,956 Kcal (20.0%) and 9,168 Kcal (5.6%). Primary consumers (both herbivores and detritivores) contributed only 17.1% of the total energy.

The changes in the pattern of energy utilization in the riverine system over the years have resulted in considerable change in the yield pattern. The two rivers have shown considerable decline in the energy output as fish over the years. Apart from the changes in the pattern of energy utilization another important factors responsible for decline in fisheries is heavy siltation and drastic reduction in the volume of water. The efficiencies of energy utilization from primary energy to fish (0.099 to 0.288%) also support the above fact.

Table1:Energy transformation by producers in different rivers (First trophic level)

Rivers	Visible light energy available on water surface (Calm^{-2}d^{-1})	Net carbon production (mgCm^{-2}day^{-1})	Net energy fixed by producers (Cal m^{-2}d^{-1})	Photosynthetic efficiency (%)
Ganga				
Allahabad	18,67,000	515.27	5060	0.271
Patna	18,65,000	292.77	2875	0.154
Yamuna				
Allahabad	18,67,000	230.5	2263	0.121
Ghagra	18,70,000	252.5	2497	0.133
Sone	18,65,000	321.5	3157	0.169
Brahamputra	18,36,500	271.54	2666	0.145
Tributaries of Brahamputra:				
Subansiri	18,10,000	193.5	1900	0.105
Jia Bharali	18,40,000	178.4	1752	0.095
Manas	18,54,000	314.4	3087	0.167
Buri Dihing	18,18,000	392.1	3850	0.212

Table 2:Pattern of energy utilization in river Ganga

Parameters			River Ganga			
			Allahabad		Patna	
			1972-78	1989-93	1961-66	1989-93
Visible radiant energy Kcalha^{-1}y^{-1}X10X^{6}			-	6814	-	6807
Energy fixed through primary production (Kcalha^{-1}y^{-1}X10$^{4)}$			-	1874	-	1050
Contribution of fishes at different trophic level (Kcalha^{-1}y^{-1})	Primary consumers	Herbivores	1356	576	17,844	1200
		Detritivores	6744	1692	8674	984
	Secondary consumers		900	432	3420	1548
	Tertiary consumers		5892	4752	17940	5952
	Miscellaneous species		10632	11088	39060	20544
Total energy output as fish (Kcalha^{-1y-1})			25524	18520	86940	30228
Fish production potential (Kcalha^{-1}y^{-1})				210228		1,19,448
Efficiencies %	Potential to actual			8.81	-	25.31
	Primary energy to fish			0.099		0.288

Table 3: Pattern of energy utilization in river Brahamaputra (Kcald^{-1})

Fishes at various trophic levels		***1973-79***	***1996-98***
Primary consumers	Herbivores	55,992	20,436
	Detritivores	31,296	7,824
Secondary consumers		18,444	9,168
Tertiary consumers		64,656	32,952
Miscellaneous species		65,928	94,428
Total energy output as fish		2,36,316	1,64,808

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AQUATIC BIODIVERSITY - ISSUES, THREATS & PERCEPTIONS

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Introduction

Biodiversity or biological diversity may be defined as the variety of & variability of flora, fauna and microbes in an ecosystem. In recent years sustainable utilization of biodiversity has assumed great significance in the face of increasing threat perceptions. Over exploitation of biological resources to feed the growing human population, specially in densely populated third world countries, is so instance that most of the resources, be it terrestrial or aquatic, have developed symptoms of impairment which is a matter of serious concern for one and all. Biodiversity conservation has, thus, become a necessity so as to protect this planet from disintegration. The level of debates on conservation and rational utilization of biological wealth is going on for quite some time the same has, however, received an impetus after the Earth Summit held in Rio de Janerio in 1992. The realisation for its conservation and sustainable exploitation has made considerable dent in the planning processes world wide, of late, yet nothing tangible could be achieved in absence of unanimity on priority areas of its management, specially in third world countries, owing to ever increasing human population and subsequent pressure on resources. In India too the biodiversity has attracted attention in recent past and at least debate is on for its rational and sustainable exploitation.

Biodiversity has intimate relationship with the progress and development of human civilization, as most of the human needs are linked with biological resources be it ; food, clothing, shelter, medicine or recreation. It is essential, therefore, that the same is carefully nurtured and rationally exploited, so as to save the human civilization from heading its dooms day. The level of information & the perceptions on biodiversity conservation is still poor, specially in developing countries like India, where biomass economy holds the key of development. It is a paradox, however, that the understanding on aquatic biodiversity is still in its nascent stage in spite of the fact that the aquatic resources covering 75% of the Earths' crust. It has been been envisaged that this resource would be playing a very positive and significant role in food front of the world in the future. This assumption may may appears to be at the conceptual stage for the present, but such eventualities can not be ruled-out altogether if, the growth of world's population continues at this rate. Fast diminishing per capita availability of land & subsequent pressure on biological production from terrestrial source, may drive people towards aquatic resources for harnessing food for sustenance. Evidently, in such a scenario the land biodiversity would become very critical whereas the aquatic biodiversity may assume greater significance as the main supplier of food for people.

The biodiversity in terms of gene-pool and genetic variability has been under a constant threat in recent years due to various omission & commission by the people. It is a must situation for biodiversity conservation, not only for economic gain but also to preserve the *aesthetic* and *social* values. Proper & thorough understanding of biodiversity conservation and its sustainable utilization is the need of the hour for better management of biological resources. The euphoria generated at the *Rhio Earth Summit* must not be allowed to degenerate into a series of platitudes in which the words like biodiversity & sustainability become only a *catch words* for convenience rather than *words of meaning*.

Definition of Biodiversity

In order to have better understanding, a clear idea of the meaning of biodiversity besides its attributes and values is a must. The literary meaning of biodiversity is variability of plants and animals. The most accepted definition, propounded at Rhio Conference reads as :

> **"Biological diversity means the variability among living organisms from all sources including *inter alia*, terrestrial, marine and other aquatic systems and the ecological complexes of which they are part; this includes diversity within species, between species and of an ecosystem"**

The definition in question suggests that biodiversity does not mean only the variability of species and the conservation of threatened biota but it covers the whole range of natural environment, from microbes to landscape. It is suggestive, therefore, that the conservation of biodiversity must be viewed in its totality rather than restricting our observation to living ones only.

Status of Biodiversity in India

The Earth has a huge variability of plant and animal species, somewhere in between 5 and 50 millions, but only 1.7 million could be identified till date. India, being the junction of three major but divergent global ***biogeographic realms*** (*Indo-Malayan*, *Eurasian* and *the Afro-tropical*), is considered as one among the worlds' top twelve mega- diversity regions. The country has varied agro-climatic conditions with distinct ecological zones, ranging from perpetual snow cover to equatorial & tropical conditions; from mangroves to humid tropics and from hot to cold deserts. The country has an estimated number of 54,000 species of plants accounting for 12% of the total plants of the world. The flowering plants alone estimated at 15,000 in number (16% of the global diversity). Nearly 33% of the plant wealth, available in India, is endemic and about 1000 species are endangered. The animal wealth on the other hand has been estimated at 68,371 in number which includes 60,000 insects, 1693 fish, and 372 mammals. The marine lives of India still remain, by far, unexplored to its potential, inspite of a long coastline of 7500 km, more than 45 million ha continental shelf and an extended economic zone of 201 million ha.

Issues on aquatic biodiversity conservation

The sustaining debate on biodiversity conservation in the face of increasing threat perceptions has emanated a series of issues which need to be addressed on a priority basis so as to promote better understanding of various ecosystems. Conservation of biodiversity is not a luxury rather a compulsion for increasing productivity to meet socio-economic demands. One of the major issues has been the importance of people's needs in the management of natural resources. It is time to shift our emphasis from beneficiary oriented schemes to eco-conservation and eco-restoration to achieve sustainable development. Precisely the issues which need immediate attention are :

- Prioritisation of activities and related management norms for conservation of biodiversity

- To ensure better international and regional cooperation & coordination

- To assure effective implementation of various projects for conservation,restoration, and sustainable management of aquatic systems

- Identification of Institutions for carrying-out socio-economic and conservation studies

- Systematic and uniform sampling designs for data collection, monitoring and evaluation of results

The options for biodiversity conservation are highlighted in Table. 1.

Threats to aquatic biodiversity

The aquatic ecosystems have been subjected to various forms of environmental stress, during the past few decades. Most of such environmental problems are man induced and not natural. Increased human activities in the catchment area of various aquatic systems have affected the natural processes of the systems adversely thereby threatening the normal growth of biotic communities. Some of such threats to aquatic biodiversity are as under:

Encroachment:

Changing land use patterns with increasing demographic pressure has been identified as a potential threat to natural resources including aquatic systems. Encroachment of natural water bodies for various usage such as agriculture, urban expansion, industrial growth and so on has become the order of the day.

Siltation:

Siltation in natural water bodies is one of the major problems affecting the biodiversity. Deforestation and other anthropogenic activities have accelerated the pace of soil erosion causing higher rates of siltation. The resultant impact is shrinkage in effective water area, both in terms of physical extension and water depth, leading to stress on biodiversity. The wetland ecosystems in India are the worst sufferer and may be cited as the best examples.

Weed infestation:

Presence of aquatic macrophytes in reasonable quantity provides stability to an ecosystem. However, its excessive colonization assuming the status of weed is highly detrimental to ecological balance and hence the aquatic biodiversity. In such ecosystems locking of necessary nutrients in the hydrophytic chain takes place and the phenomenon of *survival for the fittest* operates resulting which many sensitive and fragile organisms are either eliminated completely or at least become endangered.

Pollution:

Water pollution has assumed a serious proportion in recent years affecting the aquatic resources adversely, both physically as well as biologically. The natural water bodies have been subjected to an indiscriminate ingress of domestic sewage, factory effluents and solid wastes. Agricultural run off containing fertilizers and pesticides has added to the complexities. The net out-come of such developments end-up in excessive nutrient enrichments leading to eutrophication and as a result impairment in biotic growth. Emergence of algal blooms or massive invasion of macrophytes are some of the symptoms indicating habit imbalance and creation of unfavourable aquatic regime, non-conducive for normal distribution of biota.

Over grazing/ exploitation:

Over exploitation of aquatic systems for various economic activities viz. abstraction of excessive water for agriculture, industries & others; indiscriminate fishing & aquaculture etc. are some of the factors have been found affecting the normal biodiversity in an ecosystem.

Symptoms of strain

The symptoms of strain due to the cumulative effect of the aforesaid may be reflected into:

- *decrease in biological diversity specially of endemic species*
- *deterioration in water quality*
- *sedimentation and shrinkage in water area*
- *decrease in population of migratory birds, fish and other fauna*
- *prolific growth of unwanted & obnoxious algae or aquatic weeds*

In the event of such symptoms it may be prudent to believe that the biodiversity of water body is under threat and needs necessary corrective measures to conserve the same.

Monitoring biodiversity

Conservation or preservation of biodiversity is essential to save this planet from catastrophe. But the moot point is as to how this can be attained ? The answer lies in the introduction of a well designed monitoring protocol for better result. The broad principles for biodiversity monitoring can be as under:

- *monitor to record integrity of sites (SIM) such as nature reserves, sanctuaries etc. in view of increasing threat perceptions.*
- *monitor to ensure the quality of such sites (SQM)*
- *monitor to record the long term ecological effects of climatic changes*
- *monitor to detect the effects of over-grazing, over exploitation, irrigation, pollution or salinisation*
- *monitor to record changes in the distribution of endangered or threatened endemic species*
- *monitor to keep a track of the richness or diversity of the biotopes that we value.*

Evidently, the monitoring of biodiversity has to be pursued adopting one or more than one mode of operations as per the demands of the objectives. The most accepted and practiced modes of biodiversity monitoring are **Survey** (recording at one time), **Surveillance** (repeated surveys), **Monitoring** (repeated recording with clear objectives and using a standardized approach) and **Census** (repeated recording of a single species including fluxes such as births and deaths).

Research options / priorities for biodiversity conservation

In view of the importance of biodiversity conservation concerted efforts are required not only to maintain the ecological balance, but also for sustaining human welfare through rational utilization of biological resources. It is necessary to have an integrated approach interlining various facets for the conservation and sustainable use of biological diversity besides various concerned agencies working in perfect harmony.

It is necessary to have well planned strategies to conserve genes, species, habitats, and ecosystem *in situ.* This can be supplemented through restoration of lost species to their original habitats and by *ex situ* preservation of species in gene banks, sanctuaries etc. In the long run, however, both *in situ & ex situ* methods may be necessary and for which prioritization of research needs is a must under following heads:

1. Survey, 2. Composition, structure & function of ecosystems, 3. Monitoring, 4. Sustainable use, 5. Valuation, 6. Integration of traditional knowledge & skills, 7. Social, economic & cultural factors, 8. Development of restoring technologies, 9. Biotechnology application and so on.

Areas of investigation and collaboration

Considering the present status of knowledge on aquatic biodiversity in India the following areas of research and collaboration have been identified :

1. *Developing suitable package of practices for RSM (rapid survey methodologies) for aquatic ecosystems.*

2. *Evolving an integrated management plan with greater emphasis on biodiversity conservation*

3 *Exploring the possibility of applying GIS and mathematical modeling for conservation of biodiversity.*

4. *Extensive research and coordination in certain selected water bodies from various ecological zones.*

5. *developing suitable methods to prevent ingress of unwanted effluents and silt.*

6. *Conducting research in population biology of races/threatened species of biota.*

7. *Efforts to prepare field identification keys based on collaborative work in taxonomy.*

8. *Generation of adequate trained man-power to take- up field surveys and investigations.*

9. *Training in taxonomic studies of flora and fauna of aquatic systems to develop adequate expertise vis-a-vis needs.*

10. Coordination of work done by various agencies such as Institutions, Universities, developmental agencies and others to avoid repetition and drainage of resources.

11. Establishment of effective net-working for biodiversity research and conservation.

Why aquatic biodiversity be conserved ?

The aquatic environments are highly stressed today, even to the extent that the aquatic biodiversity essential for human welfare has gone array and is reeling under the threat of total elimination. Available statistics suggest that nearly half of the existing plant and animal species is likely to extinct within a span of next 100 to 300 years if, the present rate of environmental perturbations continues (Wright *et al* 1993). The role of habitat loss is even a greater threat to aquatic biodiversity (Sinha *et al* 1999). In many countries like Philippines about 67% of the mangrove forests have been lost within a short span of 60 years only (Dugan, 1990). Similarly, majority of the wetlands of Asia in general and India in particular are facing severe threats of resource loss, both physical & biological (Scott & Poole, 1989 ; Sinha & Jha, 1997, Sinha et al 1999) . Environmental aberrations have affected genetic resources at the molecular level also thereby physiological and reproductive functions have been impaired putting a question mark on the very ability of a particular taxa to adopt the changing conditions and accordingly in such a scenario maintenance of population may becomes difficult. The point of debate is as to why the conservation and its sustainable utilization of biodiversity are so important? The answer is not simple because a series of arguments may emerge such as *precautionary, moral, indicative, aesthetic* and *economic.*

I. **Precautionary argument**: Our knowledge on biodiversity is still insufficient for making any judgment as to how much loss of biodiversity an ecosystem can sustain without losing its ecological balance. In order to ascertain this and till our knowledge becomes adequately sufficient, we must conserve the biodiversity so that it can be used on sustainable basis. ***The precautionary approach, thus is necessary to avoid the risk of losing the valuable genes from genetic pools.***

II. **Moral argument**: The moral argument for biodiversity conservation is based on the fact that man being the most evolved amongst the animals, he is morally bound to protect and improve the environment as a steward so that the same can be handed over to the next generation with a pride. ***It implies, therefore, that the physical or biological resources need be exploited with utmost care so as to preserve them in reasonably good shape for handing over to the next generation.***

III. **Indicative argument**: The indicative argument for biodiversity evaluation is based on the fact that it provides the necessary indication of the health of an environment. A change in the level of population or texture of biodiversity is often the first indicator of shift in an ecosystem. The phenomenon of eutrophication in lakes, for instance, is a function of nutrient enrichment in the system leading to considerable shift in community structure. ***It is evident, therefore, that being the custodian of natural wealth we must react as situation demands so as to protect the nature's gift.***

IV. **Aesthetic argument**: Conservation of biodiversity also has cultural & emotional overtones such as the feelings that biodiversity, landscape and natural ecosystems which support various species used to provide a sense of solace and a feeling of homeliness. However, in developing countries including India may not attach too much importance to the aesthetic, moral and cultural values of biodiversity as having different priorities for biodiversity utilization in the face of high density of population living in abject poverty and often leading to over exploitation of biological resources. ***Obviously, we have to accept the ground realities of biodiversity needs in densely populated countries but a sense of rationality must be there.***

V. **Economic**: The biological diversity can be considered a capital asset with enormous potential for yielding sustainable benefits. However, quantification and fixing of its realistic price is rather difficult. All the more the functional values of an ecosystem are much more difficult to price. The value of an aquatic ecosystem in relation to some of its attributes can be priced such as a value of its habitat as tourist attraction, fishing activities, source of recreation etc. There is a plethora of values for biodiversity which need not be viewed in a monetary term only. However, pricing of activities in an aquatic system would prevail for some time, specially in developing economy which have an inherent problem of bridging the gap between demand and supply of basic requirements. ***It can be expected, therefore, that the biological diversity of aquatic ecosystems likely to face the problem of over exploitation, a negative factor for meaningful conservation of aquatic biodiversity. Obviously, there is a need to infuse the sense of sustainability amongst the user groups.***

A Broad Action Plan for Biodiversity Conservation

Broadly, the biodiversity of the aquatic systems can be conserved in two ways viz. *in situ conservation* & *ex situ conservation*. These two strategies are complimentary to each other and as such must be taken up simultaneously for optimum results. Conservation of biodiversity is essential to promote sustainable economic and social development, specially in developing countries where biomass economy is predominant. In order to make the biodiversity conservation programmes a success immediate attention on the following areas is a must.

- Prioritization for conservation and sustainable use of biological diversity and agenda for Scientific and Technical research.
- Evaluation of potential economic implications of conservation of biodiversity and its sustainable use, and evaluation of biological and genetic resources.
- Technology transfer and financial issues
- Modalities of a protocol for transfer and handling of any living organisms resulting from biotechnology.

The implementation of conservation strategies may be pursued as under:

- *In situ* (in a site) conservation of target species or ecosystem
- *Ex situ* (off a site) conservation of target species
- Conservation through gene banks
- Through public awareness & training
- Through peoples' participation
- Motivating NGOs
- Developing a conservation net- work of various working groups
- Identification of hot spots affecting biodiversity.etc.

Conclusion

Conservation of aquatic biodiversity is a must not only for ecological balance of aquatic environment but to save the entire civilization on this planet. The task is no doubt daunting but not impossible, provided the problem is being tackled in a broad perspective rather than in isolation. It is imperative therefore, while conserving the biodivetrsity of aquatic system we must take into consideration the human use, both the resources within the system and that external to it. Water quality, quantity and hydrology are known to be the essential component in catchment use and ecosystem performance. A quantitative assessment of these factors in the form of nutrient budget, sediment budget, hydrological profile etc. are must for effective conservation of aquatic ecosystems and the biodiversity. Aquatic systems need be monitored in time series so as to keep a track on the changing face of biodiversity with increased human pressure. Effective conservation laws are also the need of the hour to put a halt on the irrational exploitation of aquatic resources. Coordination and net-working between various developmental agencies is a must to make the task of biodiversity conservation more effective and relatively easier.

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Table 1. Various options for biodivrsity conservation

DEAD		⇒	PRESERVATION	⇒	- HERBARIA - MUSEUMS
ALIVE	***Ex. situ*** **conservation**	⇒	**Complete organism**	⇒	**- Bot. Garden - Zoo. Park - Zoos**
			Organism parts	⇒	***Bio-Bank*** **- pollen/seed - sperm/egg - embryo - tissue - genes**
			Single use wildlands/ waters	⇒	***Genetic reserves*** **Crop/non-crop Forest tree, wild**
	Plants/animals/fish				
	In situ **conservation**	⇒	**multi-use wild lands / waters**	⇒	**- biosphere reserv. - national Park - sanctuaries - ethono bio-reserves etc.**
	Ex situ/In situ	⇒	**non-wild Lands**	⇒	**converted lands for genetic diversity etc.**

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RIVER VALLEY MODIFICATIONS AND THEIR IMPACT ON ENVIRONMENT AND FISHERY

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Introduction

River valleys are modified for a variety of developmental activities such as generation of electricity, water storage for irrigation, industrial and domestic uses, flood control, regulation of flow for navigation etc. But these activities often trigger innumerable secondary problems. Petts (1989) identified four phases in the era of modern river modification.

i) Phase-I from 1750-1900 : During this time a lot of regulation schemes were implemented in many of the large European rivers for navigation, flood control and utilization floodplain land.

ii) Phase-II between 1900-1940 : This is the period of development of technology to build great dams specially in North America, Europe and Southeast Asia.

iii) Phase-III from 1950-1980 : This is the time of maximum activity in dam building world wide. The activity reached such a height that in late 1970s dams of over 15 m in height were being completed at the rate of over 700 per year.

iv) Phase-IV from 1980 till date : The pace of dam building has slowed down to about 500 per year world-wide. It is estimated that by the year 2000, over 60% of the total stream flow in the world will be regulated.

All river valley modifications have both positive as well as negative effects on fishery and environment. Some of the impacts have been outlined in Fig 1. Damming a flowing river and create a lake can make radical changes in the physico-chemical and biological features of the water body. Water abstraction for irrigation and other local water uses to trans-basin diversions reduces the flow of river, which can alter in-stream habitat. Pollution from organic and industrial wastes poses a continuing threat to water quality in the heavily used rivers. Intensive land use affects streams by altering the landscape, through deforestation, spread of agriculture, and growth of settlements. Global climate change including air borne pollution, altered temperature and rainfall regimes is likely to change the physical state of many river systems. It is said that large impoundments even alter the microclimate of the area (Sreenivasan, 1986). Baxter (1977) observed that the reduction of flow of river Mcckenzie in Canada delayed the onset of springs and the same effect was caused by the hydroelectric project on river Ob in Siberia due to flow regulation. In this chapter, the impact of impoundments on environment and fishery is discussed.

Impacts of Reservoirs on Environment

The construction of dams and their associated earth works can have devastating effects on the natural aquatic ecosystem of the area.

Earth movement- A major problem is the disturbance due to the movement of large amounts of solid materials and the exposure of soils to erosion and dispersal by wind, water and machineries. The removal of top cover and top soil leads to violent run off of rain water and the scouring of the bare surface. The debris which range from pieces of rock to fine silt can block waterways and drainage channels in addition to the air pollution due to dust particles. Many a times near to the construction site there may be devoid of aquatic life. Excavation and earth movement also may uncover areas of toxic materials (e.g. lead and copper compounds) which may be flushed into the water courses.

Urbanisation- A small township is being developed for the secondary services near the dam site. This may pollute the prestine water with domestic wastes, sewage and chemical wastes.

Tree felling- Clearing of the forest area for the construction of dams can adversely affect the climate of the area. Lack of rains can directly affect the biotic as well as abiotic features of the aquatic ecosystem. Deforestation leads to soil erosion at an alarming rate.

Water flow- The construction of a dam or barrage act as a barrier to the natural drainage flow. Construction of an impoundment upstream generally alters drastically the water regime at downstream. The original water flow and riverine environment is being reduced or disappeared completely. This prevents the sediment renewal, needed for the soil fertility to support a productive fishery at the downstream.

Rivers with low silt load are "silt hungry" with an increased tendency to erode the banks and instream structures (Dunn, 1989). However, from time to time due to flood or for repair works, a large drawdown is imposed which follows a rise in water level downstream. This could affect the ecology of the aquatic environment.

Seismic effects- The water retained in larger and deeper reservoirs can produce tectonic strains in the earth beneath which can lead to earth quakes. The earthquake at Koyna dam (Western India) in 1967, was attributed to changes in geophysical stability and the consequent seismic activity following the filling of Koyna reservoir (Murray, 1977).

Water quality- The discharges from a dam may affect the quality of water downstream, specially in hydel project, when turbines are driven by water extracted from the lower layer of impoundment, where stratification exists. This layer is of low temperature, low in dissolved oxygen, presence of hydrogen sulphide, low in sediment load and high in dissolved salts. However, water discharged as overspill is generally from upper layer which is well oxygenated with high temperature as well as with large quantity of plankton population (Dunn, *op.cit.*). The bottom water of Pechiparai reservoir in Tamil Nadu contained as much as 26.0 ppm iron while the surface water contained only 0.01-0.20ppm (Sreenivasan,1986).

Impacts of Reservoirs on Fishery

Fish and their habitats are considerably affected by river valley projects. Though reservoir is only a combination of fluviatile and lacustrine systems, it develops certain features of its own (Sugunan, 1995). Eventhough lotic sector of the reservoir maintains a fluviatile ecosystem, the lentic zone and the bays sustain a lacustrine ecosystem. The dam as a whole alter the river hydrology both up and downstreams, making a very new environment. The quality of impounded water varies from watershed to watershed depending on soil quality, human interferences and climatic conditions. To a large extend it also depends on the morphometric characters of the reservoir like shape of basin, area, mean depth and the regularity of the shore line. There are positive as well as negative impacts of reservoirs on fishery.

Positive factors effecting fish production due to impoundment

Reservoirs act as silt traps and hence the suspended matter settles down at the bottom. This leads to increased primary production. In most Indian reservoirs, from first year of impounding there appeared a phytoplankton bloom which persisted in many reservoirs like Stanley reservoir, Bhavanisagar, Amaravathy *etc.* of southern India (Sreenivasan, 1986). In running water plankton population is generally very low.

According to Baxter (1977) impoundments improve water quality. During the filling period of reservoirs, there is usually an initial spurt of plankton and benthic communities due to the increased availability of nutrients released from the decay of submerged vegetation. This trophic burst is also on account of the saprogenic lacustrine species filling the vacant niches created by the disappearance of saprophobic riverine animals (Sugunan, *op.cit.*). The reservoirs yielded very high production after damming the rivers. Ubolratna reservoir in Thailand is an example (Bhukasawan, 1980).

Ramakrishnaiah (1994) described many instances where reservoirs acted as sanctuaries by citing examples of *Barilius bola* in Tilaiya (R. Damodar) *Osteobrama vigorsii* and *Mystus krishnensis* in Nagarjunasagar (R. Krishna) *Tor khudree* in Shivajisagar (R. Krishna) etc.The inundated tree trunks can act as substrates for a thick periphyton growth which promotes the production of fishes like *Labeo rohita* which feed on periphyton.

Water level fluctuations in reservoirs benefit the fishery. When water inundate land area along with the vegetations, abundant food is made available for the fishes due to the decomposition of the vegetation which releases nutrients to the water for the growth of biotic communities.

Negative role of impoundments on fishery

The problems which may arise for fishery due to the construction of a reservoir are associated with unfavourable physico-chemcial conditions of water, unavailable food and feeding areas, migration, spawning grounds, excessive growth of aquatic weeds and change in species composition of fish.

Physico-chemical condition- The physico-chemical condition of a reservoir depends on the prevailing climatic condition including air temperature, wind velocity, rainfall etc. During summer, in the static condition of the reservoirs, surface water gets heated up and the bottom layer remains unaffected. When the bottom gets warmed up, decomposition of organic matters gets accelerated and the result will be quick release of nutrients. The thermocline does not allow a mixing up of rich nutrients at the bottom layer which got locked up at the bottom. In a lotic condition mixing up of different layers of water permits equal distribution of nutrients. The amount of rain fall determines the rate of inflow into the reservoir hence plays a vital role in bringing in the water replenishment and nutrient enrichment. In reservoirs, the inflow rate is affected as the rainfall in the catchment of the rivers situated hundreds of kilometres away from the reservoirs.

The productivity of reservoir is determined by its depth also. In shallow reservoirs the greater part of their water is in euphotic zone facilitating greater mixing and circulation of heat and nutrients and hence higher productivity. In deep reservoirs the organic matters accumulate in the bottom and become unavailable at the photosynthetic zone. The spillway discharge removes the oxygenated clear water at the top layer leaving the oxygen-deficient, turbid bottom water. The deep drawdown also removes the decomposing materials including nutrients.

The oligotrophic tendencies shown by some of the reservoirs are mainly due to the poor nutrient status and other chemical deficiencies. In most cases, poor water quality is a direct reflection of the catchment soil. All reservoirs in Kerala show low primary productivity and poor plankton abundance. The reservoirs in Kerala also recorded low specific conductivity (<50 μmhos) and total alkalinity (<50 mg/l).

Unavailable food- Damming of a river denies the free flow of silt which causes its deposition of silt. Silty bottom is unfavourable for benthic invertebrates and this reduces the production of benthivorous fishes.

Sudden changes in water level, inflow and outflow directly affect the biotic communities viz. plankton, benthos and periphyton pulses which coincide with the least level fluctuations. Storage and release of water from dams are governed by its primary objectives like power generation, irrigation, flood control etc. The spillway discharge dislodges the standing crop of plankton. Lack of plankton affect the planktivorous fish production.

Migration- Fish and their habitats are considerably affected by river manipulations. The blocking of a lotic environment creates lacustrine condition which allows only few fluviatile species to colonise the new environment. Anadromous migratory fish *Hilsa ilisha* has virtually extinct from Cauvery River System after the construction of dams and anicuts. Mahseer, *Tor khudree* and *Acrossocheilus hexagonolepis* also disappeared from the above river system.

Spawning ground- The rapid water level fluctuations damage the spawning grounds of many fishes. Silt deposition affects the spawning ground of fishes and smother the eggs of fish. (Walker, 1983). Many fishes have a tendency to swim against the current and spawn. In the reservoir condition such facility is available only at the upper reaches of the reservoir where to some extend lotic condition exists. The fishes which cannot adapt themselves to the changed lacustrine condition will perish.

Excessive growth of vegetation- The lentic condition of reservoir encourages the growth of micro as well as macro vegetation. However, Indian reservoirs are almost free from such problems. In African reservoirs, Kariba and Volta, floating aquatic weeds especially *Eichhornia* even choked the water. This condition prevents the light penetration, loss of nutrients and loss of water due to high rates of evopotranspiration.

This affects the growth of other biotic communities in the reservoir. Excessive growth of *Salvinia* (30% of lake area) in lake Kariba leads to the low (6-12 kg/ha/yr) fish production (Sreenivasan, *op.cit.*).

Change of fish fauna- Riverine fish fauna is subjected to a series of habitat changes such as water current , turbidity levels, fishing pressure, loss of breeding grounds and the changes in fish food organisms due to lake formation. The species which could withstand these changes only survive, others perish. In many reservoirs transplantation of fishes from other basins take advantage of the vacant niches and the introduction of exotic species led to the changes in species spectrum. Many of the indigenous fish fauna which were relished by the natives gave way to the introduced species. Fig. 2 depicts the affected ichthyofauna of Indian reservoirs.

Fishing- The trees which are left behind when a reservoir is filled pose a major problem to fishing and operation of boats in the reservoir. In reservoirs gill nets are in maximum use due to the hindrance of submerged trees to the operation of other gear.

Fish parasites- The change from lotic environment of river to lentic condition of reservoir with slow current and higher temperature favour the multiplication of parasites. This can affect fishery in the long run.

Conclusion

To manage and to restore and preserve the biological integrity of rivers effectively, we must address their function in the context of human influence. Many of the adverse effects of impoundments can be overcome by adopting suitable management measures as early as at the planning stage of river valley projects.

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ENVIRONMENTAL IMPACT ASSESSMENT OF RIVERINE ECO-SYSTEM

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Introduction

Changing scenario of aquatic resources in India, especially through water abstraction and land use profile (reclamation for agriculture, human settlement, road construction and other development activities) have rendered the aquatic systems most vulnerable, leading to deterioration of water quality, bio-diversity and productivity. Such developmental activities of water resource utilization for agriculture, industry or flood control, navigation etc. are in considerable conflict with fisheries.

To evaluate the impact of anthropogenic activities on riverine ecosystem monitoring of environmental component is an important pre-requisite for formulating abatement action plan. Monitoring of physico-chemical factors alone may not be enough to understand the cumulative effect of pollutants on community metabolism and accordingly inclusion of biomonitoring in EIA studies is a must for better results.

Environmental Impact Assessment (EIA)

EIA aims at logical and rational decision making in relation to environmental issues. Environmental Impact Assessment is a study process used to predict the environmental consequences of proposed major development projects. Such projects may include, for example building hydroelectric dam or a factory, irrigating large valley or developing harbour. An EIA study concentrates on problems, conflicts or natural resource constraints that could affect the viability of a project. It also examines how the project might cause harm to people, their homeland or their livelihood or to other nearby developments. After predicting potential problems the EIA identifies measures to minimize the troubles and outlines ways to improve the projects suitability for its proposed environments. The EIA predicts the likely environmental impacts of projects; finds ways to reduce unacceptable impacts and to shape the projects so that it suits the local environments. It presents these predictions and options to decision-makers.

Various workers have defined EIA; according to UNEP, 1978, "EIA is to identify, predict and to describe in appropriate terms the pros & cons of a proposed development. To be useful the assessment needs to be communicated in terms of understandable by the community and decision – makers and the pros & cons should be identified on the basis of criteria relevant to the countries affected."

According to Heer & Hagerty, 1977 " EIA assessment consists in establishing quantitative values for selected parameters which indicate the quality of the environment before, during and after the action".

EIA PROCESS

1. **Screening**: - it is the first and simplest tier of project evaluation, screening helps to clear types of projects which in past experience are not likely to cause serious environmental problems.

2. **Preliminary assessment**: - If screening does not automatically clear a project, the developer may be asked to undertake a preliminary assessment. This involves sufficient research and expert advice to – identify the project key on the local environment. Generally, describe and predict the extent of impacts, briefly evaluate their importance to decision-makers.The preliminary assessment can be used to assist early proper planning for instance narrow the decision of possible sites- and it can serve as an early warning that the project may have serious environmental difficulties. It is in the developer interest to do a preliminary assessment since in practice, this step can clear projects of the need for a full EIA.

3. **Organization**

   If after reviewing a preliminary assessment the competent authority deems that a full EIA needed, the next step for the project developer is the organization of the EIA study. This entails:

- commissioning and briefing an independent co-ordinator and expert study team (the disciplines that will be represented are decided after the Scooping stage, but the team always includes a communication expert),

- identifying the key decision makers who will plan , finance, permit and control the proposed project, so as to characterize the audience for the EIA,

- researching laws and regulations that will affect these decisions.

- making a contact with each of the various decision-makers.

- determining how and when the EIA's findings will be communicated.

4. Scooping

The first task of the EIA study team is " Scooping" the EIA. The aim of the Scooping is to ensure that the study addresses all the issues of importance of the decision-makers. First the study team outlook is broadcasted by discussions with project developers, decision-makers, the regulatory agency. Scientific institutions, local community leaders and others to include all the possible issues and concerns raised by these various groups. Then the study team selects primary impacts for the EIA to focus on choosing on the basis of the magnitude, geographical extent, significance to decision makers or because of special local sensitivities e, g. Soil erosion the presence of endangered species or a nearby historical sites.

THE EIA STUDY

After Scooping, the EIA study itself begins. Simply put the EIA study attempts to answer five questions.

1. What will happen as a result of the project?
2. What will be the extent of the changes?
3. Do the changes matter?
4. What can be done about them?
5. How can decision-makers be informed of what needs to be done?

Identification

Taking these findings into account, the full EIA study now formally identifies those impacts, which should be assessed in details. These identifications phase of study may use these or other methods. Compile a candidate list of key impacts – such as changes in air quality, noise levels, wild life habits, species diversity landscape views, soil and cultural systems. Settlement pattern and employment levels from other EIA's for similar projects.

Predictions.

The next step called ' Prediction answers the EIA second question, What would be the extent of changes? As far as possible prediction scientifically characterize the impacts causes and effects and its secondary and synergistic consequences for the environments and the local community prediction follows an important within a single environmental parameters, e.g. to toxic liquid effluent into its subsequent affects in many disciplines e.g. reduced water quality adverse impacts on fishing economic affects on fishing villages, and resulting Socio-cultural changes. Prediction drains on physical, biological, Socio-economic and anthropogenic data and techniques.

The third question addressed by the EIA "Do the changes matter "it evaluates and predicts adverse impacts to determine whether they are significant enough to warrant mitigation. This judgement of significance can be based on one or more of the following:

- Comparison with laws, regulations or accepted standards.
- Consultation with the relevant decision-makers.
- Reference to present criteria such as preferred sites features on species.
- Consequently with governments policy objectives.
- Acceptability to the local community or the general public.

Mitigation

If the answer to the 3rd question is 'Yes' then changes do matter ' then the EIA proceeds to answer the fourth question – What can be done about them". A wide range of measures are proposed to prevent, reduce, remedy or compensate for each of the adverse impact evaluated as significant. Possible mitigation measures include:

- Introducing pollution controls, waste treatment, monitoring phased implementation, and, personnel training special, social seminar public education.

- Offering loss compensation restoration of damaged resources, money to affected persons. Conservation on other issues or all sites program to enhance some other aspects of the environment or quality of life for the community.

Documentation

It comprises in detail about EIA studies and mitigation action plan. It contains following documents.

- An executive summary of the EIA findings.
- A description of the proposed development project
- The major environmental and natural resource issuing needed clarification and elaboration
- The project impacts in the environmental in comparison with a base line environment as it would be without the project and how these impacts were identified and predicted.
- A discussion of opinions for mitigating adverse impacts and for shaping the project to suit its proposed environment and an analysis of the trade off involved in choosing between alternate actions
- An overview of gaps or uncertainties in the information
- A summary of the EIA for the general public
- All of this should be contained in a very concise, easy to rent document with cross-references to background documentation which is provided in an appendix.
- The short document is sometimes called as Environmental Impact Statement.

The pollution of water is an immediate hazard to many aquatic resources, their environmental changes may also be determined to aquatic life, and because they produce measurable changes in the species involved, they can often be evaluated.

What is EIA.

Environmental Impact Assessment is a procedure for assessing the environmental implications of a decisions to enact legislation, to implement policies, plans and development project. The broad objectives of the procedures and identification and examination of significance of environmental impacts and (ii) assessment of whether or not the impacts can be mitigated. Finally recommendations of preventive and corrective measures is the motto of environmental impact assessment.

Till 70s the main concentration of aquatic pollutional research was on toxicity evaluation of contaminants in relation to different test organisms. With the advancement, the concept changed to regularity in ecosystem testing to better in sight into how interacting populations within a community respond to contaminant exposure. Main objective of such testing necessitates careful attention to the boundaries of potential impact, the major ecological, components affected, and what state variables affect base line conditions.

Hervicks and Carn (1982) recommended a close coupling of prediction and monitoring, and the incorporation of appropriate toxicological testing in biomonitoring programme to assess damages to an aquatic ecosystem should have criteria like:

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

Assessment Measures

In evaluation of EIA in aquatic ecosystem numerous problems arises viz;, local regional and national perspective. As a result these programs include acute, long term and large scale monitoring to assess the conditions at points, regions and the aquatic system in totality.

The following assessment need to be done in EIA studies of Riverine Ecosystem:

1. Water and Soil Quality Assessment.

The principle media for aquatic sustenance; water and bottom sediments, control qualitative distribution of the organisms. Physico-chemical qualities like, temperature, transparency, DO , pH, alkalinity, hardness, chloronicity etc; are adequate in predicting the inhabitant population structure. For sediments, richness in nutrients, organic percent and bacterial composition, are indicative of the possible flora-fauna composition in the bottom of the aquatic systems. Spatio-temporal monitoring of water and sediment qualities provide information in time scale shifting the biocommunity structure with environmental changes.

2. Toxicant Assessment.

Organic wastes which form bulk of toxicants are hence persistent and non-residual materials and thus produce toxicity affect for restricted period limited to the areas of contamination. More problems are with non-biodegradable toxicants like, metals, pesticides and radioactive materials. However, toxic effect may have on the bio-components, these toxicants toxify the water and sediments first which immediately or in the long run often contaminate the inhabitant population. Advancement in science resulted in precise estimation of toxicants from water, sediments and biotic samples.

3. Bioconcentration

It is the accumulation of water born chemicals by the aquatic animals and plants through non-dilatory routs i.e. as the result of competing rates of chemicals uptake and elimination. The bioconcentration of metals and other non-biodegradable materials varies greatly with the species and the specific toxicants. Size of organism can also influence bioconcentration rate. Metals initially accumulate in the gills of both invertebrates and fish. Bioconcentration is a complex system dependent upon the spectra or organisms, exposure concentration and period, environmental factors and the specific toxicant.

4. Acute Toxicity Assessment

It considers ' rapid damage to the organisms by the fastest acting mechanism of poisoning, fatal unless the organism escapes the toxic environment at an early state'. Mortality of exposed organisms in 96 hours is the acute toxicity evaluation of the contaminants. Such experiments termed (bioassay) are useful for toxicity evaluation of condition i.e., in situ as well as controlled conditions of laboratory. Flow through laboratory tests are designed for the bioassay to replace toxicant and to dilutes water either continuously or at intermittent intervals. Flow through tests are generally the better than static tests because they maintain much higher water quality and ensure the health of the test organism. In situ acute toxicity bioassay performed in natural flowing water for a discharged effluent, expose test organisms in small enclosures at selective points adjoining the discharge resource considering variability in the dilution rates.

The results for in-situ and laboratory bioassay are expressed in terms of lethal time (LT) or lethal concentration (LC) which ever is appropriate considering the nature of toxicants and the mode of their contaminating the environment.

5. Chronic Toxicity Assessment

The organisms are exposed to a toxicant / contamination a significant portion of their life cycle, typically one tenth or more of the organisms lifetime. Chronic studies measures toxicants effect on growth, reproduction and also changes in behavior, physiology and biochemical constituents under sub-lethal concentration. These studies exposed embryos and young ones to toxicants. The early embryonic developmental stages of major carps have been most effectively used as test organisms for acute toxicity bioassay in laboratory conditions for various toxicants and in situ experiments in evaluating the toxic effect of effluents in riverine ecosystems.

6. Long Term Ecotoxicological Assessment

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

i) Intrinsic importance, emphasizing endangered or commercially important species.
ii) Early warning indicators
iii) Sensitive indicators
iv) Process indicators.

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

7. Stress Effect Evaluation

It is a complete process utilizing the biological state of affairs for ascertaining time scale changes in individual biological constituents and community structure as a whole. To assess the responses of individual and population of a community under actual exposure conditions, to assess the potential toxicant for indirect and sublethal effects, and to determine if threshold levels for effect, increased in the laboratory, have any validity for ecosystem. In ecotoxicological biomonitoring programme a sound experimental design is critical to the assessment of ecological damages (Karr,1991). The design required an understanding of the complicity of the aquatic system such that factors like, current velocity, depth, transparency, organic matter, nutrients etc are considered for sample comparison. Sampling approach need be unbiased for better ascribing of changes in the flora and fauna to anthropogenic activities. The index of biotic integrity. To reveal the integrative nature of fish communities responding to changes in water quality has been developed for application. Problems in biological activities like growth, reproduction and recruitment potential of fish is also ascertained as supporter's evidences for changes in community structure.

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BIOMONITORING-AN EFFECTIVE TOOL IN EIA STUDIES

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Introduction

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

The water cycle

About 75% of the Earth's surface is covered by water. Most of this water around 97.3% is salty and is contained in the oceans. Water evaporates from the sea surface to gather as clouds in the atmosphere, and from here it precipitates as rain to the Earth's surface. Over 75% of the freshwater in the world is stored in the polar ice glaciers and a further 23% is in groundwater below the surface of the Earth. Only a very small percentage is found in river and lakes.

Some of the rain which falls on our countryside is lost to the atmosphere by evaporation from the surface and by transpiration from plants. The reminder percolates through the soil and is collected into streams, lakes and rivers and returned to the sea. The chemical composition of this water reflects the geology of the land from which it drains. The chemical properties of surface water, together with the temperature and speed of the water current, control the types and species of animals and plants which can live in different freshwater areas. Some organisms are adapted to fast-flowing streams whereas others thrive in sluggish rivers and lakes. So, even in the absence of man's activities, our surface waters would support a rich and varied diversity of plant and animal communities depending on the type of terrain which they drain.

Water management

Although, lakes and rivers contain a very small proportion of the Earth's freshwater- 0.33 and 0.004% respectively – they have played an important part in the development of our civilisation. They have provided a necessary supply of drinking water, so that settlements developed along their banks. They provided a defensive barrier against attack, and means of transport and communication. The fish were harvested for food. As the human population increased, so the landscape was changed. Forests were cleared and crops planted, land was drained and tilled. Rivers were canalized and watercourses straightened for flood prevention. Wetlands were reclaimed and extensive drainage systems built. Increasing amounts of water abstracted for public supply, industry and land irrigation. All these activities have caused radical changes in the physical nature of our rivers, lakes and other waterbodies. The Indian water resources are depicted in Table 1.

The onset of pollution

Probably, very few of our watercourses are now in a "natural" state in terms of their configuration *i.e.* average water velocity and seasonal variations of flow rate. In densely populated cities, most rivers have been changed to such an extent that so long so the population pressure is not controlled, our surface water will not return to their primal state. The industrial growth has led to significant changes in river water chemistry. The heavy industries which abstract large quantities of water, return it as effluents loaded with chemical residues. The animal and plant communities in these receiving waters were drastically changed and in some areas they disappeared completely. To some extent, all these changes are generally regarded as an acceptable consequence of increased prosperity and better standards of living.

Definition

Environment includes water, air, and land and inter-relationships which exist among and between water, air, land and human beings and other living creatures including micro-organisms. However, pollution will encompass following aspects:

"the introduction by man, directly or indirectly, of substances or energy (*e. g,* heat) into the aquatic environment resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to activities including fishing, impairment of quality for use of water and reduction of amenities.

To put it another way, pollution has occurred when we are prevented from deriving various benefits from our freshwaters because they contain unacceptable levels of chemicals or heat derived from man's activities. These benefits are listed as under:

i) Direct abstraction to potable supply
ii) Food for human consumption derived from freshwaters
iii) Protection of freshwater fish
iv) Protection of aquatic life
v) Irrigation of crops
vi) Livestock watering
vii) Industrial abstraction for food processing
viii) Recreational use for bathing and water contact sports
ix) Aesthetic acceptability

Some of these uses apply to a limited number of locations in our rivers and lakes, others, such as the protection of freshwater fish and aquatic life in general, can apply throughout the entire system. Thus pollution occurs when the additional load in terms of nutrients is sufficient to reduce the value of the resource to an unacceptable degree.

Unacceptable changes

When do the changes caused by man to the aquatic environment become unacceptable ? It is clear that any loading over and above the natural loading will have an additional effect on the aquatic communities. Indeed, it is these very changes which have been used by aquatic biologists to classify the deterioration of water quality; biological indices have been constructed based on the number and abundance of sensitive and resistant species at sampling sites which provide a quantitative measure of the extra loading. There is no scientifically defined boundary between what changes are unacceptable and what are acceptable; this is a value judgement. However, few would argue that a river made fish-less by the discharge into it of toxic effluents was acceptable. The ability of the resource to withstand a small increase in loading is known as the "assimilative capacity". Within this zone, some pollution – sensitive species will be reduced in number or disappear but this may be acceptable, if they do not play a vital role in the aquatic community and are replaced by more resistant species with a similar function within the aquatic ecosystem. Clearly, species that are valued for recreational, commercial or scientific purposes should by definition be unaffected by this small loading, so that such resources remain unimpaired.

Water pollution

The disposal of human wastes has been always constituted a serious problem. With the development of urban areas, it became necessary, from public health and aesthetic considerations, to provide drainage or sewer systems to carry such wastes away from the area. The normal repository was usually the nearest watercourse. It became soon apparent that rivers and other receiving bodies of water have a limited ability to handle waste materials without creating nuisance conditions. It has long been known that all natural bodies of water have the ability to oxidize organic matter without the development of nuisance conditions, provided that the organic and nitrogen (primarily ammonia) loading is kept within the limits of the oxygen resources of the water. It is also known that certain levels of dissolved oxygen must be maintained at all times, if certain forms of aquatic life are to be preserved. A great deal of research has been conducted to establish these limits. In the past, streams have been classified into the following four categories (I) those to be used for the transportation of wastes without regard to aquatic biodiversity but maintained to avoid the development of nuisance conditions, ii) those in which the pollutional load will be restricted to allow fish to flourish, iii) those to be used for recreational purposes, and iv) those that are used for water supplies. But at the present time the consensus is to require the highest practical degree of treatment of all wastewaters, regardless of stream purification capability. Thus, effluent quality or effluent standards have for the most part superseded stream standards.

Historically, the major concern with regard to pollution of surface waters was with their oxygen resource. However, in the past two decades, an increasing concern is the pollution of surface waters and ground waters with pollutants of primarily industrial or agricultural in origin. During the past three decades, many new chemicals have been produced for agricultural purposes. Some of them are used for weed control, others for pest control. There has been dramatic increase in the application of nitrogen fertilizers, although this trend appears to be changing recently. Residues of these materials are often carried to water courses during periods of heavy rainfall and have serious effects upon the biota of streams. A great deal of research by chemists and biologists has demonstrated which of the materials have been more damaging to the environment, and many products have been outlawed.

Table 1. Water resources of India

Rivers (km)	29,000
Irrigation canals (km)	1,20,000
Flood plain lakes (ha)	2,02,213
Upland lakes (ha)	72,000
Freshwater ponds (ha)	7,53,000
Reservoir (ha)	31,57,908
Estuarine wetlands (ha)	50,000
Brackishwater impoundments (ha)	9,02,000
Estuaries, mangroves, backwaters and brackishwater lagoons (ha)	60,00,000

Conditions of fish growth

Water is essential for all forms of fish farming. Cultured aquatic animals require oxygen and all farming systems must be designed to convey oxygen to the cultured stocks. The water supply is only 'source of this oxygen for most cultured species, although there are exceptions like air-breathing fishes, such as *Channa* spp. and *Clarias* spp. The availability of dissolved oxygen to cultured organisms depends on the amount of dissolved oxygen entering the aquaculture system and/or processes within the aquaculture system design. Intensive aquaculture systems with short water residence times rely heavily on inflowing water to supply the dissolved oxygen requirements of the cultured stock. In this situation, the carrying capacity (amount of stock biomass that can be held) is determined by the respiratory requirements of the stock and their physiological tolerance to low concentrations of dissolved oxygen in relation to the supply of dissolved oxygen in inflowing water. A water supply can be an important source of harmful toxins but it is also an important medium for receiving and dispensing excretory products and other aquaculture waste materials which may prove harmful if allowed to accumulate. The physical and chemical characteristics of the water also play an important role in aquaculture nutrition and growth.

Environmental impact assessment

It is clear from above account that most of the developmental activities have an impact on environment in general and aquatic resources in particular. Therefore, the procedure for assessing such impact and for ensuring appropriate environment safe-guards has been engaging the attention of scientists and development authorities. While the Government attaches high priority to the formulation and timely execution of development activities consistent with the socio-economic objectives of the State Policy, the Government now have realised that it is essential that such development does not result in indiscriminate and destructive uses of natural and other resources; nor should it lead to adverse environmental consequences. Now by law the EIA has been made mandatory in case of all development projects and accordingly a detailed EIA or preliminary EIA will depend upon the type of project and its likely magnitude of impact on the environment. It is to address these issues that suitable techniques have been evolved and under the process of refinement to assess and predict the positive or negative impacts on natural resources as a result of any activity.

The techniques of Environmental Impact Assessment (EIA) have been evolved in the last decade in the developed countries which have become an essential tool for environmental planning and management. This kind of analysis when built into the economic analysis of the project costs and benefits, helps the decision makers to perceive more or less objectively, some of the major environmental concerns arising from the project. While such analyses don't always yield precise quantitative optima on all environmental issues, they do focus attention on the major ones and thus help in examine alternative options before choosing an environmentally acceptable course of action.

Of all development projects, industrial projects have a profound influence on society and environment, both in the positive and negative directions. Industries mean more jobs, generation of goods and services and some observable rise in a standard of living as positive impacts. But they bring in their make the associated ills of environmental pollution resources depletion, overcrowding, health effects, loss in biodiversity and deterioration of aquatic resources. The EIA procedure can help to anticipate such fallout and thereby help to decide on alternative technology and resetting. It also makes possible anticipatory pre-planning and implementation of adequate environmental safeguards, especially for pollution abatement and even undertaking simultaneously environmental improvement programmes. Thus, EIA is a most efficient and effective aid to planners of industrial development in any country or setting.

It is to be fully realised that development goals and environmental aspirations have to be reconciled without conflict. It is believed that environmental safeguards built into the development projects at the planning stage and implemented during pre-and post-execution stages, would reinforce and enhance the benefits derived from the development process. In India, all round development is essential not only for meeting the basic minimum, needs of the people but also enhancing the quality of life in the country. However, such developments must take place along right lines in consonance and in harmony with the environmental and ecological conditions. For this, it is necessary to conserve and indeed develop natural resources, adopt energy-efficient means of production and reduce, if not avoid, wasteful pollution.

Suggested steps in EIA

a) Project description – constituent activities from land acquisition to development, to operational aspects and alternatives.
b) Site description – present socio-economic and environmental status and site requirements for project implementation.
c) Enumeration of impacts – physical, chemical, health, ecology, socio-economic, both adverse and beneficial.
d) Evaluation of impacts in quantitative or qualitative terms.
e) Aggregation of impacts on environmental components (land, water, air, forest, flora, fauna, settlements, health etc.)
f) Forecast short and long term environmental changes – identification or modifications and safeguards to protect the environment, including resetting and process alternatives.

g) Recommendation of alternatives, environmental safeguards, monitoring process for feedstock on compliance and performance in the operation phase.
h) Review and assessment in the post – completion phase.

Biomonitoring

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

Methods used in biomonitoring

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

A. Eco-taxonomical approach	
Indicator species	***Community structure***
Score system	Species diversity index
Algal index	Dominance index
Trent biotic index	Evenness index
	Similarity index
B. Physic-chemical approach	
Biological function analysis	***Toxicity testing***
ATP	Short-term acute
Primary production	Long-term
Chlorophyll	Avoidance studies

History of biomonitoring

The biological surveillance of fresh waters started with the development of Saprobian system at the turn of the twentieth century (Kolkwitz and Marsson, 1902, 1908, 1909). But early attempts to use biological information to detect pollution utilising both flora and fauna were made by Butcher (1928, 1946) in U. K. But gradually among all flora and fauna it was macro-invertebrates which assumed increased importance (Hawkes 1956; Hynes 1959). It was, however, the publication of the Trent Biotic Index (Woodiwiss 1964) a method based entirely upon macro-invertebrates, establishing its utility for routine biological surveillance of pollution. Subsequently, the Trent Biotic Index (TBI) has been modified in many European countries for their local use. In U. K. the appearance of TBI was followed by a proliferation of score and index systems based on macro-invertebrate. Many of these were developed for limited geographic areas but recent one, Biological Monitoring Working party (BMWP) score, was devised by a committee of freshwater biologists for national use (Chesters 1980; Armitage *et al.*, 1983).

Bioindicators

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

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

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

Biomonitoring schedule

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

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

Limitations of biomonitoring

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

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

Effectiveness of macro-invertebrates in biomonitoring

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

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

RIVPACS- A Multivariate Approach

One of most advanced, yet simplest and most successful programmes for assessing water quality from the invertebrate assemblages, is the U. K.'s River

Prediction and Classification System (SIVPACS). One of its main strengths is its ability to assess whether a species/assemblage is absent due to pollution or simply a lack of available habitat. Under this programme, analysis of data has a two stage process. Firstly, sites are classified according to the taxa present. Criteria here is that the resulting classifications should be ecologically interpretable and that new sites could be easily attributed to a classification group without recourse to detailed further analysis. The next stage is to use the environmental data to interpret the biological information. An essential pre-requisite here is that the method should provide a procedure for predicting the likely occurrence of macro-invertebrates from the knowledge of chemical and physical features of the sites.

Conclustion

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

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NUCLEIC ACIDS AND ENZYMES AS AN INDICATOR OF FEEDING INTENSITY IN STRESSED ECOSYSTEM

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For obtaining growth of aquatic fish species, the essential features should form a proper husbandry condition, monitoring of the stock and availability of desired water quality. Since the growth of fish remains directly proportional to the availability of sufficient quantities of nutritious food, particularly at younger stages of growth, this aspect should also be looked into carefully.

The recruitment process of fish larvae in various water bodies necessitates the knowledge on the nutritional status of fish and there should be some indicators to ascertain the nutritional condition of the stock.

Buckley (1979) indicated the relationship between ribonucleic acid (RNA)/deoxyribonucleic acid (DNA) ratio and growth rates in fish. Clemmensen (1987) performed laboratory experiments on the RNA/DNA ratios of starved and fed fishes. Hjelmeland *et. al*. (1984) demonstrated the role of trypsin and trypsinogen as indicators of growth and the survival potentialities of fish. Martin *et al.* (1985) investigated the importance of food supply to nutritional status of fish larvae. Pederson *et al.*(1987) observed variations in the content of trypsin and trypsinogen in different larval stages of fish digesting copepod nauplii. Ueberschar (1988) determined the nutritional condition of very young fish from natural open waters by analysing their proteolytic enzyme activities.

It appears that there may have some sort of indicators that can be used to determine the nutritional conditions of fish and among them, the RNA/DNA ratios and tryptic enzyme activity measurements perhaps seem to be appropriate indices to ascertain the nutritional status of very young fish, particularly the larval stages. The experiments can be calibrated by initiating studies on fish larvae reared under definite laboratory conditions and the method can then be applied to fish larvae of unknown nutritional condition from field. A stressed ecosystem sometimes may exhibit loss of appetite in fishes, resulting in subsequent cessation of feeding. In some other stressed ecosystems, there may be shortages of foodstuffs leading to starvation of fish. These may occur in fish from both the natural open waters as well as from the culture systems.

The present topic describes the application of RNA/DNA ratio and tryptic enzyme activities of fed and starved fish larvae that can be used for evaluating the nutritional conditions of fish from a field sample, based on laboratory experiments and results.

Fish larvae of approximately 10-65 days of age may be used for the determination of RNA/DNA ratio and larvae of 1-45 days, for the measurement of tryptic enzyme activities, reared under laboratory conditions. Larvae can be fed with *Brachionus* (5/ml) and *Artemia* (1/ml) nauplii or deprived of food for intervals of 5-10 days (for RNA/DNA ratios) or 1-5 days (for tryptic enzyme activities). Larvae can be obtained from culture water areas or captured from natural open waters by using nets of appropriate mesh size. Collected samples may be shock-treated and frozen under ultra-low temperatures.

RNA and DNA may be estimated by conventional methods. The DNA is estimated by well-known diphenylamine reaction. Isolated tissue DNA is reacted with diphenylamine under acidic conditions, when a blue compound is formed that shows a sharp absorption maxima at 595 nm of spectrophotometer. The RNA is estimated by well-known orcinol reaction. The pentose of RNA is heated in the presence of concentrated HCl. Furfural is formed which reacts with Orcinol, in presence of $FeCl_3$ as catalyst, to produce a green colour whose extinction is measured at 665 nm.

Alternately, RNA and DNA contents of the larvae can be determined by the method of Clemmensen (1988) with some modifications (Clemmensen, 1990).

The tryptic enzyme activity measurements can be carried out by the method of Ueberschar (1989) or by the method described by Mukhopadhyay and Hajra (1986).

A comparison of RNA/DNA ratios and tryptic enzyme activities of laboratory reared starved and fed larval fishes can be done. It may be observed that RNA/DNA ratios as well as the tryptic enzyme activities were significantly lower in the starved larvae, than the fed ones. The nucleic acid ratios and the tryptic enzyme activities of both the starved and fed larvae would further exhibit a linear increase with larval length and hence the age.

An assessment of nutritional status of field-caught larvae could then be performed based on the results of RNA/DNA ratios and tryptic enzyme activities carried out on starved larvae from laboratory.

Such an investigation reveals that both the indicators (RNA/DNA ratio and tryptic enzyme activity) may prove to be adequate to distinguish between the feeding and starving populations of fish. The results from laboratory rearing would clearly demonstrate depressed value in starved larvae for both the indicators, the depressions being statistically significant. This observation may thus be used for an assessment of nutritional status of unknown young fish from the field.

The actual values of RNA/DNA ratios and tryptic enzyme activity measurements may vary from one fish species to the other and hence it appears pertinent to use laboratory results on starved larvae, to assess the nutritional status of unknown larvae or young fish from fields of the same species.

It can be demonstrated that both these indicators are quite able to indicate larvae that have undergone starvation intervals for a minimum period of 5-10 days. Both the indicators may also correspond well when assessing the proportion of starved larvae from a normal or stressed environment.

The proteolytic enzymes respond faster to food deprivation compared to the other indicator (RNA/DNA ratio). The tryptic enzyme activity becomes significantly depressed after about 2 days of food deprivation, compared to the fed larvae. The RNA/DNA ratio needs about 4-6 days to demonstrate a significantly depressed level. Therefore, the fishes that remained un-fed or have undergone a starvation interval of 2-6 days may lead to significantly depressed enzyme activity, in contrast to more conservative RNA/DNA ratio which becomes useful for proper estimation with a longer starvation interval of 6-9 days.

Since, an increase in temperature may exhibit a faster depression in the levels of both the indicators, depressed values may be obtained in shorter time intervals. The absolute values of both the indicators from larvae facing long-term starvation, however, are not expected to be influenced by the temperature.

This type of investigation can, therefore, demonstrate the efficacy of RNA/DNA ratio and tryptic enzyme activity for assessing the nutritional status of fish and detecting the starvation level in field samples, if any. It is also important to note that such methods may be of use towards rearing conditions in culture units including the presence and availability of optimum food density, the quality of food, feeding activity and finally the growth.

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UTILITY OF FISH HEALTH MONITORING IN PRODUCTION SUSTENANCE

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Production an unit time biomass gain from any ecosystem, comes out of complex processes of eco-physiological interactions. In other words, the production achievement is dependent on ecological clarity and richness, and physiological soundness or abilities of the top grazers grazing on diversed niches. In aquaculture or open water fisheries the ultimate harvest constitutes of fishes, shell fishes or other aquatic organisms like molluscs etc. However, as a major contributor to animal protein production, fishes play an undoubtable role all over the world. Eventually, much of research work has been carried out on this group of animals. Today's emphasis in aquaculture is an adoption of intensive culture technologies which beside satisfying the demands of high protein requirement, emerges as with various problems relating to environment and production insecurity. There are solutions for the problems of environment, but production insecurity has many a reasons which can be overcome only when multi-angle approaches are considered. Health monitoring can act as an effective measure in minimising the production hazards by indicating the physiological problems affecting growth and eventual death leading to lower survival in extreme situation.

Health stress in fish

The fishes are poikilotherms and in general highly tolerant to environmental fluctuations. However, few of these animals have narrow range of environmental tolerance. Many of the fish species bear the ability to breath on atmospheric oxygen for quite a long time. While few need high concentration of ambient oxygen for normal life. Like environmental tolerance fishes are also equally adaptable to food and feeding habits. In acute shortage of natural food the carnivores and herbivores often turn to omnivores to save themselves from starvation and death. Inspite of these qualities, fishes may fail to maintain normal health under culture or natural systems. Such situation arises due to extreme environmental deviations and/or drastic changes in food web cycles. These extrinsic factors lead to starvation and improper growth. Prolonged starvation causes physiological disorders and immunosuppression in the affected fish. Fishes suffering from ill health and immunosuppression become the ideal hosts for many a pathogens.

Environmental contamination due to natural and anthropogenic reasons is inevitable since the nature is uncontrollable and human development is an unending process. Unfortunately every event of natural changes and human developments ends with aquatic contacts or needs use of aquatic recourses. Whatsoever may be the reason the environment and life processes in aquatic ecosystems become the ultimate victims. Fishes at the highest of trophic level and living comparatively long life witness the health hazards of different natures.

Health monitoring in fish

Unlike other terrestrial vertebrates, fishes are less attended regarding health problems and also development of treatment or preventive measures. As a result this important aspect related to fish and finally fisheries is inadequately known to us. Since recent past, with the emerging of community structure index concept in environmental impact assessment, the importance of fish composition including their health condition has been recognised. Fishes, because of being beyond human sight, needs monitoring measures effective to assess the overall impact of abiotic and biotic conditions on their health. Examination of external characters like features and growth performance and cheek up of haemotological, histological and biochemical abnormalities have been tried and proved to be effective methods for diagnosis of health problems in fish. However, in aquaculture systems or even in natural ecosystem, beside that of individual fish health conditions of overall population plays significant role in production processes. Periodical monitoring and follow up measures for health protection contribute immensely in production sustenance of fisheries.

Methods of health monitoring

Behaviour: Behavioural changes like surfacing, gasping, movement irregularities, extrusion etc. indicate stress effects in fish. Any of these unusual behaviours necessitates examination of the affected fish for detail diagnosis.

External features: The first hand information on health condition of fish is gathered from examination of body shape, injuries, disease infestation, slime secretion, blood oozing and gill conditions. Thorough checking of external features reveals the degree of external stresses and also helps in suitably treating the affected fish.

Growth performance: In fishes, the health condition can be assessed from growth performance through length-weight studies. Several workers have suggested mathematical expression of length-weight relationship which is used in determination of condition factor for the entire population and also relative condition factors for size clusters within the population of a species. Comparison of condition factors from different ecosystems or different points of same ecosystem reveals health status of the fish under different environmental conditions.

Hematology: Blood parameters, specially haemoglobin, haematocrit and total count of RBC and WBC are well known stress indicators. Variations in the values of these parameters indicate not only the haematological disorder but also the related problems like asphyxia, anaemia and excretary stresses.

Histology: Cellular deformities leading to dis-function of physiological systems may be assessed through histological examination of tissues. In fishes, gills, liver, kidney and brain are most studied organs, since the cell level abnormalities can be detected easily in these organs. However, selection of organs for histological examination depends on the expected/anticipated nature of stress and also the study purposes.

Biochemistry: Apart from the environmental and biological evaluation of stress effects biochemical studies are also considered equally important in pollution investigation. Biochemical markers like metallothionein and acetlycholinesterase are well established indices for metal and pesticide contamination in fish.

Benefits of fish health monitoring

Monitoring of health besides benefiting the fish in maintaining well being helps in other ways too.

Indicators of environment

Monitoring of fish health through growth performance, haematology, histology and biochemistry reveals the environmental conditions of the habitats. Besides for open water systems health monitoring also plays an important role in indicating the state of environmental affairs in culture systems. Health monitoring and evaluation of physiological stresses suggest the corrective measures to be followed for better sustenance of the production.

Food scarcity/deficiency

Health, in particular growth is directly related to food availability and conversion efficiency. Obviously, improper growth speaks of food scarcity in the natural habitats or deficiency in the food supply in culture systems. As such, health monitoring and subsequently meeting up of demand of food either natural or artificial, if necessary, help in sustenance of production. Further, in culture systems the conversion ratio and acceptance of the supplied feed can also be ascertained from the growth performance.

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ENVIRONMENTAL STRESS AND FISH HEALTH IN THE CONTEXT OF INLAND WATERS

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The stability of a fish population in a particular aquatic habitat is very often disrupted by various factors *viz.,* disease, habitat destruction, depletion of resources, or the application of other environmental stressors. This unstable condition is manifested in fish populations by some indicators. Mortality of fish or decline in a fish population is at present the sole indicator that the affects of environmental stress factors are exceeding acclimation tolerance limits of fish. However, several physiological and whole animal changes occur that can be used to provide prior information that the effect of stress will exceed acclimation tolerance limit and lead to dysfunction such as impaired fish health, growth or survival. These changes are a direct or indirect result of the physiological response to environmental stress and can be quantified and used as predictive indices. Moreover some fish parasites can also be utilized as indicators of stress. The succeeding pages will elaborate on these aspects.

Definition of stress

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

Environmental alterations commonly encountered creating fish stress

Aquatic environment due to anthropogenic activities are subjected to various physico-chemical stresses either of short or prolonged duration. These effect the health of resident fish populations. Some of the very interesting examples of alteration in the aquatic environment investigated resulting in stress to fish populations are given below.

A. A sewage fed freshwater wetland

This wetland receives municipal sewage from Calcutta and fish. Indian major carps and *Tilapia* are cultured. The environmental parameters discussed below obviously act as predisposing stress factor for fish. The environmental parameters of importance creating stress to fish are given in Table 1.

Here the dissolved oxygen ranges between 0 and 18 mgl^{-1} during 24 hrs. The rate of change of DO per hour in the midday and during night is around 3 $mg\ l^{-1}$ indicating high rate of photosynthesis in day time and high rate of respiration after dusk. Microbial consumption of DO per hour is 2.4 mgl^{-1}, indicating that DO is exhausted at night in the absence of light at a very fast rate. Transparency range is between 12 and 14 cm mainly because of planktonic bloom. The range of unionised ammonia present during the investigation is high.

It is thus evident from the observation that the high organic load, low transparency and high phosphate level is indicative of eutrophic condition in the ecosystem. The high microbial consumption of DO per hour (2-4 $mg\ l^{-1}$) indicates exhaustion of DO for a few hours at night creating a stressed condition to fish. Moreover, the high fluctuation in pH, and consistently high levels of unionised ammonia create chronic stress to fish.

B. Sewage fed saline wetlands

Observations on the water quality in some of these wetlands where prawn and fish culture is done are given in Table 2.

These wetlands had organic matter in the decomposing phaze with consequent higher concentration of unionised ammonia. As a result in all these wetland except Agamaru the fishes are stressed and fish and prawn diseases are prevalent.

C. *Water quality of some EUS affected water bodies*

The water quality of some of these water bodies where fishes are affected by EUS is given in Table 3. In the outbreak of EUS low alkalinity and hardness associated with the low calcium acidic soils acts as a pre disposing stress factor for outbreak of EUS. This is very much evident in some of the water bodies in Assam, Tripura, Meghalaya, Bihar, Kerala where intensity of the disease outbreak is severe.

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.

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.

A. *Use of the physiological response as indicators of stress*

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

Primary stress response

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

Secondary stress response

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

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

Haemoglobin/Haematocrit : 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-4.

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.

B. *Biological indicators of stress*

In all of these water areas mentioned above the very common initial symptom of stress exhibited by fishes is excessive secretion of mucus from gills and body surface. In fact this physiological aspect of fishes can be fruitfully utilized for fish stress detection or detection of suboptimal water quality.

There are certain trichodinid parasites (*Trichodina* sp., *Tripartiella* sp.) ubiquitously present in fish gills especially of Indian major carps which can serve as good indicator of stress in fish. Excessive mucus secretion serve as substrate for these trichodinids which increase in number. A methodology has been developed where the presence of these trichodinids above 20 numbers in 0.05 ml of gill mucus in indicative of stress. (Table 5).

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.

Table 1

Time (hours)	pH	DO mgl^{-1}	Transpa-rency (cm)	Gross primary production mgCm^{3} hr^{-1}	Phos-phate-P mgl^{-1}	Ammo-nium-N mgl^{-1}	Free Ammonia mgl^{-1}	Nitrate-N mgl^{-1}	CO$_2$ mgl^{-1}	Bicarbo-nate mgl^{-1}	Salinity ppt	Temp. °C	Carbonate mgl^{-1}
03.00	7.9	0.5	13.0	1800.00	0.80	1.40	0.084	0.10	16.0	188.0	0.35	29.0	nil
09.00	8.0	3.5	-	-	2.00	1.20	0.108	0.25	6.0	210.0	0.36	33.5	nil
15.00	9.1	18.0	-	-	0.08	1.10	0.605	0.28	nil	180.0	0.35	36.0	nil
21.00	8.0	Nil			1.20	1.00	0.090	0.38	6.0	200.0	0.35	32.5	nil

Table 2

Name	pH	Alkalinity ppm	Hardness ppm	Unionised Ammonia ppm	Salinity
Agamura (Unaffected)	8.3	127	18000	0.1	9.02
Beel Samity	8.5	126	3000	0.5	10.25
Kathore	8.6	127	2800	0.3	6.4
Tripley	9.0	147	3200	0.2	7.0
Maligada	8.6	125	3000	1.1	9.0

Table 3

State	pH	Alka-linity mgl^{-1}	Hardness mgl^{-1}	Chloride mgl^{-1}	Free CO_2 mgl^{-1}	Ammonia mgl^{-1}	Salinity ppt
Assam	7.1-7.5	13-74	11-38	4-23	4-10	N-0.4	
Tripura	6.7-7.6	7-49	9-45	3.5-18	2-8	N-0.6	-
Meghalaya	6.5-7.5	7-14	10-15	2-12	4-6		
West Bengal	6.7-7.5	10-170	6-180	2.9-13	2-7	N-0.6	N-1.0
Bihar	6.1-6.8	25-30	13-20	4.7-7	4.0	1.8-2	
Orissa	6.8-7.4	44-138	55-180				1.5
Uttar Pradesh	7.5-8.0	40-217	42-234	0-5.8			
Tamil Nadu	7.8-8.3	103-139	105-158				
Rajasthan	8.0-8.2	140-150	80-90				
Maharashtra	7.5-9.5	30-115	48-140		2.5-3.0		
Kerala	6.3-7.0	0-11	8-17	0.34			1.0

Table 4 : Recommended physiological tests to assess the tolerance limits of fish for abiotic and biotic stress factors (compiled from Passino 1984; Buckley *et al.,* 1985). The interpretations of responses listed are general but not necessarily universal; investigators should be aware that there may be some stressful situations that do not evoke a change in one or more of these physiological conditions.

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

Table 5 : Environmental quality and presence of Trichodinids in Cirrhinus mrigala

Month	Water quality parameters						*C.mrigala*				Av. no of Trichodinids
	Temp °C	Transp. (cm) mgl^{-1}	UI NH_3	Alk. mgl^{-1}	Hard. mgl^{-1}	pH	No. Exam.	Av.		Qty. gill mucus (ml)	
								L. (mm)	W (g)		
January 1995	18	15	0.3	204	-	8.3	12	170	50	0.05	27
February 1995	19	13	0.5	190	-	8.7	10	172	45	0.05	30
March 1995	28	14	0.2	195	-	8.7	25	175	45	0.05	22
April 1995	30	14	0.3	190	-	8.7	10	180	52	0.05	16
May 1995	12	15	0.6	192	-	8.8	15	165	40	0.05	18
June 1995	30	12	0.2	186	-	8.7	15	167	40	0.05	26
July 1995	30	12	0.2	190	-	8.8	15	132	25	0.05	32
August 1995	30	11	0.3	178	-	8.5	10	162	45	0.05	10
September 1995	30	13	0.4	175	-	7.4	10	140	28	0.05	10
October 1995	29	10	0.4	190	-	7.9	10	182	50	0.05	22
November 1995	28	14	0.5	185	-	8.0	20	130	25	0.5	26
December 1995	22	11	0.4	182	-	7.5	10	145	25	0.5	26

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STATUS OF HEAVY METALS & PESTICIDES IN AQUATIC FOOD CHAIN IN CONTEXT OF INDIAN RIVERS

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Introduction

Industrialization, urbanization and increased population in India have modified environment beyond limits. The problem of environmental pollution is more severe in developing countries like India, because of limited economic and technological resources than the developed countries. The disposal of industrial wastes poses a serious problem at present due to their diverse composition such as acids, alkalis, metallic ions, phenols, cyanide, pesticides and many other organic and inorganic substances, which have become a pervasive threat to the natural ecosystems.

Environmental contaminants have toxic effects on different types of organisms and affect biological processes at cellular, population, community and ecosystem levels of organizations. The problem of toxicants affecting aquatic ecosystems is complex and there is continuing need for monitoring and mitigating the effect. A study of the structure and functions of a biological community in the waste receiving water and laboratory bioassays for determining toxicants are some of the basic approaches that is required for pollution monitoring.

The toxicity of heavy metals is of considerable biological and economic interest. The term heavy metal generally includes metals whose atomic number is grater than iron or having a density greater than 5%. In recent years increasing amounts of metals are being discharged into the environment by industrial complexes. Concern over metal pollution focussed sharply when incidents involving the fatal poisoning of human being in some countries with Mercury and Cadmium came to light. Mercury, is a dangerous pollutant, is one of the worst offenders. It was responsible for several deaths in Sweden and Japan and even caused the dreaded Miniamata disease in Japan.

The establishment of metal levels in the sediments is necessary for detecting their source and extent of metal pollution in the aquatic system. The suspended particles carried by various industrial effluents and domestic sewage ultimately deposited as the sediments containing measurable concentrations of lead, zinc, cadmium, chromium, copper, nickel, cobalt, manganese and iron etc. The industrial and the sewage input to the tributary/rivers are the most likely sources of heavy metals contamination. Coal fired thermal power plant was found to be responsible for the elevation of metallic contents in the water and sediments of the upper Ganga canal.The biological indicator organisms have been used by many workers to monitor the time average abundance of trace metals and other pollutants in the aquatic environment. It has been seen that chemical analysis of the tissues of submerged plants gave valuable information about the contamination of the surrounding water.

Heavy metals concentration in water depends mainly on the pH of the system. It has been reported that the precipitation of heavy metals is enhanced at pH above 7.0. The concentration of heavy metals in the sediments depends on its pH, $CaCo_3$ and organic matter. Adsorption of 'cations' by organic matter is due particularly to a negative charge of colloids. The levels of heavy metals in the sediments play a key role in determining the sources and the extent of metallic pollution in aquatic environment. The presence of heavy metals is due to the precipitation of their hydroxide, carbonates and sulfides, which settle down and form the part of sediments. The composition of these precipitates greatly influenced by the various hydro-chemical conditions of the water body.

The heavy metal contents in the aquatic animals originates from two routes of intake, free ions and simple compounds dissolved in the water are taken up directly through the epithelium of the skins, gills and alimentary canal while others, having been accumulated in food organisms are incorporated by nutrition. The metals from the aquatic environments are generally taken up into the human body via gastrointestinal tract through drinking water and food. The heavy metals such as Chromium, Copper, Cadmium and Mercury when discharged into the water, can enter the food chain, are bio-accumulated by fish and hence pose a threat to human beings.

Under alkaline pH condition iron gets hydrolyzed and forms insoluble hydroxide, which settles down onto the sediments of the river. The hydroxides and oxides of iron and manganese constitute significant sinks of heavy metals in the aquatic system. These hydroxides and oxides readily sorb or co-precipitate "cations" and "anions" and even a low percentage of Fe $(OH)_3$ and MnO_2 has a controlling influence on the heavy metal distribution in an aquatic system. The high concentrations of different metals in the sediments of the Kali Nadi may also be attributed to the fact that metals might have precipitated along with hydrogen and oxides of iron and manganese.

The metals like Cr, Mn, Mo, Ni, may show a positive association with organic carbon present in the sediments. Positive co-relation occurs when metal ions interact in solution with dissolved organic matter that get in turn concentrated by absorption. It seems quite possible that metals might have interacted with the organic matter in the aqueous phase and then settled down resulting in high concentration of the metals in the sediments. A high degree of positive correlation is possible between the contents of organic materials and metal concentrations in the aquatic sediment

Pesticides have become an important tool of modern agriculture to protect standing crops, stored grains and human belongings from pests and help preventing certain diseases. The average consumption of pesticides has increased sharply from 3.2 g/ha in 1953, 54 to 33.69/ha in 1980 (Chattoraj, 1987) in India and still lags much behind the consumption of pesticides in United States. (1490 g/ha) and in Europe (1870 g/ha). Pesticides after application eventually reach to the aquatic system in considerable amounts via agricultural runoff from land, contaminated ground water, bottom sediments, urban runoff, municipal water treatment, manufacturing and formulating plant wastes and atmospheric fall out through rain etc. These pesticides affect the target as well several non-target species also.These pesticides make the life of non-target species hell, and amongst them fishes are the worst victims. Sufferings of fishes to pesticide may be expressed either by their mortality or by alterations in their growth, development, reproduction, biochemistry and physiology depending upon several factors like; a) physical and chemical properties as well the concentration of the pesticides, or their transformed by -products in water ecosystem (b) duration and kind of exposure (acute or chronic, intermittent or continuous) and © ability of fish to metabolize the pesticide absorbed.

One of the reasons for large scale mortality of fish and low fish landing has been attributed to the increasing concentration of pesticides in natural water bodies. In fact interacting physical, chemical and biological factors of the aquatic ecosystem complicate the process and the response of a fish to a particular pesticides exposure. With the accumulation in aquatic ecosystem, a good amount of pesticide under- goes breakdown and transformation depending upon physico-chemical and biological factors of the water ecosystem. Simultaneously , a considerable amount of pesticides and their byproducts enter the fish body, where these are distributed and metabolised depending upon the detoxifying ability of the fish, and elicit some responses in which depend on the nature and concentration in pesticide as well as the duration of their persistence in fish body. The hydrophilic pesticides are readily transported to fish then the hydrophobic ones. Water soluble pesticides enter the fish either through the body surface, or gill or mouth. Pesticides in foodstuffs get ingested and absorbed through the gastrointestinal tract. The route of entry of pesticides and duration of exposure has substantial impact on their absorption, distribution, biotransformation and consequently their effect on fish.

Types of pesticides

Pesticides can be Categorized on the basis of 1) their target organisms like fungi, algae, molluscs and hence named accordingly; insecticides, herbicides, fungicides, algaecides, rodenticides, weedicides, molluscicides etc, or 2) their chemical nature organochlorine, organophosphorous (OP) Carbamates and Pyrethroids etc, 3) their mode of actions like; neurotoxic, haemotoxic, etc.: -

1. Organo- Chlorine: - DDT, Aldrin, Heptachlor, Dieldrin, Toxaphore, Chloradone, PCB, HCB, & Endosulphan.
2. Organo- Phosphorus:- Malathion, Parathion, Diazinon, Guthions etc.
3. Carbamates:-Sevines
4. Pyrethroids: -Permethin, Aldrine, and Cyperthrin.

Fate of Pesticides on Aquatic animals

Laboratory observations on fish embryos portray their greater susceptibility of pesticide formulations. Several of the eggs failed to hatch and the embryos scumlad to the toxicity at various stages of development. Decrease in hatching among eggs of *C. carpio* with increase in Malathion concentration in the environment. Malathion is known to exert inhibitory mechanism in DNA replication during protein synthesis leading to abnormalities and death. DDT and Aldrin at safe levels indicated reproduction of the animal was totally hampered. The growth of Gastropods (molluscs) was found to be reduced by more than 25% under exposure to DDT at 0.1 ppb, and 50% at 0.5-ppb concentrations. The decrease in weight was exhibited by the thinning of the shells rather than reduction in flesh weight.

The pesticide residues studies in Indian rivers are scanty. Though number of researchers have studied in the laboratory the pesticides bioassays, bioaccumulation, biochemical aspects etc; but field data on pesticides are very few. About 2,573 t of pesticides are used in a year in the Ganga basin. Incidences and magnitude of DDT and BHC-y residues in fishes of tidal stretch of the Ganga were of higher order in the industrial zone, compared to riverine and estuarine zones. Greater accumulation of DDT (65-150 ppm) was recorded in molluscs , followed by fish (31-460 ppb), plankton (15-150 ppb) and sediments (17-80 ppb) . BHC –Y in fish was 46-210 ppb, in molluscs- 40-86 ppb and in sediments 21-70 ppb. On the basis of ambient water, the bio-magnification values were; 2,500 in Plankton, 3,600 in Gastropods (molluscs), 7500 in Fish and 15,800 in bivalve molluscs.

Among the pollution hazards from the agricultural sector, the damage caused by the pesticides is the most lethal and interminable to the environment. The Organo-chlorine pesticides are lipophilic , extremely toxic and non-biodegradable. Like heavy metals assume alarming proportions as they are prove to be biologically magnified and accumulated in fish posing serious threat to the fish eating public. Most of the commonly used pesticides in India like DDT, BHC, Endosulfan, Ethyl parathion, Methyl parathion, Dimethorate, Phosphamidon, Carbaryl, and 2-4-D, have been screened to evaluate their toxicity. All of them have been found to be toxic to the food organisms and fish populations.

Sub-lethal concentrations of DDT and BHC adversely affect the fish at tissues levels. Damage to liver cells, besides decline in growth, RBC count, HB, and PVC level has been noticed in *Oreochromis mossambicus*. Similar effects have been noticed in *L. rohita* and *C. mrigala.* Chlorinated hydrocarbons persist longer time in water gets accumulated progressively in different steps of food chain. Fishes like other animals, are capable of concentrating lipophilic compounds in their body tissues several hundred to several thousand times the ambient concentration in water. DDT can accumulate in fish to levels more than 10,000 times the concentration present in the environment. Studies have been reported indicating adverse effects at structural level and at the metabolic level.

Pesticides finding their way to aquatic habitats are found to interfere with the reproductive capacity of the fishes. Distortion in testicular and ovarian histology of *Tilapia* has been noticed. Sub-lethal levels of Lindane (0.16 ppm) and Malathion (4.0 ppm) also induced degeneration in the ovaries, drastically reducing the reproductive potential of the fishes. BHC and Dieldrin have been known to cause ovarian atrophy even in hardy fishes like *Heteropneustes fossilis*. Some workers have also noticed total arresting ovarian development.Verma et al.,(1989) detected 126 times accumulation of Endosulfan (thiodon) on the ovaries of the *Murrel, Channa punctatus,* when exposed to 1 pbb., concentration for 32 days. Toxicity of Methyl parathion was tested on the three carp's species to ascertain its impact on the liver metabolism. At sub-lethal levels, liver glycogen was reduced to the level of 50% during the first four days of exposure though the level recovered during subsequent days. Several studies indicate impairment of liver functions in fishes at considerably low concentrations of pesticides in the ambient water.

Fate of Heavy Metals on Aquatic animals

Instances of heavy metal accumulation have been reported from more and more stretches of river Ganga and its tributaries and also in almost all the rivers in India. The main sources of heavy metals are the industrial effluents. Municipal sewage is very often accompanied by trade wastes containing heavy metals. The tidal water in the lower Ganga has registered metal contamination (Zn, Cu, Cr, Cd and Pb) in the upper non-industrial zone around Nabadwip, industrial zone between Kuntighat and Batanagar and the lower non-industrial zone at Nurpur and Kakdwip. The tidal stretch of the Ganga recorded heavy metals in aquatic food chain. Heavy metal residues have been reported in the tissues of fishes, molluscs and the crabs, aquatic plants and soil sediments. Highest bioaccumulation detected in Hooghly estuary is that of zinc in the kidney of fish (295.1 ppm) followed by gonads (146.8 ppm). Biomagnification of heavy metals have been reported from the Hooghly estuary, ambient water in the main Ganga around Kanpur has shown higher metal contamination. Yamuna registered the presence of Zn, Cr, Cr,Cd and Pb, in water phase at Agra and down stretch of Delhi. In almost several studies in India indicated that in most of the Indian river heavy metals are present in significant concentrations in ambient waters followed, by in aquatic plants, plankton, gastropods, Fish and maximum in Sediments.

Accumulation of zinc in gonads at a high level 1144.8 ppm was found to be detrimental to fish health affecting to its reproductive potential in the long run. Organisms such as *Cyclops* and *Daphnia* are more sensitive to metal like zinc. Presence of such persistent pollutants in the river water not only creates unfavourable environment for fish but also causes paucity of fish food organisms.

Heavy metals are injurious to health even, some of these are known to produce toxicity by inhibiting enzyme action or interfering with blood synthesis or causing damage to the liver kidney, or even to the brain. They are also known to cause damage to the human featous, presence of lead in the body has been shown to lower IQ in children.

The concentration of heavy metals in the sediments depends on its pH, $CaCO_3$ and organic matter. Adsorption of cations by organic matter is due particularly to a negative charge of colloids. The higher concentration of heavy metals in the sediments may be due to the precipitation of these metals with carbonates. If alkàline water body comes into contact with and gets mixed in the rivers water with normal Ca^{++} and HCO_3^- levels under neutral pH conditions, the pH will increase. Consequently, the solubility product of $CaCo_3$ is drastically reduced and $CaCO_3$ is precipitated in the mixing zone carrying heavy metals from the solution along with it. The higher contents of metal may be attributed to the precipitation of metal contents along with $CaCO_3$.

The heavy metal contents of the aquatic animals originates from two routes of intake, free ions and simple compounds dissolved in the water are taken up directly through the epithelium of the skin, gills and alimentary canal while others, having been accumulated in food organism are incorporated by nutrition. The metals from the aquatic environment are generally taken up into human body via gastro- intestinal tract through drinking water and food. The heavy metals can enter the food chain are bio-accumulated by fish and hence pose a threat to human being.

Conclusion

A survey of the industrial cities of India has shown that industrial waster constitutes by volume between 8 to 16% of the total waste water generated. The remaining 84-92% being generated from the domestic sector. With the rapid industrialization, the waste water from the industrial sector is expected to rise to 33% by AD 2000. Environmental degradation is a necessity of all developmental activities. The problem of toxicants affecting aquatic ecosystem is complex and these is continuing need for monitoring and mitigating the effect. A study of the structure and functions of a biological community in the waste receiving water and laboratory bioassays for determining are some of the basic approaches that is required for pollution monitoring.

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BIODIVERSITY OF MACRO-INVERTEBRATES FROM STRESSED AND NON STRESSED FLUVIATILE REGIME AND THEIR ROLE IN ASSESSMENT OF WATER POLLUTION

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Professor Hutchinson in his book "why are there so many kinds of animals?" mentioned man's awareness about animal diversity since time immemorial. But it was later on that the interest in manifestation of diversity and studying its causes emerged eventually in human conscience. Diversity provides framework for causal explanation. It is useful and powerful tool for describing certain community phenomena. Application of diversity as biological index of community or environmental changes has been proved most effective giving satisfactory reasonings for the cause and effect of pollution.

Macro benthic invertebrates, with wide species range and distribution have importance in stress effect evaluation based on their community behaviour, density distribution and environmental sensitivity.

Why macrobenthic invertebrates

This group of bottom dwelling animals constituting gross of benthic population and remaining at higher strata of benthic food chain systems can very well reflect any effect on benthic community in response to environmental contamination, geographical changes and similar other natural or man made modifications. Organisms under this group are mostly sedentary, colonial and eco-system specific. By virtue of these qualities, benthic organisms are considered ideal for environmental impact assessment and have been accepted and utilised in pollution investigation through out the world.

Macrobenthic invertebrates in fluviatile system

Fluviatility is considered ideal in respect of sustenance of better physico-chemical quality. Such ever flowing, quality rich environment is most conducive for colonisation by the benthic flora and fauna. However, incase of macrobenthic invertebrates the bottom texture becomes limiting factor inspite of the favourable water quality condition. The benthic fauna in hilly terrain differs from those of plains in a river system. Similarly the fauna in down flowing river is not identical with those available in its tidal influenced estuarine zone.

The rocky, graveled and unpaved bottom in association with fast flow and clear pollution free environment promote the propagation and growth of some selective classes of macrobenthic invertebrates in hilly range of river, rivulets or streams. Insect nymphs by and large dominate in such hilly terrain of river system. Gradual soil drainage from catchment areas causes sediment deposition in the valley part of river and with this change in bottom characteristics the benthic faunal composition also get changed such as sediment dwellers like annelids and gastropods appear in the faunal. With salination of the environment and tidal influx in estuarine zone, the freshwater macrobenthic invertebrates disappear and get replaced by euryhaline species of crustacean (*Gammarus sp. Accetus sp.* small prawn & crabs), annelids (Polychaete worms) and molluscs (Gastropods & Bivalves). The species inhabiting estuarine systems are mostly burrowing types and hide themselves in the bottom sediment at the time of fast tidal influx and efflux.

Macrobenthic invertebrate Vs Environment

Like other animals the macrobenthic invertebrates are also reactive to environmental changes. Some of these organisms are highly sensitive to physico-chemical alteration of environment while few are highly resistant. The intermediate group of organisms which can tolerate wide range of environmental fluctuation dominate the faunal population and encountered almost in every aquatic systems. Based on environmental tolerance power these organisms have been categorised by several workers all over the world. In other words the macrobenthic invertebrates have been used in environmental evaluation of aquatic systems most successfully. Detritivorous nature of the macrobenthic invertebrates prompts these organisms to folourish in organically enriched or eutrophic zones of the river systems. By and large organisms like molluscs specially the gastropods, annelids (mostly oligochaete worms) and chironomid insects dominate in eutrophic environment an act as indicators of pollution. The dominance of these different groups is dependant on the nature of detritus or sources of organic contamination and also the prevailing water qualities. Gastropods show preference for semi-decomposed or decomposing organic matters to feed upon and a minimum level of oxygen to survive. While the oligochaetes multiply faster rate if, the environment is anaerobic and the organic materials are in decomposed state.

Macrobenthic invertebrates as indicators of pollution

The indicator organisms concept is simply that the presence of a particular species is indicative of the existence of certain environmental conditions, whereas its absence is indicative of the absence of that conditions. In biomonitoring programmes, the presence of species and their relative abundance have been shown to accurately reflect the degree of contamination in an aquatic habitat (Sheehon, 1984). 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 measure 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. The use of this measure has given rise to derived measures, indices of dominance, evenness, and diversity.

Role of macro benthic invertebrates in pollution assessment

Macrobenthic invertebrates because of their wide spread distribution, year round availability and species richness are preferred as biological index of pollution assessment in aquatic systems. Over the decades of research, these organisms have been categorised into different groups and used as *'biological* measure of stream conditions'. Methods such as this can reveal rather marked changes in community *composition*, but the arbitrary establishment of degrees of pollution without reference to social values is not very helpful. If occurrance of any single species is exceptionally large or extremely low, it signifies the system to be most favourable or antagonistic to the organism. On the basis of distribution pattern of different categories of environment sensitive organisms, the river system is classified *as healthy, semi healthy, polluted or very polluted stretches.*

Macrobenthic sampling in open water

Any method of assessment needs proper and efficient sampling for accuracy. Macrobenthic sampling in flowing water system is a difficult task. Firstly, these organisms are highly sensitive to any disturbance in their surroundings and secondly there are chances of their escapement from the apparatus of sampling. Research experiences all over the world suggest scoop net deployment in hill streams for secured samplings of macrobenthic organisms from the system. However, in large river systems like Ganga such net can only be effective in hilly terrains but in planes dredging can give better result.

Sample analysis and environmental assessment

Beside scoring method mathematical evaluation of species diversity value has been tried by several workers of which Shannon's index is widely accepted. The index in based on the equation

$$H = \Sigma \left(\frac{\underline{ni}}{N}\right) \text{Log} \left(\frac{\underline{ni}}{N}\right)$$

Where ni = Importance value of each species
N= Total of importance values

As per the values of H obtained from the equation the river environment can be measured, as below:-

Diversity value (H)	River environment
3-5	Clean
1-3	Moderately polluted
< 1.0	Grossly polluted

SUGGESTED BIOLOGICAL SCORING SYSTEM FOR THE RIVER GANGA

Biological scoring the oldest method of biological measure of environmental assessment was tried in the Ganga river system. The available species in the system were systematically classified and arranged chronologically on the basis of environmental tolerance and scores prescribed to each of the families for deriving the final score. The total score at a point is indicative of environmental status prevailing therein. The values thus obtained from different points would reveal the environmental fluctuations and level of contamination in the river system.

Siphlomridae, Heptageniidae, Leptophelebiidae, Ephemerellidae Potamanthidae	10
Ephemeridae (**Ephemeroptera**)	10
Taemiopterygidae, Leuctridae ,Capniidae, Perlodidae ,Perlidae	10
Chloroperlidae (**Plecoptera**)	10
Aphelocheiridae (**Hemiptera**)	10

Phryganeidae Molannidae Beraeidae Odontoceridae Leptoceridae	10
Goeridae Lepidostomatidae Brachycentridae	10
Sericostomatidae **(Tricoptera)**	
Lestidae, Agriidae, Gomphidae, Cordulegasteridae, Aeshnida,e Corduliidae	8
Libellulidae **(Odonata)**	8
Psychomyiidae, Philopotanidae **(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, Notonecutidae	5
Pleidae, corixidae, **(Hemiptera)**	5
Heliplidae, Hygrobiidae, Dytiscidae, Gyrimidae, Hydrophilidae	5
Helodidae, Dryopidae, Elminthidae, Chrysomelidae, Curculionidae **(Coloptera)**	5
Hydropsychidae **(Tricoptera)**	5
Tipulidae, Simuliidae **(Diptera)**	5
Planariidae, Dendrocoelidae **(Platyhelminthes)**	5
Baetidae **(Ephemeroptera)**	4
Sialidae **(Megeloptera)**	4
Piscicolidae **(Hirudinea)**	4
Valvatidae, Hydrobiidae, Lymnaeidae, Physidae, Planorbidae, Sphaeriidae **(Mollusca)**	3
Glassiphoniidae, Hirudidae, Erpobdellidae **(Hirudinea)**	3
Asellidae **(Crustacea)**	3
Chironomidae	2
Oligochaeta **(whole class)**	1

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RIVER MAHANADI- ENVIRONMENT AND FISHERY

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The river Mahanadi

Originating near "Pharsiya" village in Raipur district of M. P., the river Mahanadi covers 857 Km stretch to reach sea at paradip. Nearly 53.0, 46.3, 0.5 and 0.2% of the total drainage area (*i.e.* 1,41,589 Km^2) come under Madhya Pradesh, Orissa, Bihar and Maharashtra respectively. The river receives more than 78 tributaries directly and 22 indirectly to buid up 66,640 million m^3 discharge at the bay-mouth, recording peak discharge rate of 44,740 cumecs. More than 67 distributaries form the estuarine system in the east and the south of Cuttack. River course is brief westward then 300 Kms towards north to turn eastward at Khargoni to reach Mahadeopalli, *c.* 140 Km away, where Hirakud dam is located. Immediately after the reservoir, the river flows down *c.* 150 Km south to Sonepur, to take *c.* 265 Km final course towards east for meeting the bay of Bengal.

The riparian journey between origin and Hirakud is through plateau and then through forest clad mountain terrain up to Narsinghpur, and lastly the course is through meadows and agricultural lands interrupted by hilly areas and sandy as well as marshy deltaic patches. Primarily river bed is boulder strewn sandy flat. Initial south-north stretch has silty loam soil that transforms into sandy loam and then into loamy texture towards Hirakud. Below the reservoir, the left bank with sandy loam soil and the right bank with silty loam soil continue up to Sonepur and then change to clay loam in the eastward course through the eastern ghats. Thereafter silt loam basin is recorded up to Cuttack with a stretch of sandy loam intervening in the middle. After Cuttack, the basin has only clay loam soils. Though, Hirakud basin has red and black soils, the stretch above has red and yellow soils and the stretch below has red loam basin and deltaic laterite.

Average rainfall is 75, 75 and 1000 mm during spring, summer and rainy seasons respectively. In winter, it is 50 mm in the upper, 250 mm in the middle and 500 mm in the lower stretches. Basin temperatures are 20^0-25^0, 30^0-32.5^0, 25^0-30^0 and $<25^0$-$>27.5^0$ during spring, summer, monsoon and winter seasons respectively, showing about 2^0-3^0 less temperature in the upper reaches. This pattern in the lower basin is hit by 2 major and 2 minor cyclones annually.

Generally, river depths vary from 2.5 to 5 m with patches of <0.5 and > 15 m deep areas. Average depths for the upper, the middle and the lower stretches are 2.27, 2.60 and 4.11 m respectively when usual water current velocity of the corresponding stretches are recorded as feeble to 2.4, feeble to 2.88 and 0.3 to 4.08 Km per hour.

Scanty industrialisation is a boon for the river from pollution point of view. Rajim Rice-mill and Paragon Paper-mill do not contribute, but the industries for plastic and allied material at Sheonath; petroleum by products, drugs and pharmaceuticals, etc. up to Mahadeopally-area; caustic and acid chemicals, paper, card-board and newsprints near Hirakud; fertilizers in Jharsuguda area and Bihar stretch; tobacco in Sambalpur basin; petroleum by-products at Sonepur-Bausuni stretch; sugar mill at Baramba, drugs and pharmaceuticals, paper and pulp, cotton, etc. above Cuttack as well a tobacco, bycycle and its parts, metal tubes and conduits, etc. below Cuttack; and breweries and phosphate at Paradip are having some impacts.

Deep pools like, Dudhawa, Ravisankar sagar (Gangrel), Murumsilli, Sondur, Sikasar, Tandula, Gondli, Kharkhara, Hasdo Malpuri, Mohan, Pindhi, Dhamni, Parsada, Narayanpur, Markadi, Pahenda, Paiser, Devarghatta, Jaitpur, Chandrapur and Pasid as well as deep pool-like stretch between Mundali and Cuttack barrages, however, provide shelters to Mahanadi fishes against either draught condition, excessive flooding or pollution hazards. The river depth usually varies from 1 to 5 metres.

Weeds

Weed density of the upper stretch (1,739-21,739 g/m^2) often declines totally during monsoon. Six species *i.e., Hydrilla* sp., *Vallisneria* sp., *Ceratophyllum* sp., *Najas* sp., *Potamogeton* sp. and *Chara* sp. are very common whereas *Marsilea* sp., *Cyperus* sp. and *Polygonum* sp. occur occasionally. Hirakud reservoir has *Ceratophyllum* sp. *Najas* sp., *Hydrilla* sp., *Chara* sp., *Nitella* sp., *Vallisneria* sp. besides *Spirogyra* sp. which is also recorded in the speeding water current of the middle stretch. Freshwater region of the lower stretch has *Vallisneria* sp., *Crinum* sp., *Salvinia* sp., *Eichhornia* sp., *Brachiaria* sp., *Alternanthera* sp. *Crinum* sp., *Centella* sp., *Cynodon* sp., *Ipomoea* sp., *Marsilea* sp. and *Oriza* sp. @ 2-3 no./m^2 with several deep patches of *Vallisneria* sp. (>100 no./m^2) and *Eichhornia* sp. (5-15 no/m^2). Upper estuary has meagre abundance (0.1-0.2 no./m^2) of *Brachiaria* sp., *Centenella* sp.,*Colocasia* sp., *Coix* sp.,, *Sagitaria* sp., *Eichhornia* sp. and *Salvinia* sp. whereas lower estuary has *Oriza* sp., *Cynodon* sp., *Excoecaria* sp., *Acanthus* sp., *Phoenix* sp., etc.

Chitratala system has *Sachharum sp., typha sp., Asteriocanthus sp.,* like Alipingla stretch of the Devi river where *Nymphoea sp., Salvinia sp., Alternanthera sp., Bacopa sp., Centella sp., Coix sp., Cynodon sp., Ipomoea sp., Marsilea sp. Oriza sp. Najas sp.,* etc. also occur, indicating presence of *Lemna sp.* and *Pistia sp.* in the downstream. Thus, 34 weed species have been recorded from the stretch between Sasang and Paradip. Distributary Alanka has the maximum load of weed.

Insect fauna

Boulder prone upper stretch has abundance of 25 species of entomological fauna whereas only 11 and 20 species are sparingly present in the middle and the lower stretches. Common insects of the river are:*Nepa sp., Ranatra sp., Notonecta sp. Gerris sp., Plea sp., Anisops sp., Corixa sp., Belostoma sp., Laccotrephes sp., Lethocerus sp., Galastocoris sp., Caenis sp., Cloeon sp., Aphylla sp., Lestes sp., Gomphus sp., Hagenius sp. Anax sp., Agaria sp., Chaoborus sp., Simulium sp, Probezzia sp., Isogenus sp., Hydropsyche sp., Cordulia sp., Hyponeura sp., Cynigma sp., Dorocordulia sp., Enallagma sp.,Urothemis sp., Culex sp., Berossus sp., Cymigma sp., Nymphula sp.* and *Tabanus sp.,*

Periphyton

Ten out of 46 periphyton species of the upper stretch are ubiquitous. Remaining species comprise 15 bacillariophyceans, 4 desmids, 15 chlorophyceans and 2 myxophyceans in all seasons but monsoon. General abundances vary from 61 to 1803 u/cm^2 or 0.075 to 0.500 mm/cm^2. In the middle stretch basic algal matrix of *Oscillatoria sp.* and *Spirogyra sp.* harbours 17 periphyton species @ 256.7 u/cm^2 (average) *i.e.,* 83.6-515.5 cc/cm^2. Periphyton of the lower stretch comprises 12 bacillariophycean, 5 desmids, 21 chlorophycean, 7 myxophycean and 2 chrysophycean species, making pooled average densities of 71.30-484.35 u/cm^2 in various seasons.

When 13 species like, *Navicula sp., Fragillaria sp., Synedra sp., Gyrosigma sp., Diatoma sp., Nitzschia sp., Cymbella sp., Tabellaria sp., Pinnularia sp., Frustulia sp., Stauroneis sp., Melosira sp.* and *Surirella* sp. are available right from the origin to sea-mouth, the following species occur randomly in various stretches:-

Asterionella sp., Mastogloia sp., Meridion sp., Amphora sp., Rhopalodia sp., Cocconeis sp., Diploneis sp., Epithemia sp., Cyclotella sp., Gomphonema sp., Anomoeneis sp., Pleurosigma sp., Coscinodiscus sp., Rhizosolenia sp., Biddulphia sp., Centronella sp., among Bacillariophyceae; *Cosmarium sp., Staurustrum sp., Spirotonia sp., Desmidium sp., Gonatozygon sp., Penium sp., Closterium sp., Spondylosium sp.* among desmids; *Microspora sp., Tribonema sp., Treubaria sp., Oedogonium sp., Protococcus sp., Ulothrix sp., Uronema sp., Binuclearia sp., Draparnaldiopsis sp., Kircheneriella sp., Chaetophora sp., Hormidium sp., Bacicladia sp., Cladophora sp., Zygnema sp., Spirogyra sp. Volvox sp., Clamydomonas sp., Golenkinia sp., Coelestrum sp., Pediastrum sp. Trichischia sp., Ankistodesmus sp., Scenedesmus sp., Pithophora sp., Rhizoclonium sp., Actinastrum sp., Enteromorpha sp., Characiopsis sp.* and *Solenastrum sp.* among Chlorophyceae; *Oscillatoria* sp., *Anabaena sp., Phormidium sp., Lyngbya sp. Spirulina sp., Rivularia sp., Nostoc sp., Anacystis sp., Merismopedia* and *Gomphosphaeria sp.* among Myxophyceae; and *Epipyxis sp.* and *Synura sp.* among Chrysophycea. Aufwuch *i.e.*, Heptabenthos of course records mainly *Chromodora* sp. (nematoda) and *Thylacomonas* sp. (zooflagellata) in such periphyton matrix.

Plankton

Average plankton densities in various seasons are 57-137, 217-321 (Ghosh, 1994), 15-228 and 117-206 u/l at the upper stretch, Hirakud reservoir, the middle and the lower stretches respectively. Phytoplankton dominated in the upper (42.5-81.7%), the middle (48.8-100%) and the lower (49.1-99.7%) stretches in all seasons more or less. Dominant contributors changed from place to place and season to season. Important features of such dominance are as follows:-

Sites	***Dominated by***	***Season***
1. Sihawa	Protozans (50%)	Monsoon
2. Dhamtari	Rotifers (36.3%)	Monsoon
3. Rajim to Belsondha	Protozoans (33.3-35.5%)	Post-Monsoon
4. Durgapathi	Copepoda (100%)	Monsoon
5. Sambalpur	Copepoda (100%)	Monsoon
6. Kamalidihi (Kutri)	Copepoda (44.4%)	Monsoon
	Rotifera (55.6%)	Monsoon
7. Kokaloba	Copepoda (100%)	Monsoon
8. Kamaldihi	Copepoda (39.9%)	Pre-Monsoon
	Cladocera (21.6%)	Pre-Monsoon
9. Basupur	Copepoda (17.4-26.5%)	Pre-Monsoon
10. Teragaon	Copepoda (39.8%)	Pre-Monsoon
11. Teragaon	Copepoda (28.6%)	Monsoon
12. Barupur/Narayanpur to Marsaghai	Copepoda (18-23.5%)	Monsoon

Among phytoplankton, myxophyceans dominate at Rajim (40.9%), Chikhli (53.4%) and Tamdei (57.8%) during post-monsoon and at Tirtal- Taldanda (27.6-54.9%), Kujang-Paradip and Ostar-Teragaon (42.7-78%) in all seasons. Bacillariophyceans dominate at Jaigut (Sankhla) – Binka (41.9-84.8%) during monsoon; at Lahasara- Binka (41.9-57.8%), Tikarpara (40.8%) and Dhamo (71.8%) during post-monsoon; and at Jharpara (Kewatipalli) to Kurdi (mostly>50% & sometimes 100%) and Kakuria *i.e.,* Narasinghpur (45-51.6%) in all seasons. Chlorophycean dominance is recorded at Sasang to Cuttack (67.2-96.1%), Basupur/Narayanpur to Barpal (17.1-73.5%) and Devi-Alanka-Brahmani river systems (19.2-52.2%) in all seasons; at Sihawa to Sirpur (23.8-43.3%) and Jharpara to Kamaldihi (18.1-50.6%) in seasons other than monsoon; at Dhama to Binka (30.1-36.4%) during post-monsoon; at Sheorinarayan to Tamdei (23.4-46.7%) and Dhama (52.1%) during pre-monsoon; and at Belsondha (37.5%) during monsoon. Similary, desmid dominance is observed at Gajarajpur-Machgaon (15.7-41.7%) in all seasons; Basupur (15.3-20.9%) in seasons other than monsoon; at Sheorinarayan (29.2%) during post-monsoon; at Chikhli (14.1%) during pre-monsoon, and at Mahadeopalli to Surajgarh (14.3-33.4%) during monsoon.

Macrobenthos

Average macrobenthos densities are 474.6-1,170.1, 442.9-559.5, 1351.1-218.5 and 73.3-413.5 u/m^2 at the upper stretch, Hirakud reservoir, the middle and the lower stretches respectively. Maximum (100%) gastropod concentration is at Sihawa, Durgapalli, Sambalpur, Binka, Jharpara, Sonepur, Baudh, Kurdi and Kokaloba during monsoon; and Dhama, Sonepur, Kakuria, Marsaghai and Gajarajpur during post-monsoon. Peak concentration (100%) of Pelecypoda is observed at Paradip during post-monsoon when >40% concentration of bivalves is recorded at Sihawa during pre-monsoon and at Sirpur and Harbhanga during monsoon. Concentration of crustaceans is practically nil in the upper and the middle stretches while only 0.1-2.8% in the lower stretch during seasons other than post-monsoon. Slightly significant crustacean concentrations are noticed at Kujang, Paradip, Barpal, Ostar, Teragaon and Machgaon *i.e.,* 8-25.1% during pre-monsoon and 5.9-20.4% during monsoon seasons. Regarding entomological fauna, the upper stretch principally exhibits medium to high concentrations (*i.e.,* 26.7-59.1%), the middle stretch shows mainly poor concentrations (0-22%) like the lower stretch (0-22.5%), However, Patamundai centre in all seasons shows very high concentrations (59.6-100%) of insect fauna. Among annelidians, only oligochaetes appear between origin and Tirtal and then downwards from Taldanda there is gradual replacement by polychaetes. In the upper and the middle sretches, annelid concentrations are low (5.1-20%) whereas the same in the lower stretch is very low (0.1-4.6%) where freshwater regions exist and is very high (60-100%) where estuarine zones are encountered. Annelids disappear during monsoons from the upper and the middle stretches, remaining sparingly at the lower stretch alone. Benthic nematodes are detected mainly in the stretch between Binka and Kokaloba and at times even at 46.2-73.9% concentrations against usual poor representation of < 22.7%.

Benthic molluscs comprise *Amnicola sp., Assiminea sp., Bellamya spp., Campeloma sp., Cerethidea sp., Cyprea sp., Goniobasis sp., Gyraulus sp., Indoplanorbis sp., Littoridina sp., Littorina spp., Lymnaea spp., Melanoides sp., Murex sp., Nassarius spp., Nerita spp., Pila sp., Pleurocera sp., Pugilina sp., Tarebia sp., Telescopium sp., Thiara sp., Tryonia sp., Viviparus sp., Anadonta sp., Corbicula sp., Donax sp., Lamellidens sp., Ligumia sp., Masculium sp., Meretrix sp., Opalina sp., Perreysia sp., Pisidium sp., Siliqua sp.* and *Sphaerium sp.*

Cyclops sp., Harpacticus sp., Cypris sp., Ilyocypris sp., Gammerus sp., Chydorus sp., and *Mysis* sp. among crustaceans; *Chaoborus sp. Tendipes sp., Culex sp., Culicoides sp., Helius sp., Lumbricillus sp., Probezzia sp., Tabanus sp., Tripula sp., Leptocerus sp., Limnephilus sp., Anax sp., Aphylla sp., Argia sp., Cordulegaster sp., Progmophus sp., Isogenus sp., Elophila sp., Nymphula sp., Corixa sp., Laccotrephes sp., Caenis sp., Cloeon sp., Berossus sp., Eretes sp., Halochares sp.* and *Sialis sp.* among entomological fauna; *Chaetogaster sp., Lumbriculus sp; Nais sp., Stylaria sp., Tubifex sp., Diopetra sp.* and *Neries sp.* among annelids; and *Chromodora* sp. and *Microlaimus sp.* among helminths are also encountered in the benthos. Thus, among 78 macrobenthic species, 24, 35 and 63 species belong to the upper, the middle and the lower stretches respectively.

Primary productivity

Overall gross primary productivity values of the river vary from 327.97 to 575.37 mg C/m^3/day against net production of 60-73% of the gross values and average respiration rate of 156.35 mg C/m^3/day. The average gross primary productivities at the upper, the middle and the lower stretches are 824.75, 312.20 and 337.36 mg C/m^3/day respectively.

Physico-chemical parameters

Physico-chemical parameters of water and soil of the river are given in Table 1 . Water temperature shows wider range in the upper stretch. TDS and DOM increase in the lower estuary. Specific conductivity rises abruptly at Kujang, Paradip and Machgaon. Water transparency shows seasonal consistancy, recording maximum clearance even during the season of trubidity. Water pH is near neutral. D.O. has wider variations in other distributaries. Hardness greatly increases at Kujang and Paradip. Middle stretch is never free from free CO_2. SiO_2 increases towards downstream. Appreciable salinity is noticed in the Kujang-Paradip stretch only. Total alkalinity and

HCO_3 alkalinity remain more or less uniform in all stretches, but CO_3 alkalinity is higher in the upper stretch. Ca^{++} and Mg++ ions increase a little in the lower estuary whereas $F^{+++/++}$ ions are minimum in the middle stretch. Cl^- ion increases in the downstream when PO_4^{---} and NO_3^- reduce considerably there. Inorganic N is detected only in the downstream. Na^+ and K^+ ions increase in the downstream, but Zn^{++} and Mn^{++} ion contents maintain uniformity all throughout. Cu^+ ion is recorded only in the middle zone.

Soil is mostly sandy. Clay content increases in the downstream and silt content is the poorest in the middle stretch. Soil pH is near neutral. Specific conductance of the soil increases in the estuarine zones. Free-$CaCO_3$ percentage declines towards downstream. Organic C is a little higher in other distributaries than in the main. Available P and available N in the soil are low in the middle stretch.

Fisheries

Riverine catches of the upper stretch are directly landed at the fish markets where fish arrivals are 25-100 (av. 56.4), 12-90 (av. 29.4) and 20-115 (av. 44.8) Kg/day/market during post-monsoon, pre-monsoon and monsoon months respectively. Catfishes dominate (48%) followed by minnows (35%), IMC (15%) and miscellaneous (10%). As per data of 1985-91, the fish landings from Hirakud reservoir are 192.1 to 489.5 t/yr (Anon; 1992), comprising 45.2-56.2% catfishes, 10.8-16.3% catla, and 27.7-44.6% rohu, mrigal, common carp. Landings from the middle stretch vary from 34-250 (av. 106.7), 7-39 (av. 17.2) and 5-40 (av. 25.6) Kg/day/centre during post-monsoon, pre-monsoon and monsoon seasons respectively, consisting of 14.02-63.12% carp, 68.33-12.35% catfishes and 10-15% prawns. Average fish landings from the freshwater and the brackishwater zones of the lower stretch and from Patamundai are 86.22, 3,928.35 and 19.20 t/yr respectively. In the lower stretch, fish catches comprise 0.2-24.1% mullets, 5.7-31.3% threadfins, 2.7-36.3% perches, 0.1-51.7% clupeids, 2.9-24.4% catfishes, 1.2-28.5% sciaenids, 1.4 –40.7% prawns and 0.2-31.9% miscellaneous species.

As many as 253 species of fishes belonging to 73 families have been recorded from the river (List-1). Earlier-Hora (1940), Chauhan (1947), Menon (1951), David (1953) and Job *et al.* (1955) reported 102 species under 22 families from the freshwater region of the river between origin and Hirakud reservoir as indicated under superscript^1 in the List 1. Then they recorded only one specimen each of *Mystus gulio* and *Batasio tegona.* Thirty four species with * marks though recorded earlier are not encountered recently. Thus, the upper stretch presently reccords 68 listed species of the past and 17 newly added species under 22 families again, but excluding Amblycepidae, Anguillidae, Belontiidae of the past record and including Aplocheilidae, Synbranchidae and Cichlidae of the recent time. Recently recorded species (17 nos) are marked with superscript[2] in the List 1. So, now available species from the Hirakud reservoir are 40 under families as indicated under superscript[3] (Verghese *et. al.*, 1981; Anon., 1992) in the List[1] for Mahanadi fishes. Among prawns *M. lamarrei* and *M. malcolmsonii* occur in Hirakud reservoir and above. Middle stretch between the reservoir and Narsinghpur contains 30 commercially important fish species belonging to 11 families as indicated under the superscript[4] in List 1.

Among prawns *M. malcolmsonii, M. lamarrei* and *M. rosenbergii* are present in the middle stretch whereas in the lower stretch in addition to these species *M. dyanum, M. rude, M. monoceras, M. brevicornis, L. styliferus, P. indicus, P. monodon, P. carinatus* and *A. indicus* are also present. Freshwater zone of the lower stretch possesses 76 fish species under 22 families. Among these, 24 species barring *T. tor, T. putitora, T. khudree, C. chela, C. carpio* and *S. childreni* of the middle stretch; 39 species of the upper stretch listed under superscript[5] in List 1; and other 13 species have been encountered from the zone. Thus, all the 76 species have been included under superscripts[5&6] of the List[1].

Since past, the lower zone of the lower stretch that includes estuaries has recorded so far 160 species belonging to 65 families. These species have been indicated under the superscript[7] of the List 1. As many as 31 species as indicated under superscript[8] of the List[1] have not been recorded in the past whereas 97 species have been exclusively recorded from the estuarine zone as indicated under superscript[9] of the List 1. Of course, quite a few species of the estuaries belong to marine sources and some fishes that occurred earlier have not been noticed in the recent years. In a sense, fisheries of the Mahanadi have under gone changes through years, but the ecosystem remains congenial for prawn fisheries in a continuing manner.

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Physico-chemical parameters of water and soil of the Mahanadi river system
(Average values for diffrent seasons)

Parameters	Upper Stretch	Middle Stretch	Freshwater zone of lower Stretch	Estuarine zone of lower Stretch	Other distributaries
Water Phase					
Temperature (^{0}C)	19-36	22-32.5	24.8-34.5	24.9-34.9	24.3^0-35.3^0
TDS (mg/l)	39.0-116.1	60.0-104.6	50.7-109.4	54.1-2006.8 ⊕	54.6-920.1
DOM (mg/l)	1.81-3.93	1.22-2.33	Trace-448.90	Trace-395.10	Trace-245.20
Sp. Conductivity (µmhos)	41.2-377.0 #	105.6-236.0	92.0-227.0	109.0-16.000.0▲	100.0-621.0 ●
Transparancy (cm)	Clear-60*	Clear-182	8-137	Clear-72	Clear-195
pH	7.50-8.70	7.30-8.25	7.45-8.66	7.68-8.98	6.52-8.63
D.O. (mg.l)	5.35-9.72	4.55-9.21	6.50-9.00	6.00-8.80	1.10-10.00
Hardness (ppm as $CaCO_3$)	35.60-177.60	43.20-105.16	33.80-75.50	38.50-1685.0 ⊗	35.50-352.50
Free CO_2 (ppm)	nil-2.21	0.18-1.96	nil-1.94	nil-1.83	nil-6.10
SiO_2 (ppm)	4.78-7.15	4.75-7.81	11.59-15.33	2.39-19.20	9.38-18.53
Salinity (ppt)	-	-	0.0364-0.0404	0.0350-2.1432◆	0.360-0.8510
Total alkalinity (ppm)	58.91-106.74	52.84-85.25	45.40-90.20	44.50-112.50	47.00-99.25
CO_3^{--} (ppm)	0.46-24.42	nil-2.35	nil-9.60	nil-15.00	nil-8.00
HCO_3^- (ppm)	58.45-86.26	52.84-82.90	45.40-80.60	44.50-97.50	47.00-95.75
Ca^{++} (mg/l)	15.20-26.24	11.52-25.90	10.72-20.40	10.92-307.02	12.33-28.66
Mg^{++} (mg/l)	6.34-11.09	4.37-7.56	2.59-5.64	2.64-979.04	2.98-34.87
$Fe^{+++/++}$ (mg/l)	0.183-4.853	0.229-1.156	0.415-6.006	0.605-3.211	0.510-3.585
Cl^-(ppm)	35.15-37.96	23.91-30.92	3.60-5.80	3.00-1170.67	3.50-56.50 ■
PO_4^{---} (ppm)	0.0030-0.0055	0.0024-0.0043	Trace-0.0176	Trace-0.0180	Trace-0.0140
NO_3^- (ppm)	0.016-0.058	0.011-0.068	Trace-0.156	Trace-0.125	Trace-0.400
Inorganic N (ppm)	-	-	0.014-0.366	0.140-0.340	0.050-0.480
Na^+ (ppm)	-	39.00	5.22-38.86	4.30-403.93 ▼	4.15-166.90
K^+ (ppm)	-	45.64	2.62-46.32	3.10-528.55	2.60-41.60
Zn^+ (ppm)	-	0.0433	0.0144-0.0710	0.0100-0.0623	0.0090-0.0655
Mn^+ (ppm)	-	0.0723	0.0224-0.3300	0.1110-0.1965	0.0500-0.7745
Cu^+ (ppm)	-	0.075	-	-	-
Soil Phase					
Sand (%)	89.82-96.25	97.25-98.47	75.90-90.40	74.42-95.75	73.00-94.50
Silt (%)	2.08-6.45	1.08-1.87	3.60-9.40	3.00-9.83	2.25-10.00
Clay (%)	1.67-3.73	0.45-0.88	6.00-14.70	1.25-15.75	3.25-17.00
pH	7.05-7.41	6.84-7.16	7.45-8.04	6.76-7.87	6.66-7.92
Sp. Conductivity (µmhos)	186.58-244.46	65.07-131.06	78.40-227.60	58.00-887.50 ★	58.00-438.00
Free $CaCO_3$(%)	2.14-2.57	1.57-2.15	0.58-1.48	0.23-1.20	0.31-1. 03
Organic C (%)	0.412-0.596	0.443-0.514	0.291-0.508	0.195-0.475	0.170-1.080
Available P (mg/100g)	0.12-3.40	0.75-1.84	0.85-3.41	0.70-3.72	0.23-3.75
Available N (mg/100g)	0.790-12.440	5.481-6.931	7.840-13.240	6.233-12.300	5.600-19.500

⊕	13,868.2 (at Kujang) & 23,540.2 (at Paradip) mg/l
#	9.2 µmhos at Chapajhor
▲	27,960 (at Kujang) & 47,460 (at Paradip) µmhos
●	3,487 µmhos at Machgaon
*	250 cm at Tamdei
⊗	3,430 (at Kujang) & 46,160 (at Paradip) ppm
◆	18.9820 (at Kujang) & 33.7380 (at Paradip) ppt
■	900 ppm at Machgaon
▼	4,323.2 (at Kujang) & 8,368.0 (at Paradip) ppm
★	4,120 (at Kujang) & 5,850 (at Paradip) µmhos

List 1 : List of fishes available from the Mahanadi river system

Sl.no.	Family & Fish Species
	CYPRINIDAE
1.	*Catla catla*[1,3,4,6,7]
2.	*Cirrhina mrigala*[1,3,4,6,7]
3.	*C. reba*[1,3,4,6,7]
4.	*Labeo bata*[1,3,4,6,7]
5.	*L. calbasu*[1,3,4,6,7]
6.	*L. dyocheilus*[1]
7.	*L. fimbriatus*[1,3,5]
8.	*L. gonius*[1,3,5]
9.	*L. rohita*[1,3,4,6,7]
10.	*L. boga*[1]*
11.	*L. dero*[1]*
12.	*L. boggut*[1,5] *
13.	*L. ariza*[1,5] *
14.	*L. pangusia*[2]
15.	*Cyprinus carpio*[4]
16.	*Osteobrama vigorsii*[1,5]
17.	*O. cotio*[1,3,5]
18.	*O. cotio cunma*[1]* .
19.	*Puntius amphibius*[1,5]
20.	*P. gelius*[1]
21.	*P. sarana*[1,3,4,6,7]
22.	*P. sophore*[1]
23.	*P. ticto*[1,3,5]
24.	*P. stigma*[6,7]
25.	*P. chola*[1]
26.	*P. conchonius*[1]
27.	*P. guganio*[1,5] *
28.	*P. tetrarupegus*[1]*
29.	*P. dorsalis*[1,5]
30.	*P. phutunio*[2]
31.	*Tor tor*[2,4]
32.	*T. putitora*[4]
33.	*T. khudree*[1,4]*
34.	*T.mosalmahanadicus*[1,3,5]
35.	*Selmastoma phulo*[2]
36.	*S. bacaila*[1,5,7]
37.	*Chela laubuca*[1]
38.	*C. gora*[1]*
39.	*C. dadidurjori*[2]
40.	*C. fasciatus*[2]
41.	*C. unitrahi*[1,5] *
42.	*C. chela*[4]
43.	*C. clupiodes*[1]*
44.	*C. boopis*[1,5] *
45.	*Amblypharyngodon mola*[1,3,5,6,7]
46.	*Aspidorparia morar*[1]
47.	*Barilius barila*[1,5]
48.	*B. barna*[1]
49.	*B. bendelisis*[1]
50.	*B. verga*[1] *
51.	*Branchydanio rario*[1,5]
52.	*Danio devario*[1]
53.	*D. malabarica*[2]
54.	*D. aequipinnatus*[1]*
55.	*D. crysops*[1]*
56.	*Securicula gora*[2]
57.	*Esomus danricus*[1,3,5,7]
58.	*Perluciosoma daniconius*[3,6,7,8]
59.	*Rasbera danricus*[1]
60.	*Oreichthys cosuatus*[1] *
61.	*Crossocheilus latius*[1] *
62.	*Garra mullya*[1,5] *
63.	*G. gotyla*[1]
	NOTOPTERIDAE
64.	*Notopterus notopterus*[1,3,4,6,7]
65.	*N. chitala*[1,3,4,6]
	CLUPEIDAE
66.	*Gudusia chapra*[1,3,4,6]
67.	*Goniolosa manmina*[1,7]
68.	*Ilisha(=Pellona)motius*[1,4,6,7]*
69.	*Ilisha elongata*[7,9]
70.	*I. filigera*[7,9]
71.	*Tennualosa ilisha*[7,9]
72.	*T. toli*[7,9]
73.	*Anadontostoma chakunda*[7,9]
74.	*Nematolosa nasus*[7,9]
75.	*Herangula punctata*[7,9]
	BALITORIDAE
76.	*Nemacheilus botia*[1]
77.	*N. bota aureus*[1] *
78.	*N. denisoni (=N. dayi)*[1] *
	COBATIDAE
79.	*Lepidocephalichthys guntea*[1]
	SCHILBEIDAE
80.	*Alia coilia*[1,5]
81.	*Clupisoma garua*[1,5,7,8]
82.	*Eutropichithys vacha*[1,3,4,6]
83.	*Silonia silondia*[1,3,6]
84.	*S. childreni*[4]
85.	*Pseudoeutropius atherinoides*[1]
86.	*Pangasius pangasius*[1,3,5,7] *
	BAGRIDAE
87.	*Aorichthys aor*[1,3,4,6,7]
88.	*A. seenghala*[1,3,4,6,7]
89.	*Mystus bleekeri*[1]
90.	*M. cavasius*[1,3,4,6]
91.	*M. tengra*[1,3,5]
92.	*M. vittatus*[1,5,7]
93.	*M. gulio*[1,7] *
94.	*Rita crysea*[1,3,4,6]
95.	*Batasio tegond*[1]
	SILURIDAE
96.	*Ompak pabo*[2,4,6]
97.	*O. pabda*[2,3,6]
98.	*O. bimaculatus*[1,3,5,7]
99.	*Wallago attu*[1,3,4,6,7]
	SISORIDAE
100.	*Bagarius bagarius*[1,3,4,6]
101.	*Gagata gagata*[1,5] *
102.	*G. cenia*[6,7]
103.	*G. basio*[7,8]
104.	*Glyptothorax lonah*[1,5] *
105	*Hara hara*[1]
106.	*Nagra viridescens*[2,6]
	ARIIDAE
107.	*Tachysurus jella*[7,9]
108.	*T. sona*[7,9]
109.	*T. dussumieri*[7,9]
110.	*T. subrastratus*[7,9]
111.	*T. crossocheilus*[7,9]
112.	*T. macronotacanthus*[7,9]
113.	*T. venosus*[7,9]
114.	*Osteogeneiosus militaris*[7,9]

Sl.no.	Family & Fish Species
	CICHLIDAE
115.	*Oreochromis mossambicus*[2]
116.	*Etroplus suratensis*[7,9]
	ANABANTIDAE
117.	*Anabus testudineus*[2,6]
118.	*Coilsa lalia*[2]
119.	*C. fasciatus*[1,5] *
	CLARIDAE
120.	*Clarias batrachus*[1,3,5]
	HETEROPNEUSTIDAE
121.	*Heteropneustes fossilis*[1,3,5]
	ENGRAULIDAE
122.	*Setipinna phasa*[4,6]
123.	*S. taty*[7,9]
124.	*Anchoviella (=Stolephorus)tri*[7,9]
125.	*Coilia ramcarati*[7,9]
126.	*C. borneensis*[7,9]
127.	*C. dussumieri*[7,8]
128.	*C. reynaldi*[7,9]
129.	*Thryssocles mystax*[7,9]
130.	*T. kammalensis*[7,9]
131.	*T. hamiltoni*[7,9]
132.	*T. purava*[7,9]
133.	*T. rambhae*[7,9]
	BELONIDAE
134.	*Xenentodon cancila*[1,5]
135.	*Strongylura strongylura*[6,7]
136.	*Tylosurus leiurus*[7,9]
	AMBLYCEPIDAE
137.	*Amblyceps mangois*[1] *
	MUGILIDAE
138.	*Rhinomugil corsula*[1,5,7]
139.	*Liza parsia*[4,6,7]
140.	*L. carinata*[7,9]
141.	*L. macrolepis*[7,9]
142.	*L. tade*[7,9]
143.	*Osteomugil cunnesius*[7,9]
144.	*Mugil cephalus*[7,9]
145.	*M. jordoni*[7,9]
146.	*M. belanak*[7,9]
	AMBASSIDAE
147.	*Chanda nama*[1,5,7]
148.	*Pseudambansis ranga*[1,5]
149.	*Ambassis baculis*[1] *
150.	*A. commersoni*[6,7]
	SCIAENIDAE
151.	*Johnius coitor*[2,3,6,7]
152.	*J. dussimieri*[1,3] *
153.	*J. sina*[7,9]
154.	*Sciaena glaucus*[7,9]
155.	*S. cuja*[7,9]
156.	*Pseudosciaena soldado*[7,9]
157.	*Sciaenoides brunneus*[7,9]
158.	*Otolithoides biauritus*[7,9]
	NANDIDAE
159.	*Nandus nandus*[1,3,5]
160.	*Badis badis*[1] *
	APLOCHEILIDAE
161.	*Aplocheilus punchax*[2,7,8]
	GOBIIDAE
162.	*Glossogobius giuris*[1,3,5,7]
163.	*Awaous stamineus*[1] *
164.	*Boleopthalmus boddaerti*[7,9]
165.	*Apocryptus lanceolatus*[7,9]
166.	*Gobius personatus*[7,9]
	CHANNIDAE
167.	*Ophiocephalus gachua*[1,3,5,7,8]
168.	*Channa punctatus*[1,3,4,6,7]
169.	*C. striatus*[1,3,5,7,8]
170.	*C. marulius*[1,4,6,7,8]
	CHANIDAE
171.	*Chanos chanos*[7,9]
	MASTACEMBALIDAE
172.	*Mastacembelus armatus*[1,3,4,6]
173.	*M. panchalus*[1]
174.	*Macrognathus aculeatus*[1,5]
	ANGUILLIDAE
175.	*Anguilla bengalensis*[1,7,8] *
	SYNBRANCHIDAE
176.	*Monopterus(=Amphipnuous) cuchia*[2,6,7,8]
	OPHICHTHIDAE
177.	*Ophichthys microcephalus*[6,7]
	PLOTOSIDAE
178.	*Plotosus canius*[6,7]
	CHIROCENTRIDAE
179.	*Chirocentrus dorab*[7,9]
	MEGALOPIDAE
180.	*Megalops cyprinoides*[7,9]
	MORINGUIDAE
181.	*Moringua raitaborua*[7,9]
	MURAENIDAE
182.	*Muraena punctata*[7,9]
183.	*M. meleagris*[7,9]
	HARPODONTIDAE
184.	*Harpodon nehereus*[7,8]
	EXOCOETIDAE
185.	*Hemiramphus limbatus*[7,9]
186.	*H. cantori*[7,9]
187.	*H. marginatus*[7,9]
	PLATYCEPHALIDAE
188.	*Platycephalus indicus*[7,9]
	LATIDAE
189.	*Lates calcarifer*[7,9]

Sl.no.	Family & Fish Species
	SERRINIDAE
190.	*Epinaphalus diacanthus*[7,8]
191.	*E. malabaricus*[7,9]
	THERAPONIDAE
192.	*Therapon jarbua*[7,8]
	SILLIGINIDAE
193.	*Sillago sihama*[7,9]
194.	*Sillaginopsis panijus*[7,9]
	ECHENEIDAE
195.	*Echeneis naucrates*[7,9]
	CARANGIDAE
196.	*Caranx sexfasciatus*[7,9]
197.	*C. gallus*[7,8]
198.	*C. para*[7,8]
199.	*Scomberoides commersonius*[7,8]
200.	*S. lysan*[7,9]
	LACTARIIDAE
201.	*Caranx malabaricus*[7,8]
	MENIDAE
202.	*Mene maculata*[7,8]
	LEIOGNATHIDAE
203.	*Leiognathus equala*[7,9]
204.	*L. fasciatus*[7,9]
205.	*L. brivirostris*[7,9]
206.	*Secutor insidiator*[7,9]
	LUTJANIDAE
207.	*Lutjanus johni*[7,9]
	GERREIDAE
208.	*Gerres filamentosus*[7,9]
209.	*G. abbreviata*[7,8]
210.	*G. lucidus*[7,9]
211.	*Gerremorpha setifer*[7,9]
	LOBOTIDAE
212.	*Datnoides quadrifasciatus*[7,9]
213.	*Lobotes surinamensis*[7,9]
	SPARIDAE
214.	*Mylio(=Sparus)berda*[7,9]
	EPHIPPIDAE
215.	*Drepane punctata*[7,9]
216.	*Platax pinnatus*[7,9]
	SCATOPHAGIDAE
217.	*Scatophagus argus*[7,9]
	SPHYRAENIDAE
218.	*Sphyraena acutipinnis*[7,8]
219.	*S. lewini*[7,8]
220.	*S. jella*[7]
221.	*S. obtusa*[7,9]
	POLYNEMIDAE
222.	*Polydactylus sextaris*[7,8]
223.	*P. indicus*[7,9]
224.	*Polynemus paradiseus*[7,9]
225.	*P. heptadactylus*[7,8]
226.	*Elutheronema tetradactylum*[7,9]
	GOBIOIDAE
227.	*Odontamblyopus rubicondus*[7,9]
228.	*Brachyamblyopus brachysoma*[7,8]
	KURTIDAE
229.	*Kurtus indicus*[7,8]
	TRICHIURIDAE
230.	*Trichiurus savala*[7,9]
	STOMATEIDAE
231.	*Pampus argenteus*[7,9]
232.	*P. chinensis*[7,9]
233.	*Parastromateus niger*[7,8]
	BOTHIDAE
234.	*Pseudorhambus arsius*[7,8]
	CYNOGLOSSIDAE
235.	*Cynoglossus lingua*[7,9]
	TRIACANTHIDAE
236.	*Pseudotriacanthus strigilifer*[7,8]
237.	*Triacnathus brevirostris*[7,9]
	TETRAODONTIDAE
238.	*Tetraodon cutcutia*[7,9]
	SOLEIDAE
239.	*Solea ovata*[7,9]
240.	*Syneptura orientalis*[7,9]
241.	*Plagusia marmorata*[7,9]
	SCOMBRIDAE
242.	*Cybium guttatum*[7,9]
	ELOPIDAE
243.	*Elops saurus*[7,9]
	ORYZIATIDAE
244.	*Orizias melastigma*[7,9]
	SYNGNATHIDAE
245.	*Syngnathus cyanospilus*[7,9]
	POMADASYIDAE
246.	*Pomadasys hasta*[7,9]
247.	*Gaterin cinctus*[7,9]
	TOXOTIDAE
248.	*Toxotes chatareus*[7,9]
	TRYPAUCHIDAE
249.	*Trypauchen vagina*[7,9]
	CHARCHARIDAE
250.	*Scoliodon sorrakowah*[7,8]
	ORECTOLOBIDAE
251.	*Chiloscyllium griseum*[7,8]
	TRYGONIDAE
252.	*Trygon zugei*[7,9]
	RHINOBATIDAE
253.	*Rhinobatos obtusus*[7,9]

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Fish Stock Assessment in Indian Rivers
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RIVER GODAVARI – ENVIRONMENT AND FISHERIES

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Physiography

River Godavari, the largest of peninsular rivers, takes its origin in Deolali hills in Western Ghats near Nasik in Maharashtra. In its 1465 km long course, the river traverses through the States of Maharashtra and Andhra Pradesh and opens into Bay of Bengal near Kakinada (Fig. 1). The catchment of the river extends to 312812 km^2, 48.6% of it falls in Maharashtra, 23.8% in Andhra Pradesh, 20.7% in Madhya Pradesh and the rest in Orissa and Karnataka. It includes densely forested high rain fall zones of Western and Eastern Ghats and intensely cultivated dry regions of Deccan peninsula with moderate to low rain fall. More than 90% of the annual run off in the catchment occurs between May and October under the impact of southwest monsoon. The river is swift flowing, descends from 1524 m (msl) at its origin to 17 m at the deltaic stretch flowing through a substratum of gneissic rock forming numerous riffles and pools in its course. The river is generally confined to within the banks. The floodplain lakes, characteristic of Ganga-Brahmaputra systems, are absent.

The river course has been divided into an upper, middle and lower stretches and 5 to 8 centres have been covered for the study in each stretch. Its course in Maharashtra constitute the upper stretch and the middle and lower stretches fall in Andhra Pradesh . The river runs about 693 km in Maharashtra and has been utilized to a large extent for irrigation and domestic purposes. There are two reservoirs on the main stream (Gangapur 2230 ha, Nathsagar 35000 ha), two barrages and twelve weirs in this stretch. Purna, Pravara and Kadwa are the important tributaries joining in Maharashtra.

From Maharashtra the river enteres into Andhra Pradesh where the major tributaries; the Pranahita, the Indravati, the Manjira, the Maner and the Kadam join in the middle stretch. Deep rocky or silty pools locally called 'Madugulu' are found at frequent intervals in the middle stretch. These deep pools give shelter to fish during dry months. One big pool of about 5 km long known as 'Lanjan Madugu' is situated close to Manthani town. A large reservoir (Sriramsagar 45,3000 ha) is situated in the middle stretch.

In the lower stretch there are two old anicuts, one at Dummagudem and another at Dhawaleswaram, 189 km downstream. Recently the Dhawaleswaram anicut has been replaced by a barrage. The stretch of the river between the two anicuts serve for navigation. For about 45 km the river pierces through the Eastern Ghats flowing through a narrow deep gorge, known as the Papi hills, where the width of the river is narrow (90 m) and deep (50-60 m). Emerging from the gorge the river spreads over the deltaic area, where it widens to a maximum of 8 km at Dhawaleswaram barrage. After Dhawaleswaram the river divides into a northern distributary called the Gowthami Godavari and a southern one, the Vasista Godavari. Gowthami joins the Bay of Bengal 19 km below Yanam. Vasista further divides into Vainateyam and the main Vasista before joining the sea. Between the two main distributaries lies the rich fertile delta region the 'Konaseema'.

Soil and water quality and primary production

Soil and water quality parameters and primary production are given in Table 1. Soil texture was sandy-clay with predominance of sand throughout the course of the river. Clay content was significant in deep pools, around anicuts and estuarine regions. PH was in alkaline range 7.6-8.1 with no significant variation within the stretches. Organic carbon varied in the range 0.15-0.52%, 0.05-0.45%, 0.03-1.08% and 0.4-1.12% respectively in the upper, middle lower and estuarine stretches. Deep pools (*Lanjanmadugu),* dam and anicut areas (Pravarasangam, Parnasala and Rajahmundry) and estuarine zones (Yanam and Narsapur) recorded relatively higher values. Available phosphorus and available nitrogen were very low, the former ranged between 0.23 and 1.02 mg/100 g and the latter between 1.1 and 27.3 mg/100 g. Higher values were recorded around cities (Rajahmundry, Narsapur, Kopargaon and Nasik) where sewage and municipal wastes are discharged into the river. Free $CaCO_3$ indicated higher values in the upper stretch (3.6-7.9%) than the rest of the river 0.7-5.3%).

Mean water temperature fluctuated in a narrow range 27.2-30.0°C. Transparency showed wide variation, in middle (6-200 cm) and lower (6-152 cm) stretches. pH was in the alkaline range throughout the river course (7.4-8.2) with significant increase during pre-monsoon followed by a decrease in monsoon. Total alkalinity was mainly due to bicarbonates and it was in the range 98-191 ppm with distinctly higher values in middle stretch, probably due to inputs from the tributaries. In some deep pools it reached beyond 200 ppm in summer. Specific conductivity and TDS reflected alkalinity except in the estuarine zone where the ionic concentration was extremely high due to sea water mixing. DO values were generally high (6.4-9.8 ppm). Calcium ranged between 18.4 and 34.7 ppm and Magnisium between 6.8 and 18.0 ppm in the freshwater zone, with higher values in the middle stretch. In the estuarine zone Ca and Mg values were extremely high, the former ranged between 119 and 374 ppm and the latter between 332 and 450 ppm. Chloride content in the freshwater zone was in the range 17 to 38 ppm, except at Kopargaon (upper stretch) where it recorded higher values in the range 40-99 ppm indicating the stressed conditions.

Nitrate nitrogen was recorded in the range 21 to 55 µg/l and phosphate in the range 60-18 µg/l. Centres receiving sewage and municipal wastes as in Kopargaon, Nasik Rajahmundry and Nanded showed relatively higher values of essential nutrients. Silicates were in the range 8-18 mg/l in the riverine zone, upper stretch recording higher values.

Average gross production (GP) values for the upper, middle and lower stretches were 124, 44 and 107 mg C/m^3/h respectively indicating that the middle stretch is less productive compared to other stretches. The higher production in upper stretch may be due to stagnant water conditions in several parts of this stretch due to weirs and barrages. The GP in the upper stretch showed wide variation ranging between 47 mg to to 291 mg C/m^3/h with Kopargaon and Pravarasangam showing significantly higher rates. This could be due to the pool like conditions prevailing at these centres and sugar factory effluents at Kopargaon. The net production (NP) as well as community respiration (CR) rates also exhibited similar trend. In the middle stretch GP exhibited limited variation and ranged from 23 mg to 69 mg C/m^3/h the NP and CR also showed identical trends to that of GP. The lower stretch showed higher rates of GP in the range 50 to 202 mg C/m^3/h. Estuarine regions were more productive. Like GP, NP and CR also showed wide variations.

Pollution scenario

Rapid urbanization coupled with industrialisation have generated organic and inorganic pollutants which finally find their way into the riverine ecosystem causing environmental degradation. River Godavari is no exception to this process. The main source of pollutants in the river are effluents of paper board factory at Bhadrachalam, paper mills at Rajahmundry and Yanam, Rayon factory at Eturunagaram and Sugar factory at Kopargaon. The sewage and municipal wastes are also discharged from the cities and towns, especially at Narsapur, Rajahmundry, Nanded and Nasik. The effluents from the paper mills appear to have no adverse effect at present on aquatic life. The effluents of Bhadrachalam paper board are being lifted from the river bed and used as fertilizer to dryland crops on the banks of the river. The average BOD and COD values were in the range 0.2-1.5 mg/l and 4.0-42.0 mg/l respectively. Higher values were observed during pre-monsoon. Only two centres, Kopargaon (Upper stretch) and Rajahmundry (lower stretch) showed signs of pollution in pre-monsoon in respect of BOD and COD.

Ambient water in the upper stretch showed relatively higher concentration of heavy metals such as Zn, Cu, Cd and Pb (Table 2). Cd in general is not in detectable concentration in water. Pb Showed higher levels in the river course except at some centres in middle stretch. In the sediment, all heavy metals recorded higher levels. Higher concentration of Zn and Cu was recorded at Nanded while Paithan showed highest Pb in the sediments. In fish flesh except Pb all the metals are within the permissable limits. However, the concentration of Pb in the fish flesh is slightly higher than the permissible level.

BIOTIC COMMUNITIES

Plankton

Abundance of plankton in different centres along with other communities is depicted in Table 3. Plankton concentration in general was poor in the main river. However, deep pools (Lanjanmadugu), centres around cities receiving sewage and industrial effluents (Kopargaon, Nanded, Rajahmundry and Bhadrachalam) showed relatively richer plankton. Lanjanmadugu showed exceptionally rich plankton in post-monsoon season. Monsoon recorded poor densities in all centres while post- and pre-monsoon had relatively higher concentration due to higher nutrient levels and stagnant conditions.

Phytoplankton showed overwhelming presence in the riverine zone, especially in the upper and middle stretches. Chlorophyceae, bacillariophyceae, myxophyceae and dinophyceae represented phytoplankton. Chlorophyceae was recorded in all centres with particular dominance at Kopargaon, Nanded, Bhadrachalam and Rajahmundry. Bacillariophyceae also occurred in most of the centres with dominant presence at *Lanjanmadugu*. Myxophyceae was also significant in this centre. Dinophyceae was encountered at 2 centres in the river and estuarine centres. Presence of green algae at all centres in all the periods is indicative of freshness of the environment.

Rotifera, cladocera and copepoda with their nauplii represented zooplankton. These groups were represented only at few centres. A total of 31 genera of phytoplankton and 14 of zooplankton were recorded from river Godavari. Chlorophyceae was represented by 12 genera, Bacillariophyceae by 15, Copepoda by 7 and Cladocera by 3.

Bottom macrofauna

Macrobenthic fauna were recorded in the range 261 to 782, 252 to 2631 and 26 to 2465 organisms/m^2 respectively in the upper, middle and lower stretches (Table 3). Centres with rich fauna were Dharmapuri and Manthani in the middle stretch, Polavaram and Rajahmundry in the lower riverine stretch and Yanam in the estuarine zone. Molluscs occurred predominantly in most of the centres. Dipteran larvae were prevalent in upper stretch especially at Kopargaon and Pravarasangam. On the whole molluscs accounted for 75.26%, dipteran larvae 23.35% and rest others. Common forms encountered were *Bellamya bengalensis, Thiara tuberculata, Brotia costula, Pila globosa, P. virens, Lymnaea accuminata, Melania striatella, Lamellidens scutum, L. marginalis* and *Corbicula peninsularis.*

Periphyton

Upper stretch recorded highest periphytic colonisation (23260 units/cm^2) followed by middle (3926 u/m2) and lower stretches (2223 u/m^2). Centres with rich periphytic deposits were Kopargaon, Nasik, Nanded, Lanjanmadugu and Polavaram. Bacillariophyceae was in general predominant in periphyton at all the centres. It is interesting to note that chlorophyceae including desmids were encountered mainly in the upper stretch. A total of 31 genera were recorded in periphyton contributed by bacillariophyceae (26), chlorophyceae (4) and desmid(1) (desmid). Important forms were *Spirogyra, Ulothrix, Synedra, Fragilaria, Gyrosigma, Navicula, Gomphonema* and *Stauroneis.*

Species diversity (H) values were high (3.1-3.8) in centres with stagnant conditions (Lanjanmadugu, Parnasala), receiving sewage and factory effluents (Rajahmundry, Polavaram, Eturunagaram) and at pilgrim site (Kotipalli).

Aquatic plants and associated fauna and flora

Macrophytes were recorded in post and pre-monsoon seasons mainly confining to stagnent pools and around islands. Higher densities were recorded in the upper stretch. Common plants were *Hydrilla verticillata, Potamogeton spiralis, Ceratophyllum demersum. Typha elephantina, Najas sp., Eichchornia crassipes, Pistia sp. and Spirodela sp..* A variety of fauna and flora such as *Nitzschia, Navicula, Gomphonema, Pinnularia* and *Amphora (*diatoms), *Viviparus bengalensis, Melania striatella, Indoplanorbis, Corbicula peninsularis* (molluscs), *Ranatra Corixa, Belostoma* (insects), may-fly nymphs (insect larvae), nematodes and oligochaetes were found associated with macrophytes.

FISHERY

Craft and gear

In Maharashtra fishing is free in Godavari except in certain specified areas. Licencing system is prevailing in A. P. upto Dhawaleswaram barrage. Below Dhawaleswaram barrage it is free fishing in Gowthami and Vasista. Lanjanmadugu (middle stretch) and the Nandur Madhyameswar barrage (Nasik Dist.) have been declared as sanctuaries for crocodiles and birds respectively. Effort is generally low in upper and middle stretches due to poor catches. It is highly concentrated in estuaries and around barrages (Rajahmundry and Dummagudem). The craft and gear used in Godavari vary in different stretches as per the local conditions of the river. Plank-built boat is the main craft in the lower stretch and thermocole raft in the middle and upper stretches.

Gillnets, seines, cast-nets and bag-nets are mainly employed in river Godavari. The type of gear operated is mainly determined by the local conditions and target species. Drift gill net are mainly used in the Gowthami and Vasista branches for exploiting hilsa during flood season. Set gillnets (25-60 mm mesh bar) are operated throughout the river course exploiting carps and catfishes. The seines are *Alivivala* (large seine), *Jaruguvala* (shore seine) and *Lanjavala* (small seine), the last one is being used on large scale in lower and middle stretches for exploiting prawns. *Alivivala* and *Jaruguvala* which were predominant during 1960's have come down in recent years. Castnet is the most commonly used net throughout the river course. Almost every fisherman own a cast net. It is employed to exploit prawns and small fishes. Few units with bigger mesh (17-20 cm) are being operated around anicuts (Dhawaleswaram & Dummagudem) to exploit large sized catla and rohu. Hook and line are mostly operated between Rajahmundry and Polavaram exploiting prawns. Individual fishermen employed 2 to 3 units. Bag-nets are popular in the estuarine regions exploiting estuarine prawns and fishes.

Catch and catch composition

Fishing activity in Maharashtra stretch is mainly confined to weirs, barrages and reservoirs. Fishery is very poor in the river and catches consisted of miscellaneous fishes. Only in certain specified areas major carps and catfishes are caught. The prawn (*M. malcolmsonii)* and the mahseer (*T. khudree*) used to occur at Nanded before the construction of Sriramsagar at Pochampad in A. P. Now these species do not occur here. It is significant to note the occurrance of poecilids, *Gambusia affinis* and *Poecila (Lebistes) reticulata* in the isolated pools of the river.

Fishing in the middle stretch is done mainly during October to May. Catches consisted of carps (*L. fimbriatus, L. rohita* and *C. mrigala)*, catfishes (*M. seenghala, M. aor, S. childreni* and *W. attu)* and miscellaneous species. Fishermen are part time operators and the catches are of subsistence level. Prawns (*M. malcolmsonii)* were caught at Manthani and Eturunagaram by migrating fishermen.

Fishing in the lower stretch between Dhawaleswaram and Dummagudem anicuts and above is intense and mainly conducted by groups of migratory fishermen during October to May/June. Fishermen from down stream centres migrate with families and make temporary settlements on the sandy islands of the river. They return to their homes with the onset of monsoon. This is the most productive fresh water part of the river.

The fishery at present is dominated by prawns, miscellaneous small fishes and hilsa. Fishing for prawns is done from January to June using seines, cast-nets traps and lines. Fish is caught as a by-catch in seines and cast-nets and consisted of small sized fishes (*Osterobrama spp., Oxygaster spp., Puntius spp. N. notopterus* etc.) and juveniles of large carps (*L. fimbriatus)*, catfishes (*M. seenghala, S. Childreni)*. Fishing for hilsa is done mainly in Gowthami and Vasista distributaries. Though 2 km stretch below Dhawaleswaram barrage is a banned area, fishermen operated set gill nets close to the barrage blocking migratory route of hilsa. Dummagudem used to be a good fishing ground for *L. fimbriatus*, but the fish is no longer available here. *Benduvala* (Drag gillnet), specific to *L. fimbriatus,* popular earlier at Dummagudem is no more in operation.

In the estuarine zone penaeid prawns, mullets, hilsa, perches scienids, clupeids and catfishes accounted for the commercial catch. The bag-nets are being used to exploit prawns with fishes occurring as by-catch.

Changes in the catch and catch structure with time

The 189 km stretch between Dhawaleswaram and Dummagudem anicuts has been investigated by the Krishna-Godavari unit of CIFRI, Rajahmundry, during 1963-69. In the seven years period, the total catch declined by 34% from 330 to 218 t inspite of increase in effort. Species which showed sharp decline were *L. fimbriatus* (67%), *M. seenghala* (71%), *P. pangasius* (90%), *S. childreni* (61%) and *B. bagarius* (almost disappeared). Prawns and hilsa fluctuated around a mean characteristic of migratory species. The decline in the catch and catch per unit of effort of indigenous carps and catfishes and reduction of their mean size in the catch led to the conclusion that these stocks were overfished.

In recent years fishing is mainly concentrated on hilsa and prawns. *L. fimbriatus* appear to have reduced further in this stretch. It is no more a target species at Dummagudem as in sixties. *L. rohita* which was insignificant during earlier years have greatly improved. Large catfishes such as *M. seenghala, S. childreni* and *P. pangasius* occurred mostly by their juveniles. The juvenile fishery of *P. pangasius* at Dhawaleswaram anicut has become insignificant after the replacement of anicut with barrage.

Problem of overfishing

The studies of Krishna-Godavari unit during 1963-69 have brought out clearly that the fish stocks of Godavari, especially *L. fimbriatus, M. seenghala* and *S. childreni* have been overfished. Though remedial measures were suggested by CIFRI to recover the stocks, no efforts have been made in that direction in the last 30 years. A reduction in the effort by all gears by 25% has been suggested but the total effort has gone up by several fold during the last 30 years. Different fish species reacted differently to the increased effort. The indigenous carp *L. fimbriatus* and large catfishes *(M. seenghala, S. childreni)* which together contributed about 70 t in 1963 reduced to insignificance. Hilsa being a migratory species, quantum of flood flows decided its abundance. The juveniles of hilsa were not affected by the seining as their nursery grounds lie below the barrage. The miscellaneous species, which formed the major portion of the catch have not been affected by intensive seining because of their short life span, prolonged breeding, higher survival (absence of predation) and high relative growth.

Conservation of fish stocks *vis a vis* socio-economic status of fishers

The limited resource of riverine sector is being subjected to intensive exploitation by traditional fishermen and other communities with disastrous consequences to the biodiversity of the system. Legislations limiting effort, declaring closed seasons and sanctuaries have not made any impact. Enforcing legislations in riverine fisheries is a daunting tasks for obvious reasons. Without the willing co-operation of fishermen, implementation of various conservative measures are extremely difficult. This is possible only with the improvement of socio-economic conditions of fishermen community.

- The major fishermen community, at present migrating with families in search of good fishing, should be helped to settle permanently at one place and weaned away from river fishing by providing alternate avenues such as leasing the water bodies to them for reasonably long periods and developing fisheries in tanks and reservoirs.

Envisaged changes in the fish stocks with the construction of proposed dams

River Godavari is the least utilised river in Peninsular India. Several projects in A. P. on this river are on the anvil. One of the projects is a dam at Polavaram, 50 km upstream of Dhawaleswaram barrage. The 120 ft high proposed dam, if comes up, will have far reaching effects on the fishery of Godavari. The prawns, *M. malcolomsoni* which at present migrates as far as Manthani in the middle stretch of Godavari and also into the tributaries in Madhya Pradesh and Maharashtra, will vanish above the Polavaram dam. The species has already vanished above Sriramsagar.

The anadromous hilsa, hitherto migrates upto Dummagudem anicut during years of good flood discharge would be restricted upto Polavaram, a loss of 150 km of migratory route. The vulnerability of the fish would also increase.

Major carps which at present breed and use Dhawaleswaram barrage area as nursery ground may be affected as the breeding grounds would be restricted to the 50 km stretch. If that happens, the recruitment of carp juveniles into Kolleru lake and irrigation canals of Godavari will be affected.

However, the reservoir to be formed above Polavaram may act as a sanctuary for some carps and catfishes which have become rare at present due to overfishing. The species which are likely to flourish in the future impoundment are: *L. fimbriatus, M. seenghala, M. aor, S. childreni* and *P. pangasius.* Besides several minor carps and catfishes would also flourish.

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Table 1. Soil & water quality and primary production of river Godavari

	Upper stretch	Middle stretch	Lower stretch	Estuaries
Soil				
pH	7.7-8.0	7.6-8.0	7.7-7.9	7.9-8.1
Org. C %	0.15-0.52	0.05-0.45	0.03-1.08	0.4-1.12
Avail N (mg/100 g)	6.3-15.0	2.2-14.5	1.1-27.3	14.2-22.4
Avail-P (mg/100g)	0.45-1.02	0.3-0.69	0.23-0.39	0.42-0.81
Free Ca CO3 (%)	3.6-6.3	1.3-5.3	1.1-4.1	1.0-3.4
Water				
pH	7.4-8.0	7.7-8.2	7.8-8.2	7.8
Transparency (cm)	10-180	6-200	6-152	10-120
DO (mg/l)	6.8-8.0	6.6-7.6	8.1-9.8	8.5-8.9
Total alkalinity (mg/l)	98-120	125-191	96-123	104-125
Sp.conductivity (m mho/cm)	415-575	373-583	267-343	Very high
Ca^{++} (mg/l)	22.4-28.0	27.0-34.7	18.4-23.4	119-374
Mg^{++} (mg/l)	6.8-12.6	9.3-15.3	7.1-11.0	331-450
NO_3-N(µg/l)	26-54	21-32	31-34	31-33
PO_4 – P (µg/l)	74-180	60-83	68-100	62-65
SiO_2-Si (mg/l)	13-18	11-14	8-11	2-8
Chloride (mg/l)	22.9-69.6	28.0-38.0	17.0-36.0	Very high
Primary production				
G. P. (mgC/m^3/h)	47-291	29-69	50-121	115-202
Com. Resp. (mgC/m^3/h)	28-150	8-31	13-28	26-42
N. P. (mgC/m^3/h)	19-140	12-40	53-93	88-161

Table 2. Heavy metals (mg/l) in river Godavari

Centres	**Zn**	**Cu**	**Cd**	**Pb**
Sediment				
Upper stretch	135.5-198.4	53.32-117.9	1.6-3.3	Tr-98.5
Middle stretch	62.9-142.9	39.0-63.1	1.4-4.2	Tr-0.5
Lower stretch	63.3-157.7	35.7-69.2	0.3-1.1	Tr-1.0
Estuaries	95.4-104.7	48.0-86.1	0.7-1.0	Tr-2.0
Water				
Upper stretch	0.01-0.07	Tr-0.03	ND	Tr-0.05
Middle stretch	0.01-0.04	Tr-0.01	ND	ND
Lower stretch	0.02-0.16	Tr-0.05	ND	Tr-0.01
Estuaries	0.03-0.06	0.01-0.03	ND	Tr-0.03
Fish (Lower stretch)				
Tissue	12.9-19.2	2.2-3.8	Tr-0.1	7.5-12.5
Gill	22.5-45.2	4.6-6.9	Tr-0.4	13.8-19.2

Table 3. Biotic communities of river Godavari

	Upper stretch	**Middle stretch**	**Lower stretch**	**Estuaries**
Plankton (u/l)				
Myxophyceae	6	130	4	1
Chlorophyceae	106	107	32	5
Bacillariophyceae	25	917	14	10
Dinophyceae	-	1	-	2
Rotifera	1	2	-	6
Cladocera	-	1	-	1
Copepoda	1	6	2	31
Periphyton (u/cm^2)				
Myxophyceae	19	-	-	-
Chlorophyceae	3735	-	-	420
Bacillariophyceae	12979	4596	-	420
Desmidaceae	434	-	2694	870
Bottom biota (No/m^2)	504	1018	667	1187
Diptera (%)	63.7	-	-	-
Gastropoda (%)	27.2	82.3	79.6	49.5
Bivalve (%)	5.1	17.5	19.7	50.0
Others (%)	4.0	0.2	0.7	0.5

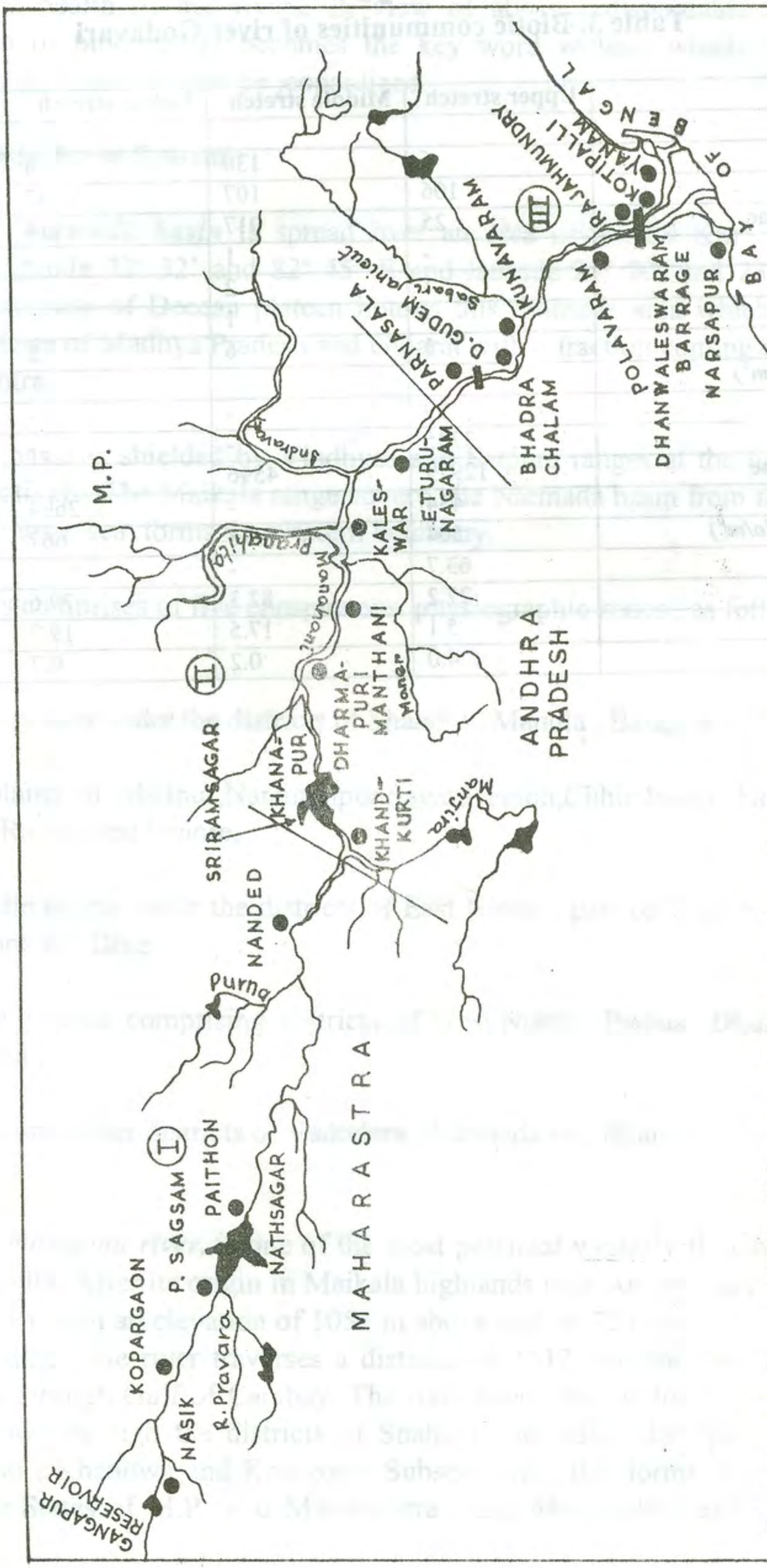

FIG. 1 - RIVER GODAVARI, ● SAMPLING CENTRES

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THE RIVER GANGA – ENVIRONMENT AND FISHERY

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Introduction

The holy river Ganga in the Indo-Gangetic delta is the fourth largest river in the world. The Ganga and its various tributaries constitute the largest river system in India. It is a perennial river taking its origin from two headwaters at a height of about 6,000 m in Garhwal Himalaya (30° 55' N, 79° 7' E) the Gangotri and the Alakananda. It enters the plains at Haridwar. Then it flows southeast and meanders through the Indo-Gangetic plains in the states of Uttar Pradesh, Bihar and West Bengal, finally leading to Bay of Bengal. The Ganga is 2,525 km long and its basin drains about one fourth of the countries area. At present the surface water availability in the Ganga basin is 446 million acre feet (MAF). The annual flow of freshwater in the Ganga is estimated at 142.6 billion m^3 resulting from the melting of snow in Himalayas during the spring and hot months and monsoon rains during June to September. The river Ganga has an annual runoff of 493 Km^3 and carries 616 X 10^6 tonnes of suspended solids to the Hooghly estuary (Qasim *et al.,* 1988). The Ganga, considered as the second major river of the world in terms of suspended load is the main contributor of sediments to the Bengal Fan which is the largest deep sea fan in the world (Lisitzen, 1972).

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

Study area

Many major and minor tributaries join the river in its entire course. The Ganga river basin is well developed because of communication, industrialisation and urbanisation. Accordingly, both the banks of the entire river course are thickly populated covering Uttar Pradesh, Bihar and West Bengal states. Along the course from Gangotri to Sagar, there are 29 major cities, more than 70 towns and thousands of villages along with 132 large industrial units (86 in U. P., 3 in Bihar and 43 in West Bengal). Each of the cities, Haridwar, Farukhabad, Mirzapur and Bhagalpur expell 16 MLD of sewage effluent while Allahabad and Varanasi discharge 100 MLD of sewage into the river Ganga. At Patna the river receives 154 MLD sewage and at Kanpur 275 MLD. The total volume of waste water discharge over the 92 Km length of river Hooghly works out to be 1,135.6 MLD.

The exploratory survey was carried out at 43 selected centres (Fig. 1). Of these nine centres (Tehri, Deoprayag, Rishikesh, Haridwar, Bijnar, Garhmukteswar, Anupsahar, Farukhabad and Kannauj) are situated in the upper stretch; eight centres (*viz.,* Kanpur, Dalmau, Allahabad, Mirzapur, Varanasi, Ghazipur, Buxar and Patna) are in the middle stretch, eight centres (Sultanpur, Barauni, Munger, Bhagalpur, Kahalgaon, Manickchawk Farakka and Dhulian) are in the lower stretch; two centres (Berhampur and Katwah) are on Bhagirathi river; while rest sixteen centres are situated in the Hooghly-Matlah estuarine system. Among these centres, Nabadwip, Krishnanagar, Tribeni, Titagarh, Dakshineshwar, Uluberia, Roychawk, Kakdwip and Frazerganj are on the main Hooghly channel. Haldia, Bhagabatpur and Moipeeth centres are located in the Haldia, Saptamukhi and Thakuran estuaries respectively. Canning and Jharkhali cnetres are on Matlah estuary, while Bagna and Hasnabad centres are on Roymangal and Ichamati estuaries respectively.

Soil and physico-chemical characteristics

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

The water pH observed was generally true reflection of the soil of the area. The present value of water pH of upper, middle and lower stretches of the Ganga ranged from 7.3 to 8.6; 7.0 to 8.8 and 7.3 to 8.8 respectively. These values were almost similar to observed values of pH in 1960 and 1984. This is so because the Ganga water has a high buffering capacity. Almost similar trend was observed in case of Hooghly estuary. Appreciable improvement in dissolved oxygen content of water was noticed in the middle (3.4 to 11.9 mg/l) and lower (4.8 to 9.6 mg/l) stretches of the river system as compared to 1985-90 period. Considerable increased value of dissolved oxygen (6.0 to 8.2 mg/l) was also observed in the estuarine system. As regards phosphate content, the entire upper stretch from Tehri to Kannauj had very low values (trace to 0.31 mg/l). In the middle stretch, besides Kanpur, Allahabad and Varanasi, the value of phosphate was found to be trace to 0.4 mg/l during summer months. Higher values were recorded at Kanpur (2.5 mg/l), Allahabad (0.8 mg/l) and Varanasi (1.05 mg/l) in the present study as compared to values in 1960 and 1985-90 periods. In the lower stretch, phosphate value was observed between 0.045 and 0.130 mg/l. In the estuarine system the fluctuation of plankton value was from 0.020 to 0.160 mg/l.

While during 1953-55 period, the plankton content was very low. After commissioning of Farakka barrage the phosphate content has shown some improvement. The present values of nitrate (tr. to 0.86 mg/l) in the river water as compared to earlier values indicate the improved condition of water quality as well as lower degree of pollution. Increased level of nitrate (0.05 to 0.54 mg/l) was also recorded from the estuarine stretch barring Tribeni centre in the present study as compared to very low values ranging from 0.03 to 0.12 mg recorded during 1985-90. Silicate content was moderately high (4.5 to 9.4 mg/l) in the riverine stretch between Tehri and Katwah. In the freshwater zone of Hooghly estuary, it was also moderately high (5.4 to 12.4 mg/l). However, it was poor (0.5 to 5.9 mg/l) in the the marine zone of the estuary. A critical analysis of the earlier works during pre Farakka barrage period and post barrage period revealed that additional discharge of freshwater through Farakka barrage had changed the ecology of the system significantly by reducing salinity and converting the earlier gradient zone into almost freshwater one. The present study indicates that the salinity incursion of the Hooghly estuary was observed upto Diamond Harbour (near Roychowk) situated 60 km from the mouth of estuary. Physico-chemical characteristics of water of the river Ganga during past and present are depicted in Figs 1(a) & (b).

Plankton

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

The present study on plankton indicates that the density has considerably decreased in the middle and lower freshwater stretches of the Ganga as compared to 1960 but the composition of plankton has not changed much. The dominant groups of phytoplankton was found to be Bacillariophyceae, Chlorophyceae and Cyanophyceae, while Rotifers and Copepods dominated the zooplankton population throughout the year. The maximum density of plankton was 80, 29; 45, 613; 25,125; 7,685; 765; 1,444 and 2,390 units/l at Kanpur, Allahabad, Varanasi, Buxar, Patna, Bhagalpur and Rajmahal respectively, while it was decreased to 3,649; 2,400; 434; 765; 365; 675 and 936 units/l in the respective centres during 1995-96. But the abundance of pollution indicator species such as *Ankistrodesmus, Coelastrum, Pediastrum, Scenadesmus, Actinastrum* (under Chlorophyceae), *Cymbella, Cyclotella, Fragilaria* (under Bacillariophyceae) and *Anabaena, Lyngbya, Merismopodia*, *Spirulina* (under

Cyanophyceae) was less in the lotic waters of Ganga during the present study which indicates better water quality. On the contrary, there is in general an increase in plankton density in the estuarine stretch in the present study as compared to pre-Farakka barrage period. This is positive effect of increased flushing of freshwater into the estuary after commission of Farakka barrage.

Macrozoobenthos

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

Fishery

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

On the contrary, many fold increase in fish yield has been observed in the estuarine zone during post-Farakka barrage period. The average annual prawn and fish yield from the estuary increased from 9,481.5 tonnes during pre-Farakka barrage period (1966-67 to 1974-75) to 33,341 tons during post barrage period (1984-85 to 1994-95) and further to 42,703.2 tonnes during 1995-97. With the commission of Farakka barrage and higher flow of freshwater in the estuary, the general habitat for hilsa in the estuary has improved for its migration, breeding and growth, resulting in its increased landing from 1,457.1 tonnes in 1975 to 5,045.8 tonnes in 1995-97. The species now spawns in the entire freshwater zone of the estuary. Certain freshwater fishes and prawn species *viz., Eutropiichthys vacha, Clupisoma garma, Rita rita, Wallago attu, Aorichthys seenghala, A. aor, C. catla, Labeo bata* etc. have made their appearance in the entire upper estuarine zone upto Uluberia and these species were not reported prior to pre-Farakka barrage period upto this extent. The freshwater zone of the Hooghly estuary is a potential source of hilsa and prawn (particularly *M. rosenbergii)* seed. Like freshwater zone of the estuary, lower marine zone is also considered as very potential for brackishwater prawn and fish seed resources. The seed of giant freshwater *M. rosenbergii* was also available in certain stretches of Sunderbans and gradient zone of Hooghly estuary where salinity range varied from 5 to 12 ppt during May to July. The present study also revels that the gradual decline in catch per unit of effort in winter bagnet fishery of lower estuary which contributes over 70% of the total estuarine catch indicated over exploitation and is thus alarming.

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

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

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

Na= Data not available

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

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

\Parameter	Bhagalpur		Rajmahal (Manichak		Hooghly Estuary								
	1960 (i)	1995-96	1960 (i)	1995-96	*Uluberia*			Roychowk (Diamond Harbour)			Kakdwip		
					1953-55 (ii)	1985-90 (iii)	1995-96	1953-55 (ii)	1985-90 (iii)	1995-96	1953-55 (ii)	1985-90 (iii)	1995-96
Water temp (°C)	18.5-31.5	18.5-31.0	18.5-31.5	21.0-30.0	20.0-33.0	Na	19.9-28.5	18.0-33.0	Na	20.5-30.0	20.0-32.0	Na	22.0-30.4
pH	7.5-8.2	7.5-8.8	7.6-8.1	7.3-7.6	8.0	8.10-8.25	7.4-7.9	8.2	7.9-8.3	7.6-8.0	7.9	8.0-8.3	7.7-8.3
D.O. (mg/l)	5.2-9.1	6.2-8.2	5.0-8.9	5.9-8.8	2.3-4.6	4.8-7.3	5.8-7.2	2.1-6.8	6.9-7.6	6.4-7.9	3.4-5.1	6.1-7.8	5.9-8.2
Free CO2 (mg/l)	1.4-10.0	Nil-2.0	Nil-6.5	Nil-5.0	Na	Na	4.0-12.0	Na	Na	3.5-8.0	Na	Na	2.5-4.0
Phosphate (mg/l)	.06-12	.06-09	.07-.12	.06-.11	Tr	0.12-.28	.05-0.10	Tr	.08-.16	.06-0.08	Tr	.04-.29	.07-.08
Nitrate (mg/l)	.09-.15	.05-.09	.08-.14	.05-.12	Na	.03-.12	.08-.54	Na	.03-.06	.05-.37	Na	.01-.04	.08-.24
Silicate (mg/l)	3.5-12.3	7.8-8.6	4.0-12.6	7.6-8.3	.09-.36	Na	6.4-7.2	.05-.20	Na	5.4-8.2	.04-.18	Na	4.8-5.9
Salinity (g/l)	-	-	-	-	0.5-14.0	Na	.04-.06	1.0-23.0	Na	.07-.39	2.0-31.0	Na	1.58-19.10

Na= Data not available. Source: (i) Pahwa & Mehrotra (1966). (ii) Bose (1956). (iii) Anon, 1997. A cost benefit analysis of the Ganga Action Plan – a draft report

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

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

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

Bhagalpur						
Fish	*1958-59 to 1965-66*	*(%)*	*1973-74 to 1983-84*	*(%)*	*1996-97*	*(%)*
M. Carps	16.60	18.2	10.06	10.8	7.31	20.4
Catfish	19.43	21.4	25.21	27.1	14.91	41.7
Hilsa	4.08	4.5	0.87	0.9	0.38	1.1
Misc.	50.82	55.9	56.96	61.2	13.20	36.8
Total	90.95		93.90		35.70	

Sourc: Annual Reports, CIFRI, Barrackpore, West Bengal

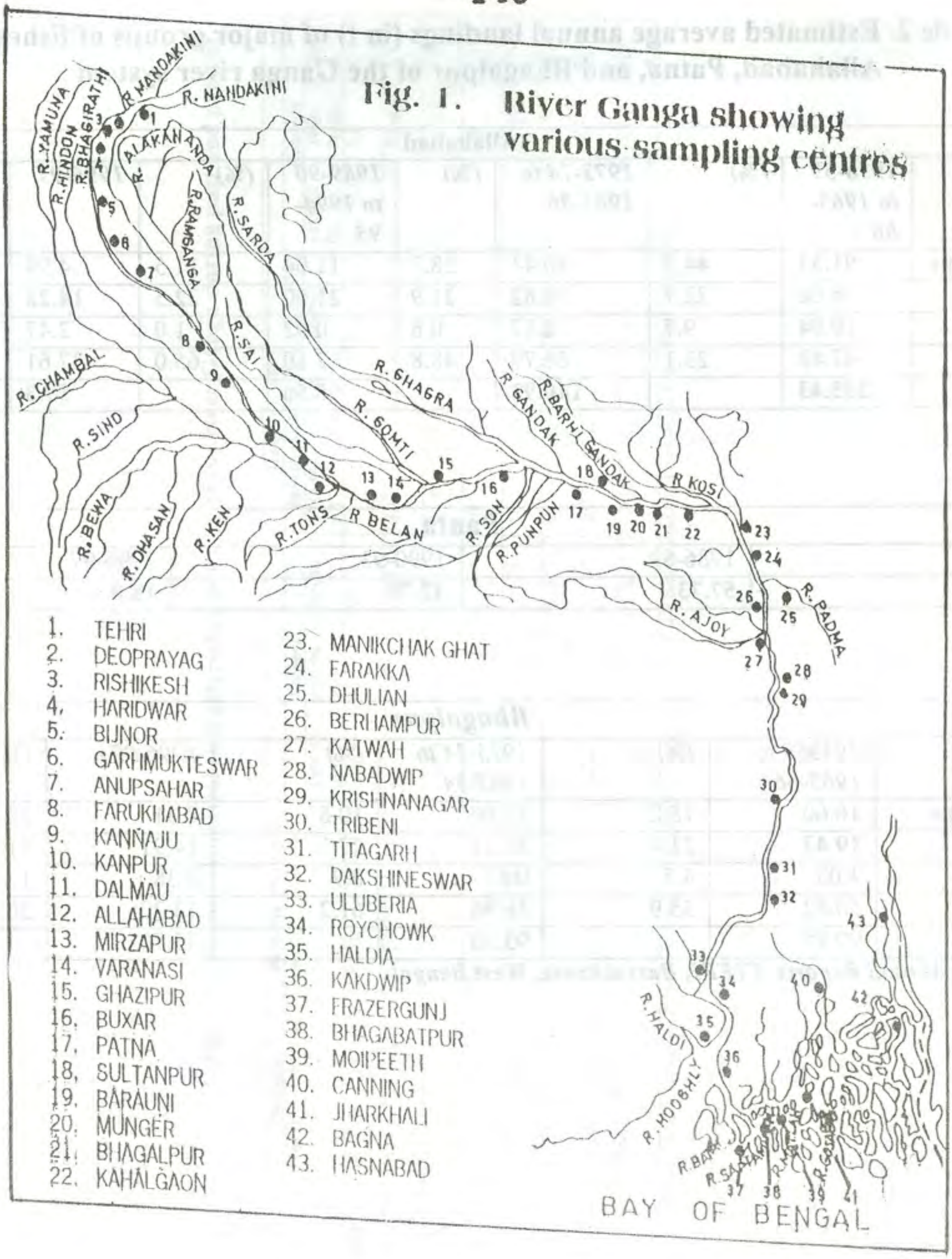

Fig. 1. River Ganga showing various sampling centres

1. TEHRI
2. DEOPRAYAG
3. RISHIKESH
4. HARIDWAR
5. BIJNOR
6. GARHMUKTESWAR
7. ANUPSAHAR
8. FARUKHABAD
9. KANNAJU
10. KANPUR
11. DALMAU
12. ALLAHABAD
13. MIRZAPUR
14. VARANASI
15. GHAZIPUR
16. BUXAR
17. PATNA
18. SULTANPUR
19. BARAUNI
20. MUNGER
21. BHAGALPUR
22. KAHALGAON
23. MANIKCHAK GHAT
24. FARAKKA
25. DHULIAN
26. BERHAMPUR
27. KATWAH
28. NABADWIP
29. KRISHNANAGAR
30. TRIBENI
31. TITAGARH
32. DAKSHINESWAR
33. ULUBERIA
34. ROYCHOWK
35. HALDIA
36. KAKDWIP
37. FRAZERGUNJ
38. BHAGABATPUR
39. MOIPEETH
40. CANNING
41. JHARKHALI
42. BAGNA
43. HASNABAD

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RIVER NARMADA - ENVIRONMENT & FISHERY

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Preamble

The rivers , from time immemorial , have been associated with the endless crusade towards perpetuality of human colonization by catering to their multifarious needs on this biosphere and as a matter of fact , cradles of civilization viz. Sindhu , Niles , Tigris have flourished on the banks of the rivers. The above crusade started initially with the fulfillment of day to day chores followed by , as a means of transport. In consonance with the changing global demand scenario, these natural water resources have experienced the agony of damming , channelisation etc. for hydel power generation and their regulated use in agricultural , industrial and domestic sectors. This enormous exercise involved with the resource development processes led to comprehensive aberrations in their pristine nature and these anthropogenic invasions have been manifested in the form of environmental degradation of these invaluable natural assets. The western region of our country has undergone a sea change owing to comparatively accelerated resource development process leading to extensive variations in the land-use pattern of this region. Many more " Golden Corridors" like one in Gujarat will come into existence in due course of time and exert impact on our riverine environment.

The rivers are our national heritage. As such ,it becomes dogmatic to have an access to their environmental status including fishery since this is a *sine qua non* for identifying the impacts released by negative developmental processes adversely affecting the health of our rivers. In view of above indispensable criterion, the conservation of biodiversity becomes the key word without which, even the very existence of the mankind may be jeopardized.

The Narmada River System

The Narmada basin is spread over an area of 98,769 Km^2 and is located between longitude 72° 32' and 82° 45' E and latitude 21° 20' and 23° 45' N. The northern extremity of Deccan plateau houses this drainage area which falls mostly under the States of Madhya Pradesh and Gujarat with a fraction coming under the State of Maharashtra.

The basin is shielded by Vindhyas and Satpura ranges at the north and south sides respectively. The Maikala range covers the Narmada basin from the eastern side while the Arabian sea forms the western boundary.

The basin is comprises of five conspicuous physiographic zones , as follows :

(i) upper hilly area under the districts of Shahdol , Mandla , Balaghat and Seoni,

(ii) upper plains of Jabalpur,Narsinghpur,Sagar,Damoh,Chhindwara , Hoshangabad Betul , Raisen and Sehore,

(iii) middle plains under the districts of East Nimar , part of West Nimar , Dewas , Indore and Dhar

(iv) lower hilly area comprising districts of West Nimar , Jhabua , Dhulia and Vadodara ,

(v) lower plains under districts of Vadodara , Narmada and Bharuch.

The Narmada river, is one of the most potential westerly flowing rivers of the peninsular India. After its origin in Maikala highlands near Amarkantak under Shahdol districts (M.P) from an elevation of 1051 m above msl, at 22 o 40' N latitude and 81 o 45' E longitude , the river traverses a distance of 1312 Km and culminates into the Arabian sea through Gulf of Cambay. The river negotiates a distance of 1077 Km in M.P and flows through the districts of Shahdol , Mandla , Jabalpur, Narsinghpur , Hoshangabad , Khandwa and Khargone. Subsequently, this forms common boundary between the States of M.P and Maharashtra ; and Maharashtra and Gujarat for the following 35 and 39 Km respectively. The Narmada river in its last leg of 161 Km exclusively flows through the districts of Vadodara , Narmada and Bharuch in the State of Gujarat.

There are 41 major tributaries of river Narmada ; 22 of these join the river Narmada at the south bank (21 in M.P and 01 in Gujarat) and the rest meet at the north bank. Besides the tributaries , there are 50 rivulets and 17 waterpools.

Ecology of River Narmada

The information offered here to define the ecological attributes, have been generated by CIFRI, while exploring the river from its origin to Gulf of Cambay.

Water Quality of River Narmada

Transparency regime of the river from its origin to its culmination varied from stretch to stretch and even within the stretch. This is attributed to stretch specific conditions. The stretch falling under tidal ingress reflected lower transparency values. Water reaction was by and large alkaline reflecting congenial conditions for biological production. However, acidic pH (6.6) was recorded at may be due to the city sewage confluencing at this point.

Dissolved oxygen content was recorded within the congenial limit. By and large, the higher values were associated with the hilly terrain with cascades and swift currents. However, drastically low dissolved Oxygen was evident at the outfall site of Gelatin Factory effluents where high free CO_2 (26.0 mg l^{-1}) was also recorded. Similarly , the other hot spot created by the effluents of Security Paper Mill at Dongarwara was observed to be associated with low dissolved oxygen (3.0 mg l^{-1}) and high freeCO_2 (23 mg l^{-1}). Free CO_2 was by and large absent through out the whole expanse except at Piparia to Harsud stretch particularly at Sandia site where it was recorded during the period coinciding with the Makar Sankranti bath.

Free Ammonia, an indicator of aquatic pollution was in traces or absent through out the whole expanse except at Dongarwara(0.05 mg l^{-1}), the confluence site of effluents of Security Paper Mill, Hoshangabad ; and Handia (0.08 mg l^{-1}) which may be caused by the decomposition of offerings of the devotees. However, this stressed condition was localised and the recovery ensued at the below out fall expanse

Total alkalinity varied from stretch to stretch (30.0 to 184.0 mg 1-1) and is a reflection of high biological productivity. However, exceptionally high total alkalinity (3020.0 mg l^{-1}) was recorded at the outfall point of Gelatin Factory effluents. Total alkalinity of the river was observed to be affected by the contribution of tributaries as evident at Gondagaon where important tributaries namely Gomati and Ganjal confluence with river Narmada.

Specific conductivity and total dissolved solids discerned parallel trend and the recorded values of these two attributes may be considered as a reflection of high biological productivity. However, exceptionally high specific conductivity coupled with very high total dissolved solids was recorded a ,the confluence site of Gelatin Factory effluents.

Pertaining to the status of the nutrients in the river, the availability of phosphate and nitrate was by and large moderate to poor. The lower tidal ingress stretch , however reflected comparatively higher nitrate content occasionally. However, the silicate content of the river , which is considered essential for the proliferation of diatoms and dinophycean taxa was considerably high.

Chlorinity and salinity levels of the river indicated that the stretches beyond tidal ingress zone were fresh waters and free from organic pollutional load. The tidal ingress expanse reflected salinity levels varying between fresh and brackish/ marine water.

The heavy metals - Zn , Mn , and Fe were recorded within permissible limits which may be considered as an indication that the river Narmada is not much imperiled by the effluents containing heavy metals.

Sediments Quality of River Narmada

Assessment of sediments quality of river Narmada revealed that the soil reaction was by and large towards alkaline side and this varied from stretch to stretch (7.63 to 9.12). However, acidic pH was recorded at Amarkantak site receiving the city sewage. High alkaline pH above 8.5 is considered detrimental for phosphate availability which has been reflected at the tidal ingress expanse.

Specific conductivity was considerably high at the expanse near the Gulf of Cambay.The soil, by and large was deficient in total nitrogen and available phosphate while free Calcium carbonate content of the sediment was high because of the river flowing through marble rocks. Organic carbon was fairly available.

The soil texture was dominated by sand which varied from 43.0 to 99.0% for the river as whole.

Biotic Communites of River Narmada.

Net-Plankton

Quantitative and qualitative assessment of the planktonic assemblage of river Narmada revealed that the phytoplankton was the mainstay of the planktonic abundance. Qualitative texture varied from stretch to stretch. Bacillariophyceae was by and large the most conspicuous floral component

The important taxa representing the bacillariophycean population were *Melosira sp., Asterionella sp.,Gyrosigma sp., Navicula radiosa., N. cuspidata, Cyclotella sp., Diatoma vulgare, Cymbella sp., Synedra ulna, Nitzschia sp.,Stauroneis sp. and Surirella sp.* while *Microcystis sp., Oscillatoria sp., Spirulina sp., Anabaena sp. and Merismopedia sp.* represented the blue-greens assemblage. The chlorophycean community was shared by *Pediastrum simplex,Eudorina sp.,Spirogyra sp., Mougeotia sp., Hormidium sp.,* and the desmids *Closterium sp.,and Cosmarium sp..* *Ceratium hirundinella* was the lone taxum representing the dinophycean assemblage of river Narmada.

The zooplankton community of the river Narmada was mainly comprised of Rotifera and Copepoda..The important taxa contributing to the rotiferan population were *Asplanchna sp., Lepadella ovalis , Filinia sp., Polyarthra sp., Brachionus sp.,* and *Trichocerca sp.* The copepod population was shared by *Cyclops sp. , Diaptomus sp.* and nauplial larval forms. Important cladocerans taxa were *Diaphnosoma sp. and Bosmina sp..*

Macro-benthos.

Macrobenthic population of river Narmada varied from stretch to stretch and even within the stretch.The prominent elements were Mollusca and Annelida followed by Insecta.

Molluscan population was constituted by *Lymnaea accuminata, Melania striatella , M. platyscabra, , Bellamiya bengalensis , Thiara granifera , Corbicula sp. , and Sphaerium sp.* while important taxum representing Oligochaeta was *Tubifex sp. Chironomus sp.* and *Chaoborus* sp. were the eminent taxa representing insect assemblage of river Narmada.

Higher abundance of chironomids coupled with tubificid worms reflected establishment of organic enrichment process at the confluence site of Gelatin Factory effluents and at Amarkantak receiving the city sewage Occurrence of molluscan population in higher proportion is also indicative of organic loading at certain sites like Narmada colony point , Gwarighat of river Narmada.

Macrophytes

Stretch represented by Piparia to Harsud experienced considerable macrophytic infestation which becomes sparse during the monsoon season. By and large, macrophytes were sparsely abundant and confined to the marginal area.

The important taxa was *Potamogeton* sp. *Vallisneria* sp, *Hydrilla* sp., *Ceratophylum* sp., *Najas* sp. and *Chara* sp.

Fishery of River Narmada

Fish catch statistics of river Narmada at Hoshangabad and Shahganj for the period 1959-64 has been reported by Karamchandani et al.(1967) . The Department of Fisheries, M.P(Anon,1971) estimated fish landings at Maheshwar , Mandleshwar, Hoshangabad and Shahganj while Rao et al.(1991) have collected data from Punasa, Omkareshwar, Mandleshwar, Maheshwar and Barwani during1989-90. A comparative statement of the above referred studies is offered in Table.1.

The major fishery of the river Narmada is contributed by the carps followed by cat fishes and miscellaneous group. Among the carps, mahaseer (*Tor tor*) formed the most eminent fishery followed by *Labeo fimbriatus.*The cat fishery was comprised of *Rita rita and R. pavimentata* with a sizeable contribution from *Mystus seenghala* and M. aor. The fresh water shark, *Wallago attu* was also observed to share significantly. *Channa* sp , *Mastacemblus* sp and *Notopterus notopterus* were recorded as forming the bulk of the miscellaneous fishery of river Narmada.

Tenualosa ilisha, the Indian Shad, and *Macrobrachium rosenbergii* constitute the major fishery of the Narmada estuarine system. Mullets, Cat fishes and Penaeid prawns also quite contributed significants in the fishery of Narmda estuarine system. Major carps are important at the upper stretch.

A comparison of data of the above referred three periods did not reflect any significant decline in the percentage composition of the carp fishery which varied from 58.20 to 65.46% while cat fishes ranged from 21.8 to 35.92%. Among the carps, *T.tor* continued to dominate (25.30 to 30.10%) followed by *L. fimbriatus*(18.54 to 24.40%). Rao et al(op. cit) and the exploratory survey of river Narmada by CIFRI revealed the occurrence of *Labeo rohita* which was not encountered during the two earlier studies. Based on the exploratory survey data, carp fishery contributed to the tune of 23.40 to 62.23% and in which *T. tor* shared the bulk. By and large , the percentage composition of cat fishes did not vary much. But based on the secondary informations and catch per unit effort, this is disheartening that the fish production has declined significantly over the years. A comparison of the availability of fry and fingerlings of mahaseers , the important constituent of carp fishery revealed a drastic decline (77.60%) from the period 1987-88 to 1995-96. This decline has been possibily caused by the disruption of breeding and nursery grounds of mahaseers. Tawa, a major tributary of river Narmada providing breeding/ nursery grounds to this important species as has been dammed resulted into habitat loss for breeding purpose. The recent information regarding dynamite fishing and fishing by using agricultural pesticides like Demicron, Thiodiaton and Rogor etc. are extremely deleterious and may drastically degrade the riverine environment.

Future Projections - The verdict

Whole of the Narmada river basin has been proposed to undergo **Compound Impounding** which will transform the valley into small, medium and major spreads of water sheets and the fluviatile character of the river will get subdued . The downstream of the Sardar Sarovar Project (SSP)dam will face fresh water crunch in due course of time in consonance to the developmental pace of the Narmada river basin projects and this has been precisely documented in the Narmada Water Dispute Tribunal award. This eventuality will lead to decline in the biological productivity of the downstream owing to restrictions in the allochthonous enrichment process and there will be considerable enhancement in the salinity regime at the downstream.The anadromous migration of *T.ilisha* will be affected leading to decline in fish production from the Narmada estuary. Moreover, due to enhanced salinity regime, other important fishery contributed by *M. rosenbergii* will also be affected adversely. The fate of the mahaseer in the upstream reservoirs is also a matter of great concern.

In Narmada basin, 92.49 mld of wastewater is generated and it goes out without any very effective provision for treatment. This quantum of wastewater will further increase with the accomplishment of the proposed plan for Narmada river basin (Table-2). Tiwari and Ali (1988) has pointed that the country utilises 16 Kg/ha of fertilizer against the world average of 54 Kg/ha. However, with the further enhancement in the irrigation facilities and other infrastructures the use of agricultural inputs in the form of insecticides, pesticides and fertizers will increase enormously aggravating the non-point source pollutional hazards. The net result will be a greater stressed riverine environment. Considering the eventualities like habitat modifications , dynamiting , indiscriminate use of agricultural chemicals, wanton killings of the juvenile fishery and above all the release of untreated wastewater, it is apprehended that the environment of Narmada river will assume new ecological dimension. Are we prepared for this eventuality ?.

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Table. 1 Percentage Compositon of Commercial fish landings in Narmada River.

Fish Species	Karamchandani (1967)	Annon.(1971)			Rao et al. (1991)
	Central Zone	Eastern zone	Central zone	Western zone	
CARPS					
1. *Tor tor*	28.00	25.30	30.10	28.10	25.87
Tor sp	-	-	-	-	-
2. *Labeo fimbriatus*	19.70	21.50	24.40	22.10	18.54
3. *L. gonius*	0.30	1.10	-	-	0.48
4. *L. calbasu*	4.10	3.70	-	5.00	5.42
5. *L. rohita*	-	-	-	-	0.36
6. *L. dyocheilus*	1.60	-	-	1.20	1.31
7. *L. bata*	1.70	1.40	2.90	1.30	1.40
8. *Cirrhinus mrigala*	2.50	1.20	1.80	2.70	2.71
9. *C. reba*	0.50	-	-	-	0. 48
10. *Catla catla*	0.60	0.60	-	0.46	0.81
11. *Puntius spp.*	-	-	-	-	2.15
12. *P. sarana*	1.40	3.60	3.50	4.60	-
TOTAL	**60.40**	**58.20**	**62.70**	**65.40**	**59.53**
CAT FISHES					
13. *Rita spp.*	-	-	-	-	*12.60*
R. pavimentata	10.20	6.40	3.00	4.70	8.18
14. *Mystus seenghala*	9.00	8.20	10.30	5.60	4.84
15. *M. aor*	4.70	6.50	9.10	6.80	7.70

Table - 1 Contd.

Fish Species	Karamchandani et.al. (1967)	Anon.(1971)			Rao et al. (1991)
	Central Zone	Eastern Zone	Central Zone	Western Zone	
16. *M. cavasius*	0.30	-	-	-	0.68
17. *M.tengra*	-	-	-	-	0.36
18. *Wallago attu*	7.70	10.56	4.40	3.90	-
19. *Clupisoma garua*	1.80	-	0.80	-	-
20. *Ompok bimaculatus*	0.40	-	-	0.80	1.56
Total	**34.10**	**31.60**	**27.60**	**21.80**	**35.92**
MISCELLANEOUS					
21. *Channa spp.*	3.70	4.20	2.00	2.60	1.88
22. *Mastacembelus spp.*	1.30	1.90	-	3.10	1.64
23. *Notopterus notopterus*	0.50	-	-	-	0.70
24. Other small fishes	-	4.10	7.70	0.33	
Total	**5.50**	**10.20**	**9.70**	**12.80**	**4.55**
GRAND TOTAL	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Table 2. Basin-wise position of wastewater generation, collection and treatment in class I cities

Major river basin	Total no. of cities	Weste water (Million liters per day)		Waste water Treatment Capacity	
		Generated	Collected	Primary only	Primary and Secondary
Brahmaputra	2	-	-	-	-
Brahmani	1	47.00	-	-	-
Cauvery	12	602.68	424.29	299.62	0.0
Ganga	80	4986.03	1148.53	-	967.93
Godavari	14	422.27	8.00	45.40	9.08
Indus	12	600.23	264.01	68.00	-
Krishna	22	727.04	229.66	165.80	41.67
Mahanadi	8	285.99	107.10	85.50	-
Mahi	2	164.60	98.00	0.00	81.00
Narmada	3	92.49	-	-	-
Pennar	3	19.16	-	-	0.00
Sabarmati	2	399.76	12.50	10.00	3821.00
Submarkha	1	117.76	0.00	0.00	0.00
Tapi	8	260.52	95.00	76.00	-
Sub total	170	8728.75	2387.09	750.32	1481.68
Coastal	23	2562.49	64.08	108.92	4.50
No. major basin	19	854.25	181.85	-	140.00
Total	212	12145.49	2633.02	859.24	1626.18

Source: Status of water supply and waste water collection, treatment and disposal in class I cities, 1988, CPCB, Delhi

1. Amarkantak
2. Mandla
3. Jabalpur
4. Narsinghpur
5. Kareli
6. Gadarwada
7. Sandia
8. Shahganj
9. Hoshangabad
10. Dongarwara
11. Gondagaon
12. Handia
13. Mola
14. Maheshwar
15. Khalghat
16. Hanfeshwar
17. Charbara
18. Gadher
19. Surpan
20. Vedgam
21. Poicha
22. Sisodara
23. Velugam
24. Jhanor
25. Ankaleshwar
26. Sakkarpura
27. Bhadbhut
28. Ambetha

Hot Spots

(I) Amarkantak (City Sewage)
(ii) Bhedaghat, (Gelatin Factory Effluents)
(iii) Gwarighat (City Sewage)
(iv) Dongarwara (Security Paper Mill Effluents)
(v) Gondagaon , Handia (Burning Ghat)
(vi) Sakkarpura (Composite Effluents)
(vii) Baijalpur, Bharuch (Domestic and Industrial)

Fig. 1. Map of Narmada River Basin showing the proposed plan of impoundments and sampling stations(O)

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ECOLOGY AND FISHERIES OF HOOGHLY-MATLAH ESTUARINE SYSTEM

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Introduction

The complex Hooghly-Matlah estuarine system on the Indian coast is one of the largest estuarine systems in the country covering a major portion of the Gangetic delta. It is located in the state West Bengal between latitude 21.23 °N and longitude 88-89 °E. The deltaic region of the system is occupied with a vast marshy area criss-crossed by many major and minor estuaries of the system called Sunderbans-the world's largest mangrove ecosystem. The entire estuarine system is estimated to be about 8,029 Km^2 and the total area of the Sunderbans estuarine water is about 2,340 Km^2. The principal components of the estuarine system are the main Hooghly channel, its five tributaries *viz.*, Jalangi, Churni, Damoder, Rupnarayan, Haldi and the adjacent estuaries such as, Saptamukhi, Thakuran, Matlah, Gosaba, Harinbhanga, Ichamati and Raimangal. The latter seven estuaries are since long disconnected from the main Hooghly due to heavy deposition of sediment in the upper reaches of these estuaries. As a result they are now considered as estuarine inlets of the area.

Estuaries are among the most productive natural ecosystem in the world. Hooghly-Matlah estuarine system is not an exception to this and it is recognised to be the most productive estuarine system of the country. The entire system offers bounteous biological wealth characterised by its diversified rich flora and fauna including fisheries. It also provides rich breeding and nursery grounds for innumerable numbers of marine and freshwater fin and shell fish species as they are physiologically suitable environment with respect to temperature, salinity and other physico-chemical parameters. Therefore, the complex Hooghly-Matlah estuarine system plays a vital role in fisheries and acts as a potential source of fish and prawn seed.

The main channel Hooghly (the end portion of river Ganga) of the system is a positive estuary of the mixohaline type with the pattern of increasing salinity towards the mouth of the estuary. The dynamic estuarine ecosystem is subject to rapid changes by natural or man made interferences. In case of Hooghly-Matlah estuarine system, a major change in the water quality and fishery resources was noticed after the construction of barrage across the river Ganga at Farakka. Prior to the construction of barrage, the main channel Hooghly was deprived of getting sufficient freshwater and gradually became inactive as bulk of discharge used to flow through river Padma , the other off-shoot of river Ganga. After commissioning of Farakka barrage in 1975, the main Hooghly estuary is fed directly by the Ganga through feeder canal and Bhagirathi. The additional discharge of freshwater into the system has changed the ecology of the estuary. These changes significantly affect the biological and physico-chemical factors responsible for plankton, benthos and fish production. The present communication deals with major changes in ecology, fish population trends and also suggests for its conservation for a sustainable production.

Ecology

A critical analysis of the earlier works during pre-Farakka barrage period (Dutta *et al,* 1954; Bose 1956; Shetty *et al.,* 1961; Basu and Ghosh, 1970; Saha *et al.,* 1983 and Sinha *et al.,* 1998) relevant to hydrology revealed that additional discharge of freshwater through Farakka barrage had changed the ecology of the system significantly by reducing salinity and converting the earlier gradient zone into almost freshwater one. Presently, the salinity incursion of the Hooghly estuary was observed upto Diamond Harbour situated 60 Km from the mouth of estuary. On the contrary, the salinity incursion of the Hooghly estuary during pre-Farakka barrage period was observed upto Konnagar situated 162 Km from the mouth of estuary. The Hooghly estuarine system, being a positive estuary, showed distinct levels of salinity gradients. Presently, the upper freshwater zone has extended downwards for a distance of 238 Km from Nabadwip to Diamond Harbour. Nabadwip and Diamond Harbour are located 298 and 60 Km respectively from the sea face. The gradient zone Diamond Harbour to Kakdwip and marine zone Kakdwip to sea face have been very much reduced and pushed back towards the mouth of the estuary (Fig. 1). During pre-Farakka barrage period the upper freshwater zone was extending from Nabadwip to Konnagar, middle gradient zone from Konnagar to Diamond Harbour and lower marine zone from Diamond Harbour to seaface. The present salinity values in the upper freshwater zone ranged between 0.04 and 0.13 g/l while in the gradient and lower marine zones the values varied from 0.32 to 4.54 g/l and 1.58 to 32.5 g/l respectively. The salinity in the main Hooghly channel including Muriganga was always lower than the other distributaries of the estuarine system where fluctuations of salinity are brought about only by the freshwater received from the catchment areas and overflow from adjoining Hooghly during monsoon months. All estuaries around Sunderbans had high salinity. The salinity values in Saptamukhi, Thakuran, Matlah, Roymangal and Ichamati vaired between 4.54 and 29.6 g/l, 2.92 and 27.62 g/l, 7.25 and 17.2 g/l and 0.39 and 13.54 g/l respectively.

As regards physico-chemical parameters of the estuary during pre and post-Farakka period an appreciable change in the value of certain parameters was observed. At present an increase value of dissolved oxygen in the Hooghly estuarine system at Uluberia (5.8 to 7.2 mg/l), Diamond Harbour (Roychowk) (6.4 to 7.9 mg/l) and Kakdwip (5.9 to 8.2 mg/l) in the present study as compared to earlier study during 1953-55 when the values varied from 2.3 to 4.6 mg/l at Uluberia, 2.1 to 6.8 mg/l at Diamond-Harbour (Roychowk) and 3.4 to 5.1 at Kakdwip may be due to increased influx of freshwater in the estuary after commissioning of Farakka barrage. Phosphate, nitrate and silicate contents of the estuarine waters were very low during pre-Farakka period, while after commissioning of Farakka barrage, the phosphate, nitrate and silicate contents increased almost similar values were observed upto recent years.

Plankton

The overall plankton production in the Hooghly estuary during post-Farakka barrage period was high when compared with the earlier studies during pre-Farakka barrage period. The total plankton production for the Hooghly estuarine stretch was maximum at Frazerganj (1262 units/l) and minimum at certain stretches of freshwater as well as gradient zones of the estuary. The low production of plankton at these stretches may be due to discharge of industrial effluent which caused maximum adverse effect on production of plankton. The bulk of plankton in the Hooghly was constituted by phytoplankton. Bacillariophyceae, Chlorophyceae and Cyanophyceae are the principal groups in order of abundance. Phytoplankton production was maximum at Frazerganj in the Hooghly estuary as compared to other distributaries *viz.* Saptamukhi, Thakuran, Matlah, Roymangal and Ichamati. The range of annual plankton production varied from 74 to 392 u/l in the Saptamukhi estuary at Bhagabatpur from 76 to 221 u/l in the Thakuran estuary at Moipeeth, from 52 to 585 u/l and 19 to 594 u/l in the Matlah estuary at Canning and Jharkhali respectively, from 50 to 298 u/l in the Roymangal estuary at Bagna and from 42 to 237 u/l in the Ichamati estuary at Hasnabad. At Bagna (298 u/l), Jharkhali (594 u/l) and Bhagabatpur (392 u/l) plankton production was maximum during summer and at Moipeeth (221 u/l) during winter, while maximum production was observed at Canning (585 u/l) and Hasanabad (237 u/l), during monsoon months.

Macro zoobenthic fauna

Information on macrozoobenthic fauna of Hooghly estuarine system during pre and post-Farakka barrage periods are very scanty. At present the overall population of macro-zoobenthos ranged between 37 and 5207 units/m^2 maximum production was observed in freshwater zone of the estuary. In the freshwater zone, the dominant species under gastropods were *Thiara tuberculata, T. lineata, T. scabra, Bellamya bengalensis, B. dissimilis, Assaminea francessiaei, Brotica costula, Corbicula noetlingi, Indoplanorbis exustus, Neritima smithi, N. violacea, Gangetica miliacea, Pila globosa, Mactra luzonica, Segmentina calatha,* contributing 65 to 100% of the total population. Other community available were *N. polybrancia* (Polychaeta), Tubifex Oligochaeta), *Ocypodid* sp. (crab). *P. favidens* (bivalve).

In the gradient and lower marine zones of Hooghly estuary the macrozoobenthos density ranged between 92 (Haldia) and 828 units/m^2 (Frazerganj), 254 (Frazerganj) and 561 units/m^2 (Haldia) and 37 (Kakdwip) and 1049 units/m^2 (Frazserganj) during summer, monsoon and winter seasons. The annual production of macro-zoobenthos in Saptamukhi estuary at Bhagabatpur (184 to 991 units/m^2), Thakuran estuary at Moipeeth (256 to 1472 units/m^2), Matlah estuary at Canning (82 to 294 units/m^2), Roymangal estuary at Bagna (74 to 331 units/m^2) and Ichamati estuary at Hasnabad (239 to 294 units/m^2) also exhibited the dominance of gastropods in the population. *Cerithidea cingulata, Columbella duclosiana, Natica tigrina, Neritina auriculata, Telescopium telescopium* were the dominant gastropod species in the lower marine zone of the Hooghly as well as estuaries of Sunderbans.

Fishery

A wide variety of fish and prawn diversity was observed in the freshwater zone, particularly in the lower stretch of this zone from Uluberia to Diamond Harbour being the admixtured of fresh and saline water, euryhaline species were also encountered in the region. The fish and prawn fauna available in the stretch between Nabadwip and Calcutta were *Tenualosa ilisha, Aorichthys seenghala, Eutropiichthys vacha, Clupisoma garua, Setipinna phasa, Ailia coila, Puntius ticto, Mastacembelus armatus, Bagarius bagarius, Pangasius pangasius, Xenentodon cancila, Amphipnous cuchia, Mystus cavasius, Ompak pabo, M. gulio, Notopterus notopterus, N. chitala, Wallago attu, Labeo rohita, L. calbasu, Catla catla, Cirrhinus mrigala, L. bata, Chela* spp. Among prawns, *Macrobrachium rosenbergii, M. malcolmsonii, M. rude, M. villosimanus, M. lamarrei, M. mirabiles, M. birminicum birminicum, M. scabriculum* and *M. dayanum* were available in the stretch. The availability of featherback (*N. notopterus* and *N. chitala)* and carps (*L. rohita, L. bata, L. calbasu, C. catla* and *C. mrigala*) was mostly confined to the stretch between Nabadwip and Tribeni and their abundance was poor in comparison to total catch. The important fish available in the stretch between Uluberia and Diamond Harbour were *Pama pama, S. phasa, T. ilisha,* *Polynemus paradiseus, Silaginopsis panijus* and *Rhinomugil corsula.* Among prawns, *M. rosenbergii, M. mirabile* and *Metapenaeus brevicornis* were the most dominant species. Freshwater species *viz., E. vacha* and *C. garua* were available upto Uluberia.

Dominant species in the gradient as well as marine zone of Hooghly including other estuaries of Sunderbans were *Harpodon nehereus, Trichiurus* spp. *T. ilisha, Setipinna* spp. (mostly *S. taty), P. pama* and prawns *(Parapenaeopsis sculptilis, P. stylifera, Metapenaeus brevicornis, M. monoceros, Penaeus monodon, P. indicus, P. semisulcatus, Expalaemon stylifera, E. tenuipes* and *Leptocarpus fluminicola).* Next to these other important fish species were *P. paradiseus, Eleutheronema tetradactylum, Lates calcarifer, Polydactylus* sp. *Polynemus indicus, Coilia* spp. *Stromateus cinereus, Arius sona, A. sagor, Ilisha elongata, Osteogeniosus militaris, Otolithoides biauritus, S. panijus, Liza parsia, L. tade, Chirocentrus dorab, Raconda russeliana, Plotosus canius, Cynoglossus spp. Anchoviella commersonii, Scatophagus argus, Etroplus suratensis, Therapon jarbua, Synbranchus bengalensis, Strongylura strongylura.*

The annual average fish and prawn yield from the estuarine system has increased from 3,204 tonnes during the period 1960-63 to 51,126.1 tonnes during 1996-97. In the Hooghly estuarine system, fishing exploitation by migratory bagnet was an important feature of the lower estuarine zone during winter months from November to January. The winter migratory bagnet fishery contributed to the tune of 65-75% of the total yield of the estuary. More than 90% catches are marketed as dry fish. The dominant species contributing in the winter migratory bagnet fishery were *H. nehereus, Trichiurus sp.. Setipinna spp., Arius spp., P. pama* and *Coilia* spp. On the whole, the lower marine zone of the estuarine system during post Farakka barrage period contributed about 95% of the total catch of the entire Hooghly estuary and Sunderbans deltaic region and the maximum contributors were *H. nehereus, Trichiurus spp. Setipinna spp.,* and prawns.

The present trend of catch statistics shows that some fish species *viz., Liza tade, Plotosus canius, Pangasius pangasius, Lates calcarifer* of the estuarine system have shown a sharp declining trend during post-Farakka barrage period. Reduction in overall salinity coupled with over exploitation and destruction of brackishwater fish and prawn seed for selective stocking of *Penaeus monodon* in coastal aquaculture are apparently the probable reasons for the decline of these fisheries.

The general habitat of migratory hilsa in the estuarine system has improved for its migration, breeding and growth. The average annual landings of the species which remained at 1,500 tonnes prior to 1975 has increased to more than 7,000 tonnes in recent years.

Sunderbans estuarine system is a potential source of estuarine fish and prawn seed. The present observations on the abundance of commercially important prawn and fish seed in the Sunderbans during post-Farakka barrage period revealed that the magnitude of abundance of certain prawn and fish seed has reduced to a great extent as compared to pre-Farakka barrage period. The seed of most commercially important prawn *P. monodon* are available extensively alongwith seeds of other important penaeid (*P. indicus)* and metapenaeid *Metapenaeus brevicornis* and *M. monoceros)* prawn as well as fishes *Liza parsia, L. tade* and *Lates calcarifer).* At present the upper limit of availability of the marine fish and prawn seed has become restricted to 50-60 Km upstream from the seaface while during pre-Farakka barrage period seeds of *P. monodon* and *P. indicus* were available from Uluberia and Noorpur centre of Hooghly main channel located 113 and 83 Km respectively above the mouth of the main estuary. Reduction in salinity due to increased freshwater discharge is apparently the probable reason for this. The overall availability of seed in the lower estuarine system was found to have declined.

Giant freshwater prawn, *Macrobrachium rosenbergii* contributes to a fairly good fishery in the freshwater zone of Hooghly estuarine system. The range of downstream migration of the species during pre-Farakka barrage period was upto Noorpur (1.90 to 21.2 ppt salinity) located 83 Km upstream from the estuary mouth. The species now migrates further downstream towards seaface as far as diamond Harbour, Kakdwip, Namkhana, Sonakhlai, Basanti, Jharkhali, Nazat, Hasnabad areas of Sunderbans indicating a long range migration. The migration of barried females in particular, takes place in the water bodies (2.30 to 19.00 ppt salinity) of Sunderbans usually during early in March/April and continues upto July. The downstream migration of the species upto that extent was not observed during pre-Farakka barrage period.

It is observed that a huge quantity of both commercial and non-commercial prawn and fish seed is being destroyed during selective collection of bagda seed (*P. monodon)*. The present exploitation of bagda seed during the peak abundance period from February to June was estimated for five consecutive years of 1993-97. The average yearly (February-June) exploitation of bagda seed was estimated to be 885.5 million from the Sunderbans region. It is also recorded that bagda seed constitute only 5 to 10% of the total catch of the nets. The total amount of seed destroyed over a period of five months during February to June was estimated to range from 9,139.5 million to 19,294.5 million. This wanton destruction of seed is detrimental and may lead to decline of estuarine as well as marine fisheries in future.

Recommendations for the conservation of estuarine fisheries

1. The Hooghly-Matlah estuarine environment should be judiciously exploited so that natural resources of fish and prawn stocks and their recruitment level are not damaged or destroyed.

2. Indiscriminate fishery, irrational exploitation, wasteful utilization of resources should be avoided through planning, development and management.

3. The mesh size of fishing gears for drift gill net, drag net, seine net should be adjusted to ensure non-capture of juvenile stocks of prawn and fish

4. Remedial measures should be taken with regard to extensive fishing or over exploitation of hilsa in the coastal area and mouth of estuaries. Hence, there is a need to reduce the intensity of hilsa fishing

5. The breeding periods of fin-fishes are to be critically studied to suggest regulatory measures for their exploitation by observing close period in time and space.

6 Intensive seed collection from wild for stocking the bheries should be stopped. Over stocking of the water area should be discouraged

7. Chemical, antibiotics, pesticides etc. should not be used in bheries

8. Destruction of mangrove forests and ecologically sensitive wetlands should not be done.

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STATUS AND IMPORTANCE OF MANGROVE ECOSYSTEM IN FISH AND FISHERIES

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Introduction

Mangrove ecosystem is highly significant and unique, as it protects the coastal/deltaic lands, estuarine mouths and shallow bays besides providing the ideal nursery and breeding grounds for a good number of off-shore and estuarine shell-fish and fin-fish. In addition to these, it comprises the unique assemblage of many plankton and other animals and thus can be considered as repository of rich biodiversity. Several mangrove dwelling fauna adapt best in saline environment, i.e., on salt water and saline soil, both in terrestrial or aquatic habitats. Well grown dense mangrove forest flora is known for liberating the litter/biomass at the rate of about 6000 t dry matter from one hectare area and within one calendar year (MacNae, 1968), which ultimately mineralised through microbial activities and nutrients are being released in water and soil phases (Saenger, *et al.,* 1983 and Arroyo, 1977b). Mangrove vegetation litters have been reported as highly dynamic and move from one place to another transporting nutrients like dissolved organic matter (DOM) or particulate organic matter (POM). This singular characteristic of mangrove ecosystems is significant as it becomes the ideal grazing ground for a number of shell and fin fish species and other marine or off-shore fauna (MacNae, 1968, Arroyo, 1977a; Clough, 1982 and Finlayson & Moser, 1991).

The mangrove ecosystems are localised strictly to the tropical and sub-tropical regions of both the Old World and New World (Davies, 1940 & Geriech, 1973). In recent years, however, these are threatened to a considerable extents (Aubreville, 1970; Fosberg, 1971; Mepham & Mepham, 1984 and UNDP/UNESCO, 1986). In India mangroves are distributed at the major deltas and estuarine mouths, shallow coastal regions, lagoons and margins of the Islands (Blasco, 1975 & 1977; Naskar 1987; Naskar & Guha Bakshi 1982, 1983a, 1983b, 1987 and Naskar & Mandal, 1999).

Amongst the Indian mangrove ecosystem, about 66% is restricted in the estuarine mouths of the lower Ganga delta, 18% in the Bay Island-Andaman & Nicobars and the remaining 16% distributed in Mahanadi, Cauveri, Godavari, Krishna, Mapls and Mardon's zone deltas in Orissa, Andhra, Tamil Nadu, Karnataka and Goa states.

The mangroves irrespective of their occurrence or distributation have been subjected to undue anthropogenic activities and have been degreed to an alarming pace.

Status of the mangroves and mangrove ecosystem of the world

Mangrove zones, being distributed largely in tropical and subtropical areas indicate a temperate range of 20 °C and 35 °C. Occasionally, however, the temperature has been reported to be 2 °C- 4°C in some scrub-mangrove zones at 38° 4' S latitude in S. E. Australia (with the dominant species like *Avicennia marina)* and 31° O' N latitude in Japan (with the dominant species like *Kandelia candel).* The Indo-West pacific regions, viz., East African coast Malagasy, Seychelles, pakistan, Maldves, Sri Lanka, east and West Coast of India, Andaman & Nicobar Islands, Bangladesh, most of the coastal zones of S. E. Asian countries, Tropical Australia, New Zealand etc. are the most dominant mangrove zones. The other important mangals, have also been reported from west coast of Africa, east & west coasts of tropical S. America, Mexico and the coastla areas of N. America.

Sundarbans-the dominant mangrove ecosystem

Sundarbans, the largest deltaic tropical plain of India, is located in the southern part of 24- Parganas (South and North) and is situated in the coastal belt of West Bengal (longtitude 88° 10' E and 89° 10' E and latitude between 21° 30' N and 22° 15' N). This tidal delta reserve forest area is about 4267 sq.km. (including both the mangrove forest and water ways). Of which, 1750 sq km is under the tidal rivers, creeks and brackishwater lagoons. The actual mangrove forest area in the estuarine belt/deltaic zone of Indian Sundarbans is about 2179.05 sq km (with dense mangrove 1952 sq km and 226.18 sparse mangrove covers), while the rest is a naked beach or a river flat. The entire area is interesected by large number of criss-crossing tidal rivers, canals and creeks, dividing the region into 75 forest compartments under 54 mangrove dominated islands. Furthermore, about 50 islands of these deltaic region have been converted into human habitation or agricultural fields. The denuded forest bed lying on the river banks, snad chars, forest floors and sea-shores is about 216.6 sq km (Naskar & Guha Bakshi, 1987). The delta embraces several true estuaries besides off-shores of the Bay of Bengal, viz., Hooghly, Baratala or muriganga, Saptamukhi, Thakuran, Matla, Goasoba, harinbari etc. along with large number of east to west flowing tidal rivers, creeks and canals (Naskar & Guha Bakhsi, 1987).

Since, the later half of the eighteenth Century more than 50% of the mangrove forest coverage in the Indian Sundarbans has been cleared or reclaimed for human habitations, agricultural lands, brackishwater fisheries etc. (Naskar, 1985). The 9630 sq km of Indian Sundarbans falls under 13 rural blocks in the Soth 24 Parganas and 6 rural blocks in the North 24 Parganas with dense human population (32 lakh as per Census, 1991). Most of the rural people are living in abject proverty and are solely or partly dependent on the mangals of the Indian Sundarbans. The poverty coupled with greediness of the local people and business classes are primarily responsible for the over exploitation of these mangals. This important heritage site of the world has been ignored for long without any protective measure or conservation efforts.

Considering the ecological consideration, economical potentialities and degrading nature, about 2585 sq. km. S. E. part of the Indian Sundarbans area has been declared as the 'Sundarbans Tiger Reserve' since 1973. The estuarine crocodile, *Crocodilus porosus* is being breeded and reared in the crocodile farm at Bhagbatpur at Namkhana Range and 3 Wildlife Sanctuaries viz., Sajnakhali, Holiday Island and Luthian Island since 1976. The Sundarbans mangrove forest has also been declared as the 'National Park' since 1987. Besides for overall conservation of the Sundarbans (9630 sq. km) it has been declared as 'Sundarbans Man and Biosphere Reserve' also.

The mangrove forest facing the coastal front of the Sunderbans is known to act as an effective barrier against the frequenting cyclones, besides providing a host of products and byproducts in the form of fish, wood, fuel, honey and so on. Poverty and greed of people has led to over exploitation of the resources and as a result the system as a whole has been badly impaired.

Impact of mangroves on fish and fisheries

Large number of fin and shell-fish (prawns, crabs and molluscs) species are the common inhabitants in the mangrove waterways (rivers, creeks, canals, marshes, lagoons and wetlands or estuaries). Large number of off-shore and marine species are also fully or partly, dependent on the system. However, it is difficult to assess or draw a clear-cut demarcation line between mangrove-dwelling, mangrove dependent, non-mangrove dependent or obligatory dependent on mangrove species.

Quantitative evaluation of mangrove dwelling and mangrove dependent fish and fisheries is limited, as most of the fin or shell fish species used to migrate from one place to another during different seasons and at different stages of their life-cycle. The only exception is commercially important species of molluscs and resident crabs, gastropods etc. The present fishery status is mostly based on the landing data, collected during different seasons, times and from the different parts of the mangrove habitats. All such data may not be always authentic, as collected by a heterogenous group of workers.

The only possibility for near accurate estimation and quantification of fishery may be to investigate critically the habits and habitats of different species of fin and shell-fish species and comparison be made with that of the mangrove cleared or reclaimed coastal or estuarine areas. Besides, the investigation on the life cycle of individual species, food and feeding habit, estimation of migratory pathways and abundance of dominant harvest may also help in quantification.

MacNae (1968, 1974) has reported that the rivers, canals and lagoons in and around these dense mangroves are the natural habitats and nursery grounds for varied fin and shell-fish species, of commercial importance and amongst them *Chanos chanos*, *Mugil* spp. and *Pomadasys* sp. are highly important.

Macintosh (1982) reviewed the publications of different workers from different countries on mangrove habitats. Jothy (1984) has reported that 29 commercial fin-fish species under 23 families from the malaysian magrove waterwasys (*Chanos chanos, Hilsa macrura, Lates calcarifer, Epinephelus tauvina, Liza spp., Plotosus canius).* He has also listed 13 commercial species of shell fish and five commercially important species of molluscs from the malaysian mangrove waterways. These important edible molluscs/cockles of the Malaysian mangroves are *Anadara granasa;* the other Oyster species are *Crassosthea spp.* and green mussel is *Perna viridis.* Daughery (1975) has reported that the destruction of mangroves is one of the major constraints for the declining trends of prawn catches. Jana, *et al.,* (1974) have reported that several important fish and prawns have shown declining trend in Indian Sundarbans mangals or estuarine zones due to destruction of mangrove vegetation. Umali, et al. (1987) have highlighted that mangroves, not only support or export the fishery within its own ecosystem boundary, but also supply and export nutrients for the fishery of adjacent coastal areas. These mangrove waterways and mangrove ecosystems are identified as the nursery grounds for many fish species.

In addition to these economic and potential values, the mangrove forest flora also yield strong and durable timber and wood. Mangrove reclaimed land has been identified as highly fertile land for paddy cultivation in several S. E. Asian countries. However, in some cases mangrove renovated areas has the problem of acidity, particularly the dominance of acid-sulphate soil. Mangroves also have several other economic roles for the human society, viz., mangrove bark yield tannin, mangrove flower-nectar produces honey and wax. Mangrove forest is the only preferred habitats for large number of threatened, endemic, endangered and rare fauna, besides attractive place for the tourists to meet their aesthetic needs.

Evidently in addition to direct economic importance mangroves also protect the coastal zones from the cyclonic thrust and surges from the bay.

Remarks

On the basis of earlier observations and studies, it is imperative to undertake certain measures, imposing strict rules besides making the rural people aware to protect this natural resource of multi-faceted importance.

- Assuring daily meal for rural folk by improving agriculture, aquaculture, goaterry, piggery, dairy, poultry etc., based on the available local resources besides providing training, finance, marketing and transport facilities specially to the weaker section of the society.

- Need to stop monoculture of prawn by encouraging polyculture as advocated by Central or State Fishery Research Institutes. It would help in stopping prawn seed collection and damage of natural fish and prawn juveniles and the forest destruction.

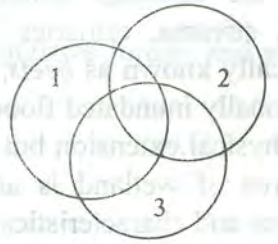
- Strict ban on operation of fine mesh nylon nets is essential. It is also necessary to stop netting of brood fish and prawn during their breeding season.

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

Conclusion

Besides fish, prawn, crab, honey and wax, wood and timber and other natural resources, the fertile agricultural and aquacultural lands of the Sundarbans directly and indirectly help the rural economy. So, for fire wood only exploitation of Sundarbans mangrove forest is uneconomical and irrational.

- Without proper education, the rural people cannot be made conscious about their entity as human beings and living in civilized manners. Illiteracy results in unlimited population growth, health hazard scarcity of proper habitation and so on.



1. Socio-economic condition
2. Education
3. Population growth

These three aspects need urgent attention with uniform stress on each. Limited or adhoc approaches may not be able to solve the problems of Sundarbans mangals and it is sure that if the present trend of exploitation continues for long many important 'gene pool' will get vanished from the System and the glamour of 'world heritage site' will be lost within no time. However, man is the highest biotic component in any ecosystem, so without protecting the interest of man the ecosystem protection will be a fruitless effort.

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ECOLOGY & FISHERIES OF FLOODPLAIN WETLANDS OF GANGA BASIN

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Introduction

India, specially its Eastern and North-Eastern parts, has been characterized by the abundance of water of various types including the wetlands. The distribution of wetlands, however, is widespread ranging from the cold areas of Ladakh to highly wet Manipur, the warm desert of Rajasthan & Gujarat to the monsooning Central India and still humid zones of down South. Literally the wetlands include a wide variety of dynamic ecosystems from perennial rivers, streams, estuaries including mangrove swamps, natural depressions & marshes (locally known as *beels, chaurs, dhars, pats etc.*), ox- bow lakes, ponds & tanks and seasonally inundated floodplains. The wetland environment is not only large and varied in physical extension but it is highly sensitive biologically also. In India the estimated area of wetland is about 4.1 million ha contributed by wetlands of various shapes, sizes and characteristics. Besides it has 6740 km^2 coastal wetlands/mangroves, of which 80% area falls under Sunderbans in West Bengal. Isolated stretches of mangrove wetlands are also available in coastal Orissa, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Gujrat and Goa.

Wetlands Resource and types in India

Broadly, the wetlands of India can be classified into three categories, depending upon their geographic location:-

i) Himalayan wetlands
ii) Indogangetic wetlands
iii) Coastal wetlands

The **Himalayan wetlands** with varied biotopes and remarkably different biodiversity are those wetlands which are located in uplands of Ladakh, Himachal Pradesh, Kashmir and North-Eastern States of Sikkim, Assam, Arunachal Pradesh, Meghalaya, Nagaland and Manipur (400 m to 5000 m above the sea level).

Some of the important wetlands of Himalayan region are:

- Pangon, Tso, Chantan, Chassul etc. (Ladakh, 4000 m above the sea level)
- Dal, Anchar, Wulur, Kranchu etc. (Kashmir valley)
- Nako, Chandertul, Surajtul etc. (upper H. P., 2500 to 5000 m above sea level)
- Khajiar, Kaveri, Rewalsar etc. (mid. H. P., 1500-2500 m above sea level)
- Remark & Kaketi (lower H. P., upto 1500 m).
- Central Himalayas have many lakes, mostly located in Kumaon region. (Nainital, Bhimtal, Nankurchiatal etc.).
- Eastern Himalays also have large number of wetlands. In the Brahamputra valley of Assam *c* 1 lakh hectare of wetlands are available. The Loktak Lake of Manipur (289 km^2) is the largest in area in this region.

The **wetlands of Gangetic plain** are known for their utility in various developmental sectors since time immemorial. East Calcutta wetlands (W.B), Chaurs (Bihar), floodplain lakes such as Surahatal (U.P.), Chambal wetlands (M. P.) and Keoladeo Ghana national park (Rajasthan) are highly significant wetlands of Gangetic plain. In recent years various multi-purpose river valley projects have taken shape giving birth to a large number of man-made wetlands in the Indo-Gangetic plain, such as Harike Barrage (Beas-Sutlej Confluence), Bhakhra and Nangal dams (H.P. and Punjab), Gandak barrage (Bhainsalotan, Bihar) etc.

The 7500 km **coastline of India has extensive areas of wetlands** dominated by mangroves, salt marshes & lagoons. Pulicate lake, Periyar lake, Chilka lake, Kolleru lake etc. are some of the important coastal wetlands. The southern peninsula as well as the Decean region, though poor in natural wetlands, are very rich is man-made wetlands in the form of small reservoirs and tanks.

The Indo-gangetic region of the country is bestowed with extensive expansion of wetlands and incidently the area has the distinction of possessing the largest wetland tract in the country. State-wise distribution of wetlands in India has been presented in Table- 1(a),whereas State-wise areas of wetlands as important fishery resources are indicated in Table 1.

Table 1(a). Number and area of Natural as well as man-made wetlands of India (after Ministry of Env. and Forest-Survey 1990)

State	Natural		Man-made	
	Number	Area (ha)	Number	Area (ha)
Andhra Pradesh	219	10 0457	19 020	425 892
Arunachal Pradesh	2	20 200	NA	NA
Assam	1394	86355	NA	NA
Bihar	62	224 788	33	48 607
Goa	3	12 360	NA	NA
Gujarat	22	394 627	57	129 660
Haryana	14	2 691	4	1 079
Himachal Pradesh	5	702	3	19165
Jammu & Kashmir	18	7 227	NA	21880
Karnataka	10	3 320	22 758	539 195
Kerala	32	24 329	2 121	210 579
Madhya Pradesh	8	324	53	187 818
Maharashtra	49	21 675	1 004	279 025
Manipur	5	26 600	NA	NA
Meghalaya	2	NA	NA	NA
Nagaland	2	210	NA	NA
Orissa	20	137 022	36	148 454

Punjab	33	17 085	6	5391
Rajasthan	9	14 027	85	100 217
Sikkim	42	1 101	2	3.5
Tamil Nadu	31	58 868	20 030	201 132
Tripura	3	575	1	4 833
Uttar Pradesh	125	12 832	28	212 470
West Bengal	54	291 963	9	52 564
Union territories				
Chandigarh	NA	NA	1	170
Pondicherry	3	1533	2	1 131
Grand total	2 167	1 450 861	65 253	2 589 266

Types of floodplain lakes in Ganga basin

The Indo-Gangetic planes is bestowed with varied kinds of natural waters ranging from river meanders to tectonic depressions and are known by different names locally such as *man, chaur, tal* (Bihar); *tal* (UP) & *beel* (West Bengal). The ploodplain lakes of Gangaetic plain can broadly be classified as under:

Based on origin

i) **Ox-bow lakes** - the cut of river meanders originated due to fluviatile activity of rivers

ii) **Tectonic lakes**- lakes originated due to geo-morphological depression on the earth crust

Based on physical status

i) **Live lakes**- Lakes with connecting channels with rivers

ii) **Closed lakes** - Lakes without any connecting channels or defunct channels

Table 1(b) Natural Wetlands in Ganga floodplain (fishery resource)

State	Natural Area (ha)
Assam	100000
Bihar	42000
West Bengal	48000

Value and Ecological roles of floodplain lakes

The wetlands are fragile ecosystems with high productivity potentials. Historically they are known to perform a number of functions and are highly significant from ecological, commercial and socio-economic point of views. They perform a kind of safety valve function ecologically by acting as reservoirs and reducing factors of floods, as a repository of biodiversity, as an ultimate sink for pollutants, as groundwater recharger and dechargers, as a stabilizer of local climatic conditions and many more (Dugan, 1990).

Besides ecological functions the wetlands have tremendous commercial and socio-economic values such as:

- shoreline stabilization of river basins.
- support for food chains leading to harvestable crop for human welfare.
- fish and fisheries activities, a traditional occupation for poorest of the poor section of the society.
- refuge of Avian fauna and an excellent habitat for many other wild lives
- water transport etc.

Reclamation/Transformation of wetlands

It is an established fact that wetlands are passing through a phase of natural transition and tend to become shallow to shallower and ultimately to dry environment with every passing year. Obviously, these ecosystems are self destructive in nature, but the process of such natural transitions were, by far, slow in nature. In recent years the increased human interventions in the form of flood control measures, reclamation of arable lands for agricultural activities, channelisation and abstraction of excessive water for various purposes, unabated discharge of effluents and solid wastes and many other man-made modifications in their catchment areas, have accelerated this process of transition from aquatic system to land system has been accelerated at an alarming pace causing rapid loss of wetlands (Sinha and Jha1977).

The sustained and varied kinds of human interferences on these fragile ecosystems, specially under Ganga and Brahamputra basins, are so intense and alarming that not only their sustainability in terms of various production functions have become a matter of serious concern but even the very survivability of their physical existence is under severe threat (Jha, 1995, Sinha and Jha, 1977, Sugunan, 1995 Yadava 1995). The high productivity potential and other multiple usage of such water bodies specially in Ganga basin (Bihar,U. P. and W. B.) may be attributed as one of the reasons for the settlement of relatively higher density of human population around the lake areas and developed various production systems along the subsistence economy from these wetlands. Both the physical and social dynamics of wetlands have been exploited to their fullest to shape the occupational pattern through arbitrary management of these resources for their livelihood. In the past few decades, however, the productive characteristics of wetlands are being exploited with increased intensity, for harnessing more production, income and other livelihood needs.

Primarily the wetlands were well recognized for fishery, agroforestry, pasture and navigation. Use of wetlands for seasonal agricultrue is practiced too in certain areas. However, the scenario has completely changed in last few decades with substantial increase in population and subsequent demand for arable land for settlement. This singular factor may be considered as one of the main degrading force affecting the wetlands adversely.

Developmental impact on wetlands

Man-made river valley modifications with increased anthropogenic interferences have brought about rapid ecological changes resulting in impaired production and productivity. The immediate impact of such developments might be helpful in improving the food security in terms of foodgrain production but such gains may end-up into a big fiasco as the loss of these vital aquatic resources would destroy the entire biotic production system of the area for good by affecting unpalatable change in the climatic condition. The adverse impact of irrational exploitation of such ecosystems can be summarized as under:

1. Biodiversity/Environmental impacts

Most of the biological resources of wetlands are passing through a critical phase of ecological transition. The wetlands are known for their rich biodiversity reserves in the form of wildlife, plants and animals but presently this significant characteristic is losing grounds at an alarming pace. Fish and fisheries, which occupies a very high priority area of economic gain and has been one of the traditional mode of aqua-farming, has, of late, suffered a great deal affecting the rural economy adversely. The wetlands of Ganga floodplain have been subjected to indiscriminate and disproportionate exploitation to the extent that many fish species have either became endangered or a number of them have already vanished from the scene. Lopsided growth of fish food organisms affecting the food chains has engineered significant alteration in the composition of fish catch structure, such as:

- *Highly prized carp dominant fishery to less valued minnows dominant fishery and in the bargain more proliferation of predators, resulting in considerable decline in harvestable fish crop* (Table 2).

The present trend of bio-productions from wetlands may be attributed to the proliferation of unwanted biota due to eutrophication. Most of the floodplain lakes in Ganga basin are reeling under severe colonization of unwanted macrophytes. The manifestation of this development is heading towards a condition of complete chaos either due to the creation of a under water desert due to surface coverage of floating macrophytes or nutrient deficient ambient water owing to locking of nutrient in hydrophytic chain. The net result is poor growth of biota required to support effective grazing chains. Macrophytes dominated water phase and molluscs dominated benthic phase are the hallmark of most of our wetlands in Ganga basin. Paradoxically, neither the macrophytes nor the molluscs are able to enter the grazing chain due to the absence of efficient grazers, thereby the out-put of fish crop suitable for human-welfare has sharply declined. The carp fishery in the wetlands of Gandak basin has been found to be a meager 1.50-8.0%, contrary to minnows which accounted for more than 60% in many cases (Jha, 1995; Sinha and Jha 1997, Jha and Chandra, 1997).

One of the major factors for the low yield in fish biomass and the decline in fish species of wetlands is poor ingress of brooders/ spawn from riverine stock due to river valley modifications and subsequent choking or siltation of connecting channels.

Table 2. Fishery of certain ox-bow lakes of Gandak basin, Bihar (Sinha & Jha,1977)

Lakes	**% abundance of different group**			
	Major carp	*Cat fishes*	*Miscellaneous*	*Shrimp*
Manika, Muzaffarpur				
1980	08.30	43.50	45.20	03.00
1981	03.09	41.30	50.00	05.88
1982	05.32	36.20	39.08	19.40
1984	14.67	23.24	45.68	16.41
Brahmpura, Muzaffarpur				
1980	22.00	18.90	53.71	05.39
1981	03.38	29.60	58.45	08.57
1982	12.00	24.00	58.75	30.25
1984	-	-	-	-
Kanti, Muzaffarpur				
1986	12.25	62.16	18.48	07.11
1987	12.85	53.81	22.99	10.35
Muktapur, Samastipur				
1988	09.03	24.67	53.77	12.53
1989	11.45	18.11	58.34	12.10
1990	15.87	17.06	57.25	09.82
1991	21.00	14.99	60.08	03.93

Wetlands inhabitants/socio-economics

The floodplains are known for their socio-economic values in rural India, specially in relation to Agriculture and Fisheries. During their early period of settlement the inhabitants extensively relied on natural resources such as forests, pastures and waters for food and other materials. Fishery continued to remain an important resource for landless or marginal farmers who earn their bread and butter through fishing from these wetlands. It has been observed that the pressure on fishing in these water bodies has increased many fold increase in population and changed land use patterns. This has led to a situation of over exploitation and accordingly once held popular belief that *Wetlands are renewable source of energy in the form of fish biomass* is losing its meaning very fast. The highly lucrative fish and fishery from such waters of earlier years has become almost a subsidiary occupation leading to large scale disguised unemployment.

The increased population and subsequent increase in efforts, in the face of diminishing biological resources, have resulted in conflicts amongst the various user groups. Gradual loss of wetlands, reduction in biodiversity including fishery, reduction in wildlife habitat etc. have led to a significant *shift from wetland based human occupation to other petty jobs* and as a result the wetland resource dominated areas have experienced a crunch in socio-economic front.

Sustainable fisheries development from wetlands

The wetlands in Assam, Bihar and West Bengal under Ganga and Brahamputra basins have shown high fish production potential in the range of 1000-2000 kg/ha/yr. Many of the wetlands, specially the live ox-bow lakes, with connecting channels with rivers, and tectonic lakes (e. chaurs of Bihar and beels of Assam), are known to act as collection sink of riverine fish stock due to the ingress of flood waters. Contrary to reservoirs with estimated average fish yield of 20 kg/ha/yr (Sugunan 1995), floodplain lakes have indicated an average yield of more than 150 kg/ha/yr even in unmanaged State.

Present status

The floodplain lakes or wetlands are generally neglected ecosystems. However, certain lakes under different states are partially managed, specially on the line of aquaculture like stocking and harvesting of fish biomass. It has been observed, however, that the fisheries management of wetlands is more of ad-hoc type rather than based on any principled or scientific approach. In case of the partially managed wetlands, fishermen cooperative societies manage such lakes on share basis. It was of general belief that harvesting of fish from wetlands renewable in nature due to their riverine connection. But, it is not the case currently as most of the water bodies have lost this vital characteristic due to a number of factors. The wetland ecosystem remains no more lucrative in terms of fish out-put for which the following factors may be held responsible.

- Destruction of habitat at an alarming rate on account of river valley modifications like deforestation, civil constructions etc.

- Large scale reclamation of the marginal areas of wetlands either for agriculture or for human settlements.

- Leaching of agriculture wastes, industrial and domestic effluents and autochthonic input of nutrients have led to high degree of eutrophication affecting the fish and fishery adversely.

- Poor autostocking of prized fish seeds together with wanton killing of juveniles and brood fish stock.

- Irrational and conflicting land use pattern in their catchment areas.

- Lack of scientific innovations and poor state of management

- Poor financial status of fishermen community and injudicious application of nets and crafts

- Poor understanding of ecological intricacies and conservation methods.

Prospects

The high productivity potential and very low level of its present realization, has left enough scope for improvement through scientific management of these precious ecosystems. The sustainable fisheries development may be the answer for effective conservation not only to biological resources but also the physical status of the wetlands.

Fish and fisheries in wetlands has a long history since the very inception of civilization. Besides fishery has a significant role in the overall sauce-economic status of wetland dominated states. It is imperative, therefore, that these natural resources are not lost for ever. However, for its sustainable fisheries development, the conservation norms have to be incorporated in right earnest to achieve the goal of sustainability. In order to do that a balanced approach has to be made 'micro' and 'macro' level planning.

Macro-level planning

Macro level planning has greater role to play with long term impact and as such it requires serious attention. The following aspects have to be taken care of for sustainable development of fish and fisheries.

- The mechanism for transfer of scientific technology should be strengthened.
- Environmental education/ awareness must be made mandatory, specially amongst the target group i.e. fishermen community
- Fishermen Cooperative Societies must be strengthened and made accountable.
- The credit and subsidy schemes should be strengthened with certain degree of rationality.
- The fishermen folk should be trained properly for better understanding of production functions.
- Like other crop, fishery sector should also use brought under insurance Scheme.
- Prioritization of wetlands based on economic, cultural, aesthetic and socio-economic considerations.

Micro level planning

- Holistic approach of development is a must with proper identification of activities to be implemented.
- Required quantity and timely arrangement of finance for effective execution of the project or projects concerned.
- Proper monitoring of activities in the frame-work of environmental variables etc.

Conclusion

The wetlands are one of the prime and traditional fishery resources in the country with tremendous scope for fisheries development. It is a paradox, however, that these natural gifts have been subjected to indiscriminate exploitation affecting the fishery as well as its biodiversity. Among so many activities fish and fishery in wetlands occupy a center stage, as a large chunk of human population has been directly linked with these water bodies for livelihood. The view that fishery, has a negative impact on such ecosystems is not true. We have experienced while working in different wetland ecosystems in Bihar, UP, West Bengal & Assam that those lakes where fishery activities are practiced regularly have indicated better aquatic regimes as compared to lakes without any fishery activities. Thick stand of macrophytes has been the hallmark of these water bodies creating hostile aquatic regime and adversely affects the useful biota, an indication of gross environmental degradation of such lakes. The process of swampification has been found to be rapid in such lakes which are either neglected or over exploited. Detailed survey of lake districts of Ganga basin has indicated highly discouraging facts that within a period of 30 years almost 35% of the wetlands have lost their aquatic characteristics. It is imperative, therefore, there is a need to conserve these resources rather than being bogged down on conflicting issues. The question of conserving biodiversity becomes irrelevant if the very existence of wetlands is lost. *Sustainable development implies rational utilization of resources, both physical and biological, without compromising the ability of future generation to garner its needs.* In the light of this it becomes the duty of all concerned to conserve this vital aquatic resource so as to harness beneficial biomass including fish to bridge the widening gaps between demand and supply in animal protein besides providing gainful employment to thousands of rural poor.

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ECOLOGY AND FISHERIES OF THE FLOODPLAIN WETLANDS OF THE RIVER BRAHMAPUTRA

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Floodplains of the rivers Ganga and Brahmaputra are characterized by the presence of wetlands, which are locally known as *mauns*, *chaurs*, *beels*, *jheels*, and *pats*. They can be typical oxbow lakes (*i.e.,* cut off portions of the meander bends), sloughs, meander scroll depressions, backswamps, residual channels, tectonic depressions or meteorite craters. Floodplain wetlands are considered as biologically sensitive ecosystems as they play a vital role in the recruitment of fish populations apart from providing nursery grounds for numerous fish species. They also perform a variety of vital functions including groundwater recharge, flood attenuation, sediment trapping, nutrient and toxicant removal and detention, water quality improvement and food chain support. A combination of the processes of river bed evolution and the effects of extensive flood control and irrigation works have reduced the production levels of many of these lakes. On account of siltation, habitat destruction, heavy weed infestation and isolation from the seasonal floods, these water bodies are deprived of the natural source of fish stock. Since floodplains with their associated lentic water bodies are a continuum of rivers, all the conservation and management norms prescribed for the rivers are equally applicable to them. Indiscriminate killing of brood fish and juveniles of commercial species during the recruitment phase badly hampers the production in the floodplain lakes as well as the parent river. Total area of floodplain lakes in India are estimated at 0.2 million ha (Sugunan, 1995) distributed mostly in the States of Assam, West Bengal, Bihar, Uttar Pradesh and Manipur (Table 1).

Floodplain wetlands of Assam

In India, the state of Assam has the maximum number and water area under floodplain wetlands, mainly associated with the rivers Brahmaputra and Barak. Locally known as *beels*, they are mostly oxbow lakes, backswamps or tectonic formations. The predominance of floodplain wetlands in Brahmaputra basin is attributed to the oft-changing course of rivers and their tributaries in the upper stretches. The river Brahmaputra passes through zones of acute seismic activity. Frequent earthquakes due to crustal instability induces local and sudden shifts in basement levels. This, coupled with heavy discharge of water, triggers the process of meander cutoffs leading to formation of oxbow lakes. Tectonic depressions are also formed due to earthquakes. Similarly,

Table 1. Distribution of floodplain wetlands in India

State	**River basins**	**Area** (ha)
Arunachal Pradesh	*Kameng, Subansiri, Siang, Dibang, Lohit, Dihing, Tirap*	2,500
Assam	*Brahmaputra*, Barak	100,000
Bihar	Gandak, Kosi	40,000
Manipur	Iral, Imphal, Thoubal	16,500
Meghalaya	Someswari, Jinjiram	213
Tripura	Gumti	500
West Bengal	Hooghly, Matlah	42,500
Total		202,213

Brahmaputra is prone to frequent and heavy floods which break the leevees leading to formation of backswamps and sloughs. Assam has 1,392 *beel*s spreading over more than 100,000 ha. This includes 322 on the river Barak in the districts of Hailakandi, Karimganj and Silchar with a water spread of 8,000 ha (Yadava, 1989). Total area of *beel*s associated with the river Brahmaputra and its tributaries is estimated at 94,500 ha (92,000 ha in Assam and 2,500 ha in Arunacal Pradesh).

Ecological status of floodplain wetlands in Assam

Floodplain wetlands form the most important fishery resource of Assam, contributing to the State's fish production to the extent of 12.5%. CIFRI has conducted an ecological assessment of floodplain lakes in Assam covering physico-chemical quality of water and soil, rate of primary productivity at phytoplankton phase, abundance and quality composition of various biotic communities and the fishery management norms practiced. Results obtained in respect of 23 *beel*s are outlined below:

Sediment and water quality

Although the soils in most of the *beel*s in Assam are acidic in nature, organic carbon levels are moderate to high (0.55 to 2.28 %) indicating high biological productivity (Table 2). Water is generally clear with transparency ranging from 17 to 98 cm and in many cases, the bottom is visible. Chemical makeup of water in terms of pH, total alkalinity, specific conductivity and total hardness are more conducive to biological productivity in the *beel*s of Golaghat and Tinsukia which is accompanied with a perceptibly higher concentration of the ions like calcium and magnesium (Table 2). This is reflected well in the distribution of benthos populations in the *beels*. However, dissolved nutrients such as nitrates and phosphates are invariably low as they seem to be absorbed at a fast rate by the macrophyte community.

Table 2. Soil and water quality of selected beels

Parameters	**Districts**					
	Golaghat	Jorhat	Sibsagar	Tinsukia	Dibrugarh	Dhemaji
Soil						
Number of beels	5	2	3	4	3	6
pH	4.8-7.4	5.2-5.6	5.0-5.8	4.7-7.2	5.0-5.7	4.6-5.7
Organic Carbon(%)	0.55-1.32	1.0-1.78	0.9-2.0	0.60-2.28	1.1-2.0	0.50-1.78
Water						
Transparency (cm)	41.5-BV	27-98	19.0-46.3	64.0	17.0-18.0	35.0-BV
pH	7.6-8.0	6.8-7.6	6.2-7.1	6.5-7.4	6.0-7.4	6.5-7.6
Dissolves oxygen(mg/l)	7.8-13.6	-	1.6-7.5	6.4-11.0	0.7-6.6	5.0-9.8
CO_2 (mg/l)	1.9-3.8	1.9-2.8	2.8-19.6	2.8-9.5	3.8-12.3	1.9-5.7
Sp. Cond. (µmhos)	102.5-335	54.6-148.7	14.6-88.8	84.2-248	61.3-229	7.7-218.0
Total alkalinity(mg/l)	37-164	30.9-96.5	14.5-54.6	36-135	36.4-89.1	6.0-120
Total hardness(mg/l)	49.5-169	18.7-48	19.2-48.1	46.3-124	43.2-62.5	10.0-89
Chloride(mg/l)	14.7-19.6	29.4-34.3	24.5-31.8	19.6-29.4	24.5-44.1	14.7-24.5
Calcium(mg/l)	19.8-64.3	7.7-13.4	3.8-5.8	9.9-64.3	3.8-5.8	5.0-59.4
Magnesium (mg/l)	29.7-84.6	3.5-5.0	1.8-8.6	29.7-59.4	8.2-10.5	5.0-34.6
Total iron (mg/l)	0.16-1.18	0.2	0.2-0.9	0.2-0.4	0.3-1.0	0.02-1.70
Phosphate(mg/l)	Tr-0.01	Tr-0.01	Tr-0.01	Tr-0.01	Tr-0.01	0.02-0.04
Nitrate (mg/l)	Tr-0.03	0.02-0.03	0.02	Tr	0.02	0.02-0.03
DOM (mg/l)	1.55-2.05	1.1-1.8	1.6-1.8	2.20-4.90	1.4-2.2	1.85-3.63

Primary productivity

The rate of carbon production by phytoplankton varies widely among *beels*/districts. Gross and net production range from 562 to 2,250 and from 0 to 1,717 mgC/m^3/day respectively (Table 3). Very low rates of net primary productivity (0 to 281 mgC/m^3/day) are recorded in weed-choked *beels* namely, Dikhow *mornai* (Sibsagar) and Puwasaikia (Dhemaji) respectively. On the other hand, the rates are high in Boka and Somrajan North *beels* of Sibsagar and Dhemaji districts respectively. However, these values represent only a small fragment of total productivity of these *beels* since, on an average, phytoplankton contributed to about 30% of the total primary production.

Biotic communities

Plankton population is negligible in the beels of Jorhat such as Borchala and Gorarmaj which are weed-choked. Puwasaikia, Kesukhana (both Dhemaji district) and Motapung (Tinsukia) recorded scanty plankton community (Table 3). In the others, plankton count range from 10 (Moridisoi) to 84 (Hollodunga). Open *beels*, which generally harbour less macrophytes, are favourably disposed for energy transformation through phytoplankton.

Benthic communities vary widely in the *beels* (0 to 960 organisms/m^2). Of the three b*eels* of Tinsukia district, Mota and Rampur beels are devoid of any benthic community. Motapung in the same district has a thin population of 32 units/m^2. The beels of Golaghat district are uniformly rich in bottom macrofauna (128-864 organisms/m^2). In Dhemaji, except Keshukhana with an exceptionally high density (960 organisms/m^2), all the others have scanty or nil population of benthos. Gastropods dominated the benthic organisms followed by bivalves, oligochaetes and insects.

Table 3. Primary productivity and some biotic communities in the *beels* surveyed in Assam

District	**Primary productivity** *(mgC/m^3/day)*			**Infestation of macro-phytes** *(%)*	**Numerical Abundance**	
	Gross	**Respiration**	**Net**		**Plankton** *(per litre)*	**Benthos** *(per m^2)*
Golaghat	750	225	562.5	20-70 *H, Cp, Wh*	10-42 *Ch, Bc, M*	128-864 *G, B, O*
Jorhat	-	-	-	70-80 *H,Wh*	Nil-16 *Bc,Cp*	64 -224 *G,O*
Sibsagar	925 - 1717.5	0-1110.0	0-1717.5	60-90 *Wh, V*	10-41 *Cp,Bc*	0-32 *G*
Tinsukia	750	600	250	70-90 *T, Wh*	0-20 *Ch*	0-32 *G*
Dibrugarh	-	-	-	50-80 *N, V*	18-49 Cp,, Cd	0
Dhemaji	562.5-2250	225-600	187.5-1750	Cl-90 *Wh, H, Nj*	0-84 *Bc, M, Ch*	32-992 *G, B, In*

Cl- clear, Wh- *Eicchornia crassipes*, V- *Vallisneria*, T- *Typha*, H- *Hydrilla*, N- *Nymphaea*, C- *Chara*
Nj- Najas
G- Gastropods, O- Oligochaetes, B- Bivalves In- Insects
Bc- Bacillariophyceae, Ch - Chlorophyceae, M - Myxophyceae, Cp - Copepods, Cd - Cladocera

Closed *beels* are mostly choked with floating (water hyacinth), submerged (*Najas*, *Vallisneria*, *Hydrilla*) and marginal (*Typha*) vegetation. Dense mat formation by marginal and floating macrophytes is observed in a few beels like Motabeel (Tinsukia). Udaipur beel in the same district is choked with water hyacinth. Open beels like Galabeel (Golaghat district) are almost free from weed infestation. However, Samrajan north in the district of Dhemaji has a good standing crop of macrophytes despite being an open *beel*.

Fish and fisheries

Fish yield of the *beels* surveyed are in the range of 163-243 kg/ha/year, most of them being managed on capture fishery norms by exploiting the natural fish stock. In the absence of any species management, these *beels* are dominated by small fishes (*Puntius* spp., *Colisa* spp., *Chanda* spp., *Mystus vittatus, Ambassis* sp., *Amblypharyngodon mola, Nandus nandus, Mastacembelus pancalus, Botia* sp., small prawns), carnivorous catfishes (*Wallago attu, Ailia coila, Ompok bimaculatus)* and air breathers *(H. fossilis, Channa punctatus, A. testudineus, N. notopterus)* and others (Table 4).

Table 4. Fish and fisheries of the *beels* surveyed in Assam

District	Area (ha)	Depth (m)	Dominant fish	Fishing methods
Golaghat	10-50	1.0-5.0	*Puntius* spp., *Danio spp.*, *Colisa* spp., *Botia* sp., *M. pancalus, M. vittatus,* small prawns, *L. gonius, W. attu*	drag net, gill net, surrounding net, cast net
Jorhat	30-89	0.9-4.5	*Puntius* spp., *Danio* spp., *Colisa* spp., *Botia sp., M. pancalus, Chanda spp., L. gonius, W. attu, A. mola*	gill net, cast net, surrounding net, *Jeng fishing*
Sibsagar	4-180	0.8-3.0	*Puntius* spp., *Danio spp.*, *Colisa* spp., *Botia* sp., *M. pancalus, M. vittatus,* small prawns, *L. gonius, W. attu*	drag net, surrounding net, *Jeng fishing*
Tinsukia	30-70	1.5-7.0	*Puntius* spp., *Danio* spp., *Colisa* spp., *Botia sp., M. pancalus, Chanda spp., L. gonius,L. calbasu, W. attu, A. mola,* small prawns	gill net, surrounding net, drag net, traps
Dibrugarh	20-45	1.0-6.0	*Puntius* spp., *Danio* spp., *Colisa* spp., *Botia* sp., *M. pancalus, M. vittatus,* small prawns, *C. punctatus, H. fossilis, A.. testudineus, L. gonius, C. catla, W. attu*	long line, gill net, *Jeng fishing*
Dhemaji	10-65	1.0-3.0	*Puntius* spp., *Danio spp.*, *Colisa* spp., *Botia* sp., *M. pancalus, M. vittatus,* small prawns, *L. gonius, W. attu*	drag net, gill net, surrounding net, cast net

Fishing methods followed in the *beels* are drag nets, surrounding nets, traps, *katal/jeng* fishing, long lines and gill nets. Small prawn form a substantial fishery in beels of Tinsukia and Golaghat districts.

Fishery status of the floodplain wetlands of Assam

By virtue of their high nutrient status, warmer water regime and the rich sunshine, *beels* of Assam are considered to be a highly productive ecosystem. In fact, many of them are passing through transient phases of eutrophication leading to weed choking. These water bodies are extremely rich in nutrients as reflected by rich organic carbon and high levels of available nitrogen and phosphorus in the soil. But, generally, the nutrients are locked up in the form of large aquatic plants, especially water hyacinth, which are not readily available as food for fishes. Decaying weeds are the main source of organic detritus at the bottom which normally support a good bottom macrofauna, comprising mainly the molluscs. However, sometimes, excessive deposition of organic matter leads to anaerobic conditions. Similarly, due to the acidic nature of the soil-water interface, release of nutrients from the soil to water is hampered.

A unique feature of the floodplain wetlands of Brahmaputra basin is the rich growth of marginal and submerged vegetation due to the allochthonous and autochthonous nutrient loading. These macrophytes often tend to replace the plankton community. Progressive replacement of plankton community with macrophytes as the main primary producer hastens the pace of eutrophication. This also leads to higher rate of evapo-transpiration and swampification of the lake. However this process can be reversed through effective management.

Types of *beels* and their management

The oxbow lake type *beels* of Assam belong to two distinct categories *viz*., the *open* beels which retain their connection with the parent river and the *closed* beels which do not have such a connection. Many closed *beels* tend to swampify at a faster rate, compared to the open ones. The two types vary widely in their nutrient status and species composition. In the open *beels*, the fishery management strategy is essentially akin to capture fisheries where the natural fish stock is managed and harvested. A thorough insight into population dynamics including recruitment, growth and mortality is very much essential to manage such systems. In order to ensure recruitment, the following parameters are taken into consideration:

(1) Identification and protection of breeding grounds,
(2) allowing free migration of brooders and juveniles from *beel* to river and *vice versa*
(3) protection of broodstock and juveniles by conservation measures.

Completely closed *beel*s or those with a very brief period of connection with the river are the ideal sites for practicing *culture-based fishery*, which emphasizes the stocking and recapture. In culture-based fishery, the growth is dependent on stocking density and survival is dependent on the size of the stocked fish. The right species stocked in right numbers in right size and their effective recapture at the optimum size are the determining factors. The basic management strategies in closed *beel*s can be summarized as size at stocking, stocking density, fishing effort management, size at capture and species management (Vinci, 1997).

Goswami (1997) who recorded 66 species of commercially important fishes from the floodplain wetlands of Assam, categorized them under major, intermediate and minor groups (Table 5). A disturbing trend of shift in the catch composition has been reported in recent years. The major group used to dominate (58%) the catch, followed by intermediate (26%) and minor groups (16%). Now the minor group contribute 57 % of the catch followed by the major group (24%0 and the intermediate (19%).

The current annual fish production from the floodplain wetlands of Assam is about 19,000 t, which is equivalent to 12.5 % of the total fish production in the state. The yield rate vary widely among the *beel*s of upper (163 kg/ha), lower (173 kg/ha) and central (225 kg/ha) parts of the state. Similar variation in yield exists among the floodplains wetlands associated with the northern (243 kg/ha) and southern (172 kg/ha) tributaries of Brahmaputra. It has been estimated that the floodplain wetlands of Assam can achieve an average yield of 1,000 kg/ha at higher levels of management.

Table 5. Commercial fish species of floodplain wetlands in Assam

Major	Intermediate	Minor
Catla catla, Cirrhinus mrigala, Labeo rohita, Labeo calbasu, Labeo gonius, Labeo nandita, Notopterus chitala, Aorichthys aor, A. seenghala, Rhinomugil corsula, Wallago attu, Channa marulius, C. striatus, Bagarius bagarius,	*Labeo bata, Cirrhinus reba, Eutropiichthys vacha, Clupisoma garua, Ompok pabo, O. bimaculatus, Heteropneustes fossilis, Clarias batrachus, Rita rita, Channa punctatus, C. stewarti, Puntius sarana, Mastacembelus armatus, M. puncalus, Macrognathus aculeatus, Nandus nandus, Notopterus notopterus, Anabas*	*Puntius sophore, P. phutunio, P. conchonius, P. gelius, P. ticto, Oreichthys casuatis, Clupisoma atherionoides, Gadusia chapra, Rasbora elanga, R. rasbora, R. daniconius, Salmostoma bacaila, Chela laubuca, C. atpar, Amblypharyngodon mola, Aspidoparia morar, A. joya, Mystus tangra, M. vittatus, M. cavasius, M. bleekeri, Batasio batasio, Lepidocephalus guntea, Chanda ranga, C.*

Pangasius pangasius	*tesudineus, Xenentedon cancila, Glossogobius giuris*	*nama, Badis badis, Tetradon cutcutea, Brachidanio rerio, Danio davario, Chaca chaca*

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IMPACT OF TRIBUTARIES ON ECOLOGY AND FISHERY OF RIVER BRAHMAPUTRA

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Introduction

The mighty Brahmaputra, "a freshwater moving ocean of North East" originates from the strout of chemayung mountains near Tachhong (Tamchok) about 100 Km south East of Lake Mansarovar at an altitude of 5150 m (Latitude 30° 31' N and Longitude 82° 10'E). It runs about 1250 Km in a shallow valley through Tibet as river Tsangpo almost parallel to Himalayan range before entering India near Tuting, Siang district of Arunachal Pradesh. Running about 160 Km in Arunachal Pradesh as river Dihang or Siang the river enters Assam on the North West of Saidiya where it meets two equally important trans Himalayan tributaries Dibang and Lohit and then assumes the name Brahmaputra. It runs about 720 Km in the state of Assam before entering Bangladesh as river Jamuna. The river is joined by many tributaries on both the banks in Assam, the combined length of the river along with its tributaries being around 4000 Km with a catchment area of 5,80,000 Km^{-2}.

Informations regarding ecology of R. Brahmaputra are very limited. Studies made so far are localised to few stretches only and practically nothing is known about its tributaries specially their impact on the main river. Attempts have been made to throw light on the ecology and fisheries of important tributaries and their impact on river Brahmaputra in this communication.

2. Water quality of important tributaries

The water quality parameters of Siang, Dibang and Lohit, the three fore-runners of Brahmaputra as well as the main tributaries have been presented in Table-1. The common features of the three rivers Siang, Dibang and Lohit were low temperature (10.7 to 12.5°C), high transparency (128.0 to 164.0 cm), rich oxygen (9.02 to 10.0 mgl-

1) alkaline pH (7.6 to 7.65), high dissolved organic matter (1.60 to 1.90 mgl^{-1}) and poor nutrients (Nitrate 0.015 to 0.025 & phosphate 0.005 to 0.055 mgl^{-1}). But considerable variations were observed in respect of chemical parameters- alkalinity, conductance, dissolved solids, calcium and hardness all being maximum in Siang (62.67 mgl^{-1}, 141.0 µmhos, 71.3 mgl^{-1}, 14.72 mgl^{-1} and 60.8 mgl^{-1} respectively) and minimum in Dibang (35.72 mgl^{-1}, 99.8 µmhos, 50.6 mgl^{-1}, 7.68 mgl^{-1} and 38.4 mgl^{-1} respectively).

The water quality parameters of North bank tributaries showed considerable variations in respect of alkalinity conductance, dissolved solids, calcium, Magnesium and hardness all being maximum in Manas (207.67 mgl-1, 345.5 µmhos,173.84 mgl^{-1}, 25.7 mgl-1, 22.02 mgl-1 and 155.8 mgl-1 respectively) and minimum in Ranganoi (23.5 mgl^{-1}, 52.6 mhos, 26.6 mgl^{-1}, 6.4 mgl^{-1}, 3.0 mgl^{-1} and 32.1 mgl^{-1} respectively). The values of all the above parameters in the other North bank tributaries ranged between the above two extremes. South bank tributaries also showed considerable variations in respect of alkalinity, conductance dissolved solids and hardness all being maximum in Digharu (131.6 mgl^{-1}, 299.0 µmhos, 150.0 mgl^{-1}, and 86.4 mgl^{-1} respectively) and minimum in Krishnoi (29.76 mgl^{-1}, 53.9 µmhos, 27.2 mgl^{-1} and 28.8 mgl^{-1} respectively). The common features of all the tributaries were rich oxygen, poor nutrients and rich organic matter. It is interesting to see that none of the two tributaries are similar in respect of water quality and the qualitative difference clearly shows the impact of catchment. The diverse hydrological set up of various tributaries have great bearing on the water quality of the main river.

3. Water quality of river Brahmaputra

The river was found to be rich in oxygen (7.0 to 8.5 mgl^{-1}), alkaline in reaction (pH 7.5 to 7.9) rich in dissolved organic matter (1.39 to 1.84 mgl^{-1}) and poor in nutrients (Nitrate 0.01 to 0.038 mgl^{-1}) & phosphate 0.003 to 0.016 mgl^{-1}) throughout the stretch. But considerable inter-stretch variations were observed in respect of chemical parameters alkalinity, conductance, dissolved solids and hardness all being maximum in Goalpara (76.23 mgl^{-1}, 174.6 mhos, 88.1 mgl^{-1} and 84.34 mgl^{-1} respectively) and minimum at Tezpur (56.9 mgl^{-1}, 134.6 mhos, 67.3 mgl^{-1} and 64.8 mgl^{-1} respectively). Comparatively higher values of above chemical parameters at Saidiya, the confluence point of three rivers was due to the impact of Digharu and Kondil rivers which join Lohit before saidiya and the water quality being more influenced by Lohit. At Dibrugarh considerable drop in the above parameters was mainly due to the impact of Dibang and Siang rivers. Considerable drop in the values of transparancy below saidiya down upto Dhubri was mainly due to high silt load brought into the river by tributaries joining between these stretches (Table 2).

4. Impact of tributaries on the water quality of Brahmaputra

Considerable inter-stretch variations in the water quality parameters of River Brahmaputra clearly reflect the impact of various tributaries joining between the stretches. The impact in some of the major tributaries have been shown in Table 3. The clear examples are the impact of Jiabharali at Tezpur, Manas at Goalpara (Jogighopa) and Gaurang, Tipkai and Gadadhar at Dhubri. As shown in the table the alkaline waters of Hiabharali resulted in sharp decline in the values of alkalinity, conductance, dissolved salts. Calcium and hardness of river at Tezpur and the impact can be seen even upto the Forestghat. In fact the water quality of Brahmaputra at Tezpur reflected more of the tributaries Jiabharali than its own. Similarly at Goalpara the highly alkaline Manas water resulted in sharp increase in the values of alkalinity, conductance, dissolved solids, calcium and hardness at the confluence point and the impact can be seen much below the confluence (Table-2). In fact the vast sheet of water at Goalpara reflected the characteristics of Manas river than the main river. A sudden decline in the values of above chemical parameters at Dhubri from much higher values at Goalpara again reflected impact of the low alkaline waters of Gaurang, Tipkai and Gadadhar, which join Brahmaputra between Goalpara and Dhubri. In fact the various tributaries joining Brahmaputra, both in North and South banks have considerable impact on the waste quality of the main river although with varying magnitude. It can thus be concluded that in maintaining the annual water quality cycle of river Brahmaputra the tributaries play key role.

5. Impact on biological characters

Considerable qualitative and quantitative shift in the biological characters also reflected the impact of various tributaries. With respect to planktonic structure considerable variations were observed between the stretches. Myxophyceae and Bacilariophyceae were main plankters in saidiya but at Dibrugarh Chlorophycea increased to 37.1% with considerable decline in diatoms and complete disappearance of Myxophyceae. The stretch between Jorhat and Tezpur was again dominated by diatoms (88 to 96%). The downstretch between Guwahati and Dhubri, however, showed shift towards (Chlorophyceae (38.2 to 50.9%). It is interesting to mention that the tributaries in the downstretch were all dominated by chlorophyceae and the increase in the population of chlorophyceae in the main river reflected the impact of these tributaries.

In respect of benthic population considerable qualitative and quantitative variations were oberved between Saidiya and Dhubri the population being maximum at Dibrugarh (365 nos m^{-2}) and minimum at Biswanath ghat (32 nos m^{-2}). The down stretch between Guwhati and Dhubri represented higher population of Gastropods (46.4 to 65.9%), at the upper stretch, Saidiya and Dibrugarh both Gastropods and bivalves while chironomids dominated in Biswanathghat (75.0%) and Tezpur (71.7%). The stretch Jorhat represented maximum population of Oligochaetes (57.2%). It may be recalled that the qualitative picture of benthic structure in the tributaries joining various stretches were almost similar to those observed in the main river, thus, reflecting their considerable impact.

Similar inter-stretch variations were also observed in respect of rate of carbon production and energy transformation by producers the values being maximum at Dhubri (359.32 $mgCm^{-2}$ day^{-1} & 3528 Cal m^{-2} day^{-1}) and minimum at Biswanathghat 212.56 $mgCm^{-2}$ day^{-1} & 2087 Cal m^{-2} day^{-1}). The production rate showed a gradual increase between Bishwanathghat and Dhubri. Based on the energy flow studies the fish production potential of the river was estimated between 72.3 and 122.2 $kgha^{-1}$ yr^{1} being maximum in Dhubri and minimum at Biswanathghat.

6. Impact on fishery

The average daily fish landing from Siang, Dibang and Lohit the fore runners of Brahmaputra were 91.0 kg day^{-1}, 102.2 kg day^{-1} and 62.5 kg day^{-1} respectively. Fishery was almost similar in all the rivers mainly represented by Mahseer *Tor putitora* & *Neolissocehilus hexagonolepis, Schizothorax richardsoni* among trout and cold water species *L. dero* and *L. dyocheilus.* Among the stretches of Brahmaputra only Saidiya showed considerable representation of above species (68.6%) in the total catch. But in other stretches miscellaneous species were dominant followed by catfishes, major carps, minor carps and feather backs. In the stretch between Dibrugarh and Dhubri the contribution of Mahseer and other cold water species were negligible. The average daily catch in the entire stretch between Saidiya and Dhubri fluctuated between 53.8 to 120.2 kg day^{-1} being maximum in Dhubri and minimum in Goalpara. Although the qualitative picture of the fishes was similar between Dibrugarh and Dhubri with an overall dominance of miscellaneous species in the commercial catches the percentage composition of various groups showed considerable variations between the stretches. The fishery of some of the major tributaries Subansiri, Noadibing, Jaibharali, Manas, Beki etc. have shown very interesting patterns. Almost 80 to 90% of the catches from upper stretches of these tributaries were represented by Mahseer *Tor putitora, Neolissocheilus hexagonolepis* and cold water species *L. dero* and *L. dyocheilus* while the catches from the down stretches towards the confluence point mainly comprised of major carps, minor carps catfishes and miscellaneous species. The daily fish catch from the major tributaries fluctuated between 20 kg to 200 kg. Among the southern tributaries Burhidihing was the most productive and almost 50% of the total landing at Dibrugarh centre was contributed by this river.

The tributaries of Brahmaputra have great fishery potential and play vital role in the qualitative and quantitative fluctuation in the fisheries of the main river. The fish production potential of some of the tributaries, where studies have been made were 65.7 kg ha^1 in Subansiri, 60.7 kg ha^1 in Jia Bharali, 106.9 kg ha^1, in Manas, 133.3 kg ha^1 in Burhidihing and 67.2 kg ha^1 in Kalong. If the fish production potential of the tributaries and the main river are taken together the system as whole has vast potential energy resource as fish and if managed and exploited scientifically, it will be a real boon for both Assam and Arunachal Pradesh so far as fish production is concerned.

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Table 1. Water quality of imporant tributaries

Rivers	Water temp. (°C)	Transparency (cm)	Dissolved oxygen (mgl^{-1})	PH	Free CO_2 (mgl^{-1})	Total alkalinity (mgl^{-1})	Sp. Conductance (μmhos)	Total dissol-ved solids (mgl^{-1})	Chloride (mgl^{-1})
Siang	10.7	128.0	10.0	7.6	0.96	62.67	141.0	71.3	27.8
Dibang	12.5	164.0	9.02	7.6	1.92	35.72	99.8	50.6	24.5
Lohit	12.1	146.2	9.73	7.65	1.2	47.87	117.4	58.8	29.4
NORTH BANK TRIBUTARIES									
Jiadahal	20.5	31.0	7.04	7.55	0.95	61.07	185.9	93.7	20.8
Subansiri	14.2	86.4	8.49	7.55	0.96	48.8	123.3	61.9	21.2
Ranganoi	14.1	Upto bottom	8.33	7.2	1.89	23.5	52.6	26.6	21.2
Dikrong	16.3	63.5	8.45	7.15	1.27	25.81	62.2	31.4	21.2
JiaBharali	16.5	91.7	8.63	7.2	1.68	34.33	76.2	38.4	23.5
Jiadhansiri	19.0	17.4	7.58	7.2	1.60	44.27	106.1	53.8	26.2
Puthimari	21.0	23.4	8.12	7.65	1.42	93.15	181.0	91.3	25.5
Pagladia	21.5	27.8	8.04	7.7	1.43	95.67	186.2	93.1	21.5
Beki	17.0	49.0	8.80	7.52	1.87	50.58	120.68	60.7	23.1
Manas	21.5	29.6	7.69	7.87	1.67	207.67	345.5	173.8	27.2
Aie	21.6	44.2	8.0	7.6	1.5	137.2	249.5	125.2	26.7
Gaurang	20.7	43.0	7.37	7.35	2.26	36.03	78.3	39.5	25.1
Tipkai	21.7	35.1	7.14	7.2	2.06	46.54	91.32	46.12	21.6
Gadadhar	20.5	23.3	6.96	7.3	2.36	37.05	72.63	36.8	9.2
SOUTH BANK TRIBUTARIES									
Digharu	14.0	Up to bottom	8.10	8.1	Nil	131.6	299.0	150.0	19.6
Burhidihing	22.3	38.3	8.59	7.9	Nil	70.42	159.3	80.7	27.8
Kalong	18.5	29.0	7.3	7.3	2.36	45.1	88.9	44.5	25.7
Dudhnoi	19.9	27.5	7.92	7.2	1.66	28.60	55.4	28.0	23.3
Krishnoi	19.2	41.9	7.8	7.0	2.33	29.76	53.9	27.2	24.5

Table 1 contd/……..

Rivers	Silicate (mgl^{-1})	Calcium (mgl^{-1})	Magnesium (mgl^{-1})	Total hardness (mgl^{-1})	Dissolved organic matter (mgl^{-1})	Phosphate (mgl^{-1})	Nitrate (mgl^{-1})
Siang	3.5	14.72	5.95	60.8	1.66	0.024	0.225
Dibang	3.6	7.68	4.68	38.4	1.90	0.005	0.015
Lohit	5.0	12.96	4.95	50.3	1.60	0.055	0.021
TRIBUTARIES OF NORTH BANK							
Jiadahal	4.4	12.48	7.55	62.4	1.51	0.0045	0.02
Subansiri	4.3	11.6	8.49	60.7	1.70	0.004	0.025
Ranganoi	6.2	6.4	3.0	32.1	1.77	0.007	0.026
Dikrong	5.9	4.48	6.18	36.8	1.84	0.007	0.016
Jiabharali	5.1	9.97	3.70	40.3	1.71	0.004	0.025
Jiadhansiri	7.13	10.25	5.22	47.5	1.97	0.010	0.015
Puthimari	5.7	17.89	15.48	109.4	1.61	0.007	0.016
Pagladia	6.5	20.03	12.13	100.3	1.80	0.022	0.021
Beki	5.3	13.53	9.83	74.8	1.67	0.004	
Manas	6.0	25.7	22.02	155.8	1.73	0.010	0.016
Aie	6.0	23.60	17.42	132.1	1.54	0.046	0.023
Gaurang	6.4	6.34	6.22	41.72	1.90	0.0034	0.018
Tipkai	6.5	7.10	7.04	47.16	2.11	0.021	0.02
Gadadhar	9.2	4.31	7.27	41.35	2.42	0.015	0.032
TRIBUTARIES OF SOUTH BANK							
Digharu	5.2	30.72	2.34	86.4	1.36	0.002	0.015
Burhidihing	5.9	8.96	11.2	68.8	1.06	0.0053	0.029
Kalong	4.9	7.68	6.64	46.8	1.82	0.025	0.046
Dudhnoi	6.0	5.28	4.92	33.5	1.61	0.006	0.023
Krishnoi	6.8	4.8	4.04	28.8	1.63	0.007	0.023

Table 2. Water quality of river Brahmaputra in different stretches

Stretches	Water temp. (°C)	Transparency (cm)	Dissolved oxygen (mgl^{-1})	pH	Free CO_2 (mgl^{-1})	Total alkalinity (mgl^{-1})	Sp. Conductance (μmhos)	Total dissolved solids (mgl^{-1})	Calcium (mgl^{-1})	Magnesium (mgl^{-1})	Total hardness (mgl^{-1})	Chloride (mgl^{-1})	Silicate (mgl^{-1})	Dissolved organic matter (mgl^{-1})	Nitrate -e (mgl^{-1})	Phosphate (mgl^{-1})
Saidiya	17.8	87.2	7.32	7.5	2.22	68.02	149.0	75.3	13.61	12.36	78.0	19.6	6.0	1.59	0.022	0.016
Dibrugarh	18.7	43.5	7.00	7.63	1.58	57.51	137.1	69.5	14.72	6.96	65.6	19.6	4.7	1.41	0.038	0.005
Jorhat	18.0	36.9	7.92	7.62	1.14	71.0	155.3	78.5	19.95	5.61	72.8	29.4	4.84	1.68	0.018	0.004
Biswanathghat	18.0	43.0	8.45	7.63	1.27	64.6	156.7	79.0	15.44	8.48	73.6	19.6	5.3	1.84	0.03	0.004
Tezpur	19.4	35.4	7.72	7.53	1.73	56.9	134.6	67.3	12.48	10.17	64.8	22.3	4.8	1.74	0.022	0.004
Guwahati	19.2	38.0	7.73	7.5	1.52	71.2	150.78	76.1	17.66	8.57	79.68	22.5	5.24	1.39	0.036	0.0072
Goalpara	19.6	43.2	8.12	7.9	1.20	76.23	174.6	88.1	18.05	9.40	84.34	27.3	5.7	1.54	0.024	0.005
Dhubri	21.2	40.1	7.7	7.7	0.93	60.75	136.0	68.5	12.67	6.72	60.24	26.5	5.8	1.49	0.019	0.0052

Table 3 Impact of tributaries on water quality of river Brahmaputra

Stretches	Water temp. (°C)	Dissolved oxygen (mgl^{-1})	pH	Free CO_2 (mgl^{-1})	Carbonate (mgl^{-1})	Total alkalinity (mgl^{-1})	Sp. Conductance (μmhos)	Total dissolved solids	Calcium Ca^{++} (mgl^{-1})	Magnesium Mg^{++} (mgl^{-1})	Total hardness (mgl^{-1})
Impact of Jiabhorali on Brahmaputra at Tezpur											
Brahmaputra	18.0	8.2	7.6	1.89	NIL	70.44	160.4	80.8	18.62	11.52	88.4
JiaBharali	14.0	8.02	7.1	1.89	NIL	38.29	82.4	41.5	11.52	5.76	52.8
Confluence (OF)	15.0	8.12	7.2	1.89	NIL	40.4	84.8	42.4	12.82	5.6	58.8
Below confluence BOF-I	16.0	8.08	7.4	1.89	NIL	52.12	98.4	49.8	14.12	7.26	60.4
Below confluence BOF-II	18.0	8.12	7.5	1.89	NIL	64.61	147.2	74.4	15.36	10.8	80.8
Impact of Manas on Brahmaputra at Goalpara											
Brahmaputra	18.0	9.8	7.8	1.89	NIL	76.44	176.3	88.0	24.96	11.52	110.4
Manas	21.0	7.6	8.1	NIL	1.85	218.7	381.0	192.0	33.04	20.80	177.6
Confluence (OF)	20.0	7.4	8.1	NIL	0.95	172.9	338.0	171.0	32.56	20.34	172.0
Below confluence BOF-I	19.2	8.0	8.0	0.95	NIL	122.8	282.0	144.0	26.12	14.28	136.8
Below confluence BOF-II	18.0	8.6	7.8	0.95	NIL	101.92	207.0	104.0	26.25	12.67	114.6

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RIVERINE FISHERY RESOURCE OF INDIA AND THE STATUS OF FISH PRODUCTION

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Introduction

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

Human race is irrationally exploiting riverine resources together with their floodplain on account of this cultural eutriphication only a few large river systems of the world retain their original functional integrity and many have probably lost much of their capacity to adjust and recover from severe perturbation. It is one of the most striking manifestation of the human failure to utilize renewable resources without deterioration of their natural basin. When, we examine the status of Indian rivers in the above context, we found the same is valid for our rivers too. Most of the rivers have lost natural purity of water and are in the process of loosing biodiversity too. Thus, there is an urgent need for understanding the causes of eco-degradation and formulation of policies for recovery of aquatic wealth. Suitable management strategies have to be formed for thorough assessment of fish stock population alongwith regulatory measures for fishing. In the present communication the status of fisheries in major rivers of the India and causes of fish decline are discussed.

Riverine Resource of India

Nature has bestowed India vast expanse of open inland waters in the form of rivers, lakes, oxbow lakes and estuaries. These water bodies harbour the original germplasm of one of the richest and diversified fish fauna of the world, comprising 930 fish species belonging to 326 genera out of 25000 total fish species.

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 is furnished in Table 1 and brief description of fisheries resources is given below.

1. **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 Himalaya, 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 the fisheries is dominated by *Schizothorax* spp.; catfishes, *Mahseers* and *Labe*o spp. The commercial fisheries in this zone is non-existing due to sparse population, unaccessible terrain and poor communication between fishing grounds and landing centres. However, commercial fisheries assumes 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 are the species belonging to cyprindae (176 species) and siluridae (catfishes). The important species are: Gangetic major carps, catfishes, murrles, clupeids and featherbacks besides migratory hilsa. On an average fish yields has fluctuated in the stretch between a high of 230 t to 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 main reasons for decline in fish yield may be attributed to (1) sandification of the river bed (upto Patna) which reduced the rivers productivity due to blanket effect (2) marked reduction in the water volume on account of increased sedimentation (3) increased water abstraction and (4) irrational fishing. These are the main reasons for decline in fish yield, e.g. 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 1960's to 311.6 Kg Km^{-1} yr^{-1} and 629.8 Kg Km^{-1} yr^{-1} in

1990's respectively. The estimated mean annual fish landings of the some important landing centres on river Ganga is depicted in Table 2.

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 2.18 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 during 1972-79, 28.69 Kg ha^{-1} during 1980-86 and 15.19 Kg ha^{-1} during 1989-93. But 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 (Table 3). Thus, in general the fish yield potential is unadequately utilized in all the sectors leaving scope for further improvement.

Brahamaputra River System : The Brahamputra river originates from a glacier (Kubiangiri) in Tibet and has a combined length of 4025 km including its tributaries. The geological nascent state of Himalayas from where this river originates has substantially contributed to the high silt in the main channel. On account of this, Brahamputra river bed 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 river flows about 700 Km only. It is joined by Ganga in Bangladesh, forming the largest delta in the world.

Fish stock composition: The upper sector of the river is not having commercial fishery of any significance. This segment harbours cold water fishes such as *Tor tor, T. putitora, T. mosal, T. progeneius, Acrossocheilus hexagonolepis* and large cat fish *Bagarius bagarius*. A total of 126 fish species belonging to 26 families out of which 41 are of commercial importance have been reported. The fish fauna is a mixture of torrential fauna, specific to northern bank and that of southern bank is of a mixed type. 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 catch at four important landing centres was estimated at 847 t in 1970's . The fisheries in the upper, middle and lower stretches of the river is dominated by catfishes. In the upper middle stretch miscellaneous fishes dominate (54.14%), followed by cat fishes (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 miscellaneous group (34%) followed by catfishes (24%), minor carps (20%) major carps (11%) and hilsa (7%). Prawn contribution in the total landing of the mid-stretch is restricted to only 4 to 7%.

In another survey conducted by CIFRI, during 1973-79 at the 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 to the tune of 5.6-fold (47.61 to 8.5 t) of catfishes by 8-folds (58.7 t to 7.3 t), and of hilsa by 2.7-folds (21.63 t to 8.02 t). Similarly, the yield per Km. of river stretch has also declined from 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) and as well as of juveniles.

Indus river system : The major portion of Indus river system lies within Pakistan but its five tributaries viz., the Jhelum, the Chainab, the Ravi, the Beas and the Sutlej originate from western Himalayas.

Fish stock composition: In head waters of these rivers commerical fisheries is absent. The common fish species inhabiting are: *Salmo trutta fario, S. gairdneri, Tor tor, T. putitora, Schizothorax* spp. *Labeo dero, Gara gotyla*; *Botia* spp. and *Nemacheilus* spp. The Beas and Sutlej rivers contain indigenous carps and catfishes akin to Ganga river. The commercial fishery operations only takes place in middle and lower reaches of these rivers, but catch data is not available. Heavy water abstraction from these rivers has been reported to be responsible for reducing fish stock. Further, faulty designed fish-ladders and fish passes in the dams, weirs and barrages for providing ascend to fishes are not functioning properly and rather act as fish traps instead of fish passes.

Jhelum in Jammu and Kashmir is reported to support commercial fisheries. The species caught are : S*hizothorax* spp., *Labeo dero, L. dyocheilus, Crossocheilus latius, Puntius conchonius, Cyprinus carpio (C. communis and C. specularis*) loaches and *Glyptothorax* spp.

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

1. **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 121 mha.

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

Fish Stock Composition :-The commercial fisheries consists of carps (*major carps* and *L.fimbriatus*), large cat fishes (*Mystus spp*., *Wallago attu*, *S.childreni* and *B.bagarius*) and fresh water prawn (*M.malcomsonii*). Hilsa formed a lucrative fisheries and its landing fluctuated widely between 15.5t to 46.3t during the 1963-69. The Indian major carps planted in the river in the beginning of 19th century are thriving well and contributing to the commercial fisheries. Among miscellaneous fishes. *Chela argentina*, *P. aurulius* and *P. conchonius* dominate the catch.

The Mahanandi River : The upper reaches harbour game fishes but commercial fishery is non existent due to unaccessible terrain. The ichthyofauna is similar to Ganga with addition of peninsular species. Hilsa is confined to lower reaches and together with major carps and catfishes forms lucrative fishery. Data on fish production and catch per unit effort is not available.

Krishna River : A number of dams have been constructed on this river which has altered the ecology of this river. In general, the physiography and fish fauna of the Krishna river resembles to Godavari river system. The headwaters support rich fishery when compared to mid-stretch, which is rocky and unaccessible. According to a report (1963) about 91 to 136 kg of fish was caught in the river Vijaywada. No information is available on its present fishery and catch statistics.

Cauvery River : The water resource of the river is extensively exploited, as numerous reservoirs, anicuts and barrages have been built on the river. The river exhibits substantial variation in its fauna. The game fishes like *Tor khudri* and *T. mussullah* are found all along the river's length except the deltaic stretch. Eighty species of fish belonging to 23 families have been reported. It's fish fauna differs signficiantly from Krishna and Godavari. The commercial fisheries comprised of carps (*Tor* spp., *P. carnaticus*, *P. dubius*, *Acrossocheilus hexagonolepis*, *Labeo kontius*) cat fishes (*Glyptothorax madraspatanus*, *Mystus* spp., *P. pangasius*, *W. attu*, and *S. childreni*. Data on catch statistics is not available.

West Coast River System : The main westward flowing rivers are Narmada and Tapti.

Composition of fish stock : Narmada river harbours eightyfour 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 - 9.80%, *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 tonnes 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) obliterating the riverine habitat.

Tapti river : Not much informaion on fish stock composition and fish yield is available. About 2.60 tonnes of fish/day is captured from the river. The commercial fishery is mainly consists of
Tor tor, *Labeo fimbriatus*, *L. boggut and L. calbasu* among carps followed by cafishes such as *Mystus* spp. and *W. attu*.

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 alternation of fish community structure. A characteristics 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 artisinal 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 nutrients loading and pollution; (v) lack of understanding of the fluvial system and infirm data base; (vi) fragmentary and out moded conversation measures lacking enforcement of machinery; (vii) inadequacy of infrastructure and supporting services (viii) affordability and palatability and (ix) socio economic and socio-cultural determinant. An intelligent management strategy has to take cognisance of key parameters such as hydrology, fish stocks and dynamics of their population together with regularity 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.

Future approach:

There is an urgent need of integrated riverine management which envisages:

i) basin-wise approach, taking into account, the multiple use of river water and the impact of developmental activities on the biotic wealth;
ii) comprehensive computer model for environmental impact assessment;
iii) a judicious water allocation policy for various sectors taking into consideration the biological threshold levels; and
iv) keeping fisheries at par with other developmental and conservation activities in the river basin.

If these measures are religiously followed, the fish yield from Indian rivers is bound to enhance which will provide not only high quality of protein but will uplift the status of fishers in this country as well as help in conservation of original germplasm.

Conclusion

Finally it may be concluded that the decision taken by legislators and politicians will have a greater impact on the future of the riverine ecosystems than any amount of limnological work. The biological solutions to many environmental problems are within reach, given the *political will and suitable legislation*. However, ecological viable management strategies will fail if do not address socio-economic and cultural contexts, or are considered in isolation from the aspirations of the local populace. The implications are clear: we must continue to contribute to the academic development of limnology, but make greater effects to disseminate our knowledge of river ecosystems and communicate with those planning large scale development as well as those whose activities have a direct effect on the ecosystems at issue. Otherwise species loss and further degradation of rivers will result from a failure to engage in wide-ranging discourse. Time has come that we should weigh our priorities, should we increase out put of scientific papers, while ignoring the *realpolitik* of conservation and management or should we devote more effort to communicating the revealance and importance of our science. Further most of the rivers are interstate and each state has its own priorities. A common property approach prevails for much of the system and management is restricted to the auction of fishing rights for river stretches, without restriction on size of catch, size of fish or fishing season. Large scale capture of brood stocks while migrating during monsoon, large scale poaching, destruction of fish in their summer refugia and enormous destruction of juveniles are more a rule than an exception. Moreover no states want to spend money on developmental auspects and their attitude is that of a spendthrift. Under these circumstances, for sustainable exploitation and development of riverine resources, there is an urgent need for establishing, a central organisation which should be responsible for holistic development of the riverine resources of the nation.

Table 1. Showing the potential fish yield from Indian rivers based on their length and basin area

River	Length (km)	Basin area (million km^2)	Catch	
			Area based tonnes	Stream length based tonnes
Himalayan river				
Ganga	2525	0.88	17443	17142
Yamuna	1376	0.37	5243	8588
Brahamaputra	800	0.19	1782	3958
East Coast rivers				
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

(After Khan and Tyagi, 1996)

Table 2. Estimated mean annual landing (metric tonnes) at different centres in Ganga

Centres	1959-66	1973-81	1981-89	1989-97
Allahabad	207.17	129.63	128.46	67.55
Buxar	65.85	13.59	25.65	N.A.
Patna	81.93	85.5	70.84	N.A.
Bhagalpur	108.86	N.A.	62.45	37.79

Table 3. Energy transformation fish production potential and extent of utilisation of potential fish yield in river Ganga at different centres

Centre	Year	Av.Carbon production mgCm^{-2}day^{-1}	Av. Rate of energy transform-ation calm^{-2}day^{-1}	Photosynethe tic efficiency %	Fish production potential kg ha-1yr-1	Actual harvest kgha^{-1}yr^{-1}	Extent of utilisation %
Kanpur	1987-88	234.5	1419	0.077	50.10	-	-
Allahabad	1974	-	4501	0.241	160.44	21.33	13.29
Varanasi	1987-88	589.1	3243	0.173	112.20	-	-
Patna	1987-88	293.0	3534	0.190	122.40	30.84	25.19
Bhagalpur	1972	-	3586	0.186	120.68	31.64	26.30
	1987-88	420.0	4124	0.220	142.80	36.75	25.73

Table 4. Estimated yield of Indian major carps in the river Ganga (kg/ha/yr)

Centres/year	1958-61	1961-69	1980-86	1989-95
Kanpur	83.5	24.3	-	-
Allahabad	15.6	21.5	9.29	17.2
Buxar	17.1	3.8	7.0	-
Patna	13.3	13.3	5.08	3.04
Bhagalpur	3.6	7.5	2.9	2.9
Mean	26.62	14.08	6.07	2.55

MAJOR ESTUARINE ECOSYSTEM IN INDIA AND THEIR ECOLOGICAL STATUS - AN OVERVIEW.

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Most of the major cities of the world are located on the bank of estuaries and for many people estuaries represent their nearest available biological resources. The estuarine ecosystem is a unique intermediate between the sea, the land and freshwater, habitats with a distinct fauna and flora. The estuarine environment remains fascinating and offers wide ranges of biological subjects. Estuaries have often been encroached, however, upon by mankind and have conversed into septic tank of megalopolis. Yet, estuaries and their inhabitants are resilient enough to assimilate many odds.

Based on physical characteristics *i.e.* on geomorphological stand point the estuaries are broadly classified into four categories, *viz.*, Drowned river valley, Fojord-type estuaries, Bar-built estuaries and Estuaries produced by tectonic process.

ESTUARINE FISHERIES RESOURCES

The east coast estuaries intermingling in the Bay of Bengal have diverse fisheries potentialities. Of all the individual species, *Hilsa ilisha* has remarkably high abundance contributing 32.5 to 38.6% and 16.0 to 25.0% of the annual landings in Hooghly and Mahanadi estuarine systems. The species contributes 1 to 5% of the yearly landings in other estuaries mainly in Andhra Pradesh and Tamil Nadu. This lower abundance in *Hilsa ilisha* is attributable to geomorphological and hydrobiological conditions unconductable for breeding migration of the species to the freshwater zones of these estuarine systems. Monsoon catch of *Hilsa ilisha* alone contributes 70-80% of the total annual landings in Hooghly as well as Mahanadi estuaries. The landings of *Hilsa ilisha* mainly comprises 2nd to 5th year age groups.

Mullets form an important group of fishes in all the estuarine systems with maximum contribution of 134 - 250 t/y in Mahanadi estuary followed by 122 - 150 t/y in Godavari, 92 - 100 t/y, 53 t/y in Hooghly and 1.5 to 4.2 t/y in Adyar estuary respectively. The dominant species are *Mugil cephalus, Liza parsia, Valamugil cunnesius, Valamugil speileri, Liza subveridis, Liza macrolepis, Liza melinoptera.* Other than mullet and *Hilsa ilisha* the commercially important species in east coast estuaries are *Setipinna spp., Pama pama, Trichiurus spp., Coilia spp., Sillago spp., Leiognathus spp., Lutianus spp., Harpodon neherius, Polynemus spp., Lates calcarifer,* pomfrets etc. About 150 - 168 species of fin fishes are available in the estuaries of the east coast region.

Prawns comprising mainly *Metapenaeus monoceros, Penaeus indicus, Penaeus monodon, Metapenaeus dobsonii, Metapenaeus affinis and Metapenaeus brevicornis, Parapenaeopsis styliferus and Penaeus sculptilis* are also equally important in the estuarine annual landings. Godavari has the maximum prawn catch, (5,000 t/y) followed by Hooghly (85.7 to 1799 t/y), Cauvery (90 to 98 t/y), Mahanadi (16 to 30 t/y), and Adyar estuary (2.1 to 3.8 t/y). These fish fauna can be broadly divided into three categories.

1. Marine species migrating upstream and spawning in freshwater areas of the estuary like *Hilsa* ilisha, *Polynemus paradiseus, Sillaginopsis panijus and Pama pama.*
2. Freshwater species which spawn in saline area viz., *Pangasius pangasius* and the prawn, *Macrobrachium rosenbergii*
3. Marine forms coming to saline zone of the estuary for breeding like *Arius jella, Osteogeneiosus militaris, Polynemus indicus and Polynemus tetradactylus.*

The three salinity zones demarcated on the basis of chloride concentration as Zone I (Freshwater zone), Zone II (Low saline zone), Zone III (High saline zone) yield significantly different fish catches so far the quality as well as quantity is concerned. The freshwater zone (I), and low saline zone (Zone II) contribute 5 - 6% of the total annual catch while rest 94 - 95% comes from the lower estuarine and coastal zones. Qualitatively marine and neritic species like *Harpodon nehereus, Arius jella, Osteogeneiosus militaris, Polynemus indicus, Polynemus tetradactylus, Coilia spp., Plotosus canius, Sciaena mugil, Sciaenoides biauritus, Lates calcarifer* form the main bulk of the lower zone catches. The Indian shad, *Hilsa ilisha* an active migrant, breeding in upper freshwater region of the Hooghly estuary and some other active /passive migrants like *Polynemus paradiseus, Pama pama, Sillagionopsis panijus* migrating within the gradient and low saline zone contribute to the middle zone fisheries of the system while in the upper zone the catch comprising miscellaneous fishes and prawns of both estuarine and freshwater nature.

Besides, Hooghly estuary has an annual average landing of 1150 t of some commercially important species of prawns mainly constituted of *Penaeus monodon, Metapenaeus brevicornis, Metapenaeus monoceros, Penaeus indicus and Parapenaeopsis styliferus.*

One special aspect of the Hooghly - Matlah estuarine system is the practice of so called migrating fishing activities during the winter especially in lower zone, when the weather remains cooler, and a large number of fishermen migrate from the upper zone of the estuary to the lower zone for intensive fishing. In winter fishing the average catch per unit of effort ranges from 29 to 156 kg during November to January, as against 2.6 kg per unit if effort during the whole year. Uniquely, bag net catch (Dutta et al.,1977, Mitra et al.,1977 and Saigal et al.,1986. The bag net species composition remains same as mentioned in the case of lower and coastal zone catches.

ESTUARINE FISHERIES OF THE MAHANADI

Owing to lower tidal impact extending upto 42 km only the Mahanadi estuary does not have much variations in the species distribution pattern within the system. However, *Hilsa ilisha* find their way to the system for upstream breeding migration and eventually they form about 30 to 40 % of the total estuarine landings. The other important groups, the mullets, thread fins, perches, sciaenids and catfishes constitute 30%, 5.4%, 3.7%, 4.9% and 1.9% of the annual landings besides prawns offer about 12.4% of the total estuarine catch.

ESTUARIES OF THE PENINSULAR INDIA

(a) **Godavari estuarine system:** Godavari estuary, the major estuary in peninsular India has an area of about 18,000 hectares. Goutami is the main source of the estuarine complex in which tidal influence extends only upto 40-50 km upstream from the mouth region. Formation of sand bars in the estuarine mouth restricts the entrance of tidal water like Mahanadi stuarine system. The total production from this estuary is estimated to be about 5000 tonnes. Mullets and prawns form the major catch of the system. *Metapenaeus monoceros*, *Metapenaeus dobsonii*, *Metapenaeus affinis*, *Metapenaeus brevicornis*, *Penaeus monodon* and *Penaeus indicus* are the important prawn species available in lower reaches of the estuary.

About 185 species of fishes have been reported from this estuary, of which 72-80% are euryhaline, 12-20% almost marine and 15% freshwater in origin . Mullets form nearly 2/3 rd of the total fish landing and are represented by *Mugil cephalus*, *Valamugil speigleri*, *Liza subviridis*, *Liza macrolepis*, *Liza melinopetra* and *Liza seheli*. The other fishes of commercial importance are : *Pristiopama hasta*, *Leiognathus* sp., *Gerres filamentosus*, *Caranx* sp., *Sillago sihama*, *Lates calcarifer* etc.

(b) Other than Godavari estuarine system there are eight small estuaries in peninsular India namely Vasishta, Vainatheyam, Adyar, Karuveli, Ponniar, Godilam, Paravan, Vellar, Killai and Coferoom. In these estuaries, the tidal influence is felt up to a distance of 6-25 km and most of them get totally cut off from the sea during winter months. The overall species composition of the fisheries of these estuaries has been found to be mullets 24.5%, prawns 24.2%, clupeids 8.4% , *Lates calcarifer* 3.9%, Polynemids 2.8%, crabs 4.0% and miscellaneous species 29.8%. Annual catch from these water areas is estimated to be about 2,000 tonnes.

KERALA

The Kerala coastal zone is famous for its beautiful beaches, estuaries and lagoons. The coastline is more or less linear, at places, it is offsetted by the presence of promotories. Another characteristic feature of the Kerala coastal zone is the high population density, 2362 person/sq.km resulting in a more or less urbanized coastal zone. The pressure on land due to the high population density makes an adverse impact on the area distribution of different wetland categories. land reclamation has been stepped up for urbanisation and agriculture. The reported area covers the entire 560 length of the Kerala coast, which extends from Majeswaram in north and Pozhiyur in the south.

Estuary/ Kayal

One of the peculiarity of the Kerala coastal zone is the presence of a number of backwaters or estuaries locally known as *Kayals*. The kayals are blessed with natural resources and support a variety of flora and fauna (Abdul Aziz *et al.* 1987). The backwater fisheries generate a lot of employment opportunities and earn considerable amount of money through export. In Kerala, the tourism industry to some extent depends on the backwaters. Even though there are efforts to preserve these economically important wetlands but indiscriminate reclamation is on the increase to cater the needs of growing urbanization.

Strandplains are often found associated with estuaries on this coast. The linearity of the estuaries is more often controlled by the strandline, present at both side of the estuary. The estuaries/kayals exist in different sizes and shapes. In general, the shape is controlled by the strandplain orientation. Kayals are separated from sea by a narrow strip of land, the width of which varies from place to place. Many of the smaller estuaries remain closed during most of the year by a sand bar formed by the persistent action of the littoral currents and waves as in the case of the Veli-Akkulam estuary near Trivandrum.

The most prominent among the Kerala estuaries is the Vembanad estuary located east of the Cochin - Alleppey coastal plain. It has maximum length of 80 km and maximum width of 15 km and an areal extent of 185.6 sq.km. The Vembanad estuary form an important economic zone in the Kerala coastal zone. Ringed by growth centres in the form of urban centres, the Vembanad estuary is blessed with aquatic wealth (Nair *et al.* 1987), lime shell deposits and natural beauty for tourism industry. The Vembanad estuary towards the Cochin area is being used as a major harbour. The economic significance of Vembanad estuary is the prime reason for the very high density of population on its shores. This in turn has resulted in the large scale reclamation of the estuary for agriculture and other purposes. Time series data shows that the Vembanad estuary is loosing its area by the reclamation process every year.

Morphologically the paddy fields (Kuttanad region) south of Vembanad estuary seems to be an extension of the Vembanad estuary. This reclaimed parts form a very important wetland category and a type locality for Kerala coastal wetlands.

The Ashtamudi estuary which is located north of Quilon (Kollam) is another economically important estuary. Next only to the Vembanad estuary , the Ashtamudi estuary covers an area of approximately 36.9 sq.km and is fringed by the tertiary explosures.

The other important estuaries in Kerala are the Shiriya, the Kumbala, the Chandragiri, the Kavai, the Valapatanam, the Bharatapuzha, the Beypore, the Mahe, the Periyar, the Chetwai, the Kayamkulam and the Veli-Akkulam etc. The areal extent of the estuaries seems to be declining over the period of years. During 1967 the estuaries together had an area of 349.3 sq.km which in 1973 has reduced to 266.3 sq.km. Satellite data of 1986 shows the total area of the estuaries to be 251.2 sq.km. Thus, the estuaries have considerably been affected by the reclamation process.

KARNATAKA

The Karnataka coast (12° 45' - 15° 00' and 74° 00' - 75° 00') is about 300 km long. The coastal zone is narrow except around estuaries. It has long, narrow and straight breaches as well as small crescent shaped pocket beaches intercepted by rocky headlands, spectacular spits, estuaries, shallow lagoons, mudflats and few patches of mangroves (Rao *et al.* 1989). The northern coast is rocky while the southern coast has long linear beaches.

The major estuaries are Chakra - Haldi estuarine complex, Kalindi estuary, the Tadri estuary and the Sharavati estuarine complex. They are all fully mixed estuaries.

Stabilised sand-dunes are noticed along the Coondapoor coast near Bijadi/Tekkatte and Kotatattu. These are noticed along the coast near Kumta and also just below the Tadri creek. Dunes are 2-3 m high and covered by Casuarina plantation. Coastal dunes can be clearly delineated because of contrast with surroundings. The dunes have brown to pink tones due to presence of vegetation and are parallel to coast. Dunes near Bijadi are quarried for glass sand.

MAHARASHTRA AND GOA

The Maharashtra coast is characterised by pocket beaches flanked by rocky cliffs of Deccan basalt, estuaries and patches of mangroves. The Goa coast has long, linear and wide beaches and rocky cliffs. Coastal dunes are seen as linear patches on the satellite image and are invariably covered by Casuarina plantations. They are found east of masdgaon, Kalangut, Ubhandanda near Malvan and Devgarh.

ESTUARIES OF THE NORTH WEST COAST

Gujarat, the western most part of India, has the longest shoreline (1600 km), among the maritime states of India. The Gujarat coast provides a wide variety of coastal features due to varied physiography, geomorphology, coastal processes and river discharge.

The Gulf of Chambhat is characterised by a number of large and small estuaries. All major estuaries like the Tapi, the Narmada, the Mahi, the Sabarmati, the Kim and the Dhadhar are marked by flared outlines and tidal meanders, except the Narmada estuary. The Narmada estuary is classified as a salt-wedge estuary where fresh water flow predominates. However, due to the high-tidal range, significant mixing also takes place because of strong tidal currents during high-tide period. The maximum deposition occurs in the mouth and this is evidenced by the presence of the Aliabet island and its gradual expansion (Nayak et. al. 1985, Shaikh et. al. 1987). This has blocked the southern channel resulting in the filling of the channel.

The Mahi, the Tapi and the Sabarmati estuaries are fully mixed estuaries as they experience strong tidal currents and weak discharge of fresh water. The Dhadhar and the Kalubhar are partially mixed estuaries and most of the sediments are other than fluvial in nature.

The Tapi, the Narmada, the Mahi and the Sabarmati estuaries bifurcate around islands and have appreciable in-fillings and hence are called estuarine delta (Nayak and Sahai, 1984,1985).

NARMADA ESTUARINE SYSTEM

River Narmada is having an estuarine stretch of about 120 km which ends in Gulf of Cambay. Gradual decline in tidal ingress is being observed due to development of sand bars at the mouth region of the estuary. However, from ten years records during 1973-82 the average annual production of the estuarine system has been estimated to be about 4,000 tonnes in which as a group hilsa contributed (40-45% average : 1,662.4 tonnes) followed by mullets (15-20% average : 686.95 tonnes) and prawns (5-8% : average 286.55 tonnes). Miscellaneous species contributed 30-38% (average 1,520.0 tonnes) of the total landings. The fishing potential estimated in a survey during 1986-87 indicated that 2,884 fishermen are actively engaged in fishing activities in the system with 103 boats (non-mechanised) and about 28,000 nets. Gill nets are in maximum use (26,414 nos.) in the lower zone of the estuary. Hilsa forms the major catch of these gill nets (80-85%). Cast nets are mainly used for prawn fishing. Besides these, the seedlings of freshwater giant prawn (*Macrobrachium rosenbergii*) form an important fishery resource in mixo-oligohaline and limnetic zones of the system.

BIOLOGICAL CHARACTERISTICS

Productive potentiality of the river stretch was found to be moderate (17.10-78.15 mgC/m^3/hr-NP) down below the dam site. In the hilly region above and at the dam site, the value was much less (21.88 mgC/m^3/hr-NP).

Plankton population was poor in the hilly region (3-4/1) which gradually increased in the planes (17-51/1) and was maximum at Bharbhud (78/1) near the estuarine mouth. In the upper stretch (Ghadher to Bhalod) of the river system, green algae represented by *Spirogyra* sp., *Enemospheara* sp., *Pedistrum* sp., *Zygnema* sp. etc. constituted the bulk of the plankton while in the estuarine region diatoms like *Nitzschia* sp., *Navicula* sp., *Fragilaria* sp. *Diatoma* sp. and *Coscinodiscus* sp. were the dominant groups.

Benthic organisms were of rare occurrence in the samples. However, the maximum number ($6/m^2$) was recorded at Bharuch. Gastropods like *Pleuocera* sp. were the dominant organisms in the benthic population.

Aquatic weeds like *Hydrilla* sp. and *Najas* sp. were observed in small ditches towards the margin of river bed at Bharuch.

FISHERIES RESOURCES

During the period of observations , considerable catches of *Hilsa ilisha* were recorded at Bharbhud near the coastal region of the Gulf of Cambay. The catch mainly comprised hilsa in the size range of 310-495 mm and the females contributed about 2/3 of the population. Both male and female fishes were in final stages of maturity. A good number of spent (4-5% of the total landing) females were also recorded. Besides hilsa, the other fishes in the landings at Bhabhud and Bharuch centres under the tidal zone area were: *Pama* sp., *Xenontodon cancila*, *Auguilla* sp., *Clupisoma garua*, *Chatoessus manmina* and prawns of *Macrobrachium* sp., *Leander* and *parapchacopsis genera*. In the upper fresh water zone (Bhalod, Jhanor, Sisodra, Poichia, Vedgram), *Tor tor*, *Aorichthys aor*, *A. seenghala*, *Wallago attu*, *Labeo fimbriatus* and *Macrobrachium rosenbergii* the dominant species in the catch.

SPAWNING GROUND OF INDIAN SHAD

Hatchlings, fertilised eggs and developing embryos of *Hilsa ilisha* were collected in good numbers (4400/net/hr) by operating shooting nets at Bharbhud, a place in the coastal region of the Gulf of Cambay about 20 km, away fro the sea. This indicates the existence of spawning grounds of *Hilsa ilisha* in the vicinity of Bharbhud in river Narmada.

PRAWN FISHERIES RESOURCES

Both adults and juveniles of *Macrobrachium rosenbergii* were available in the entire stretch down below the dam site. Jhanor was found to be a potential centre for *Macrobrachium rosenbergii* seed collection (150/net/hr).

CONSERVATION MEASURES

Since, the estuaries and continental shelves are the basic components of human civilization and are under use from unknown period they need proper attention to survey. Geomorphological, hydrological and climatological survey of the coastal areas were made by conventional methods from time to time. These conventional methods monitoring and collecting data are very difficult, time consuming and expensive besides, these are not always fact finders. The satellites have opened possibilities of surveillance/monitoring more precisely and accurately. This method of remote sensing has to be employed for the estuarine and coastal environment studies and accordingly the programmes have to be chalked out.

NATIONAL IMPORTANCE

The estuaries and the coastal waters are significant to human welfare through their role in transportation, food production, waste disposal and also recreational pursuits. Many of the large metropolitan cities in India have developed near the estuaries or on the sea coast. Majority of the important ports of India are located on the sea coast or the estuarine mouths of major river system facing the Bay of Bengal providing facilities of import and export of Industrial and Agricultural productions. Biologically speaking, these water sources are rich in innumerable aquatic flora and fauna consisting of mangrove vegetations, marsh grasses, sea weeds etc., and the molluscs, crustaceans, fin fishes and groups of other aquatic vertebrates.

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FISH BIODIVERSITY OF INDIA: PRESENT STATUS AND CONSERVATION STRATEGIES

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India is fortunate to possess vast and varied fish germplasm resources distributed widely in vivid aquatic ecosystems. The aqua resources of the country include 2.02 million square km area of Exclusive Economic Zone (EEZ) of surrounding seas, more than 29,000 km length of rivers, about 1,13,000 km of canals, about 1.75 million ha of existing water-spread in the form of reservoirs, about 1 million ha in the form of tanks and ponds and about 0.6 million ha of stagnant, derelict, swampy water-spread area.

1. Indigenous fish biodiversity

About 2,200 finfish species have been recorded by the National Bureau of Fish Gentic Resources, Lucknow from different ecosystems of India while more than 20,000 species reported world-wide. Out of these, about 400 species are commercially important which includes cultured, culturable and wild species. The approximate break-up of fishes inhabiting different ecosystems is given below:

1.1 Coldwaters The aquatic resources located 914 m above msl in Himalayas, sub-Himalayan zone and mountains of the Deccan are known as coldwaters. The temperature varies from 0^0C-20^0C with an optimal range between 10^0C-12^0C. The coldwater lakes and streams of high altitude are characterized by high transparency and dissolved oxygen and sparse biota. Most of the fishes inhabiting this ecosystem are small-sized showing a distribution pattern that depends on the rate of flow of water, nature of substrate and food availability. Some fishes living in turbulent streams have developed special organs for attachment.

The major coldwater resources are upper stretches of Indus, Ganga, Brahmaputra rivers and their tributaries, coldwater lakes and reservoirs. The coldwater ecosystem harbours 73 fish species forming 3.32% of the species available in the country. Some commercially important species are: *Tor tor* (deep-bodied mahseer), *T. putitora* (golden mahseer), *T. mosal* (copper mahseer), *Neiolissocheilus hexagonolepis* (chocolate mahseer), *Schizothorax plagiostomus* (snow-trout), *Schizothoraichthys progastus* (snow-trout), *Barilius bendelisis* (baril), *Labeo dero* (kalabans), *L. dyocheilus* (boalla) and *Garra gotyla*.

1.2 **Warmwaters:** The freshwater of inland resources below coldwater zone are known as warmwaters. Coming to the plains, the rivers become wider, the slope is slight and the current moderate to slow. The water is turbid with detritus and high temperature. The warmwater aqua resources harbour abundant fish species.

In India, fourteen major river systems share about 83% of the drainage. The major river systems are: Ganga, Brahmaputra, Indus, Mahanadi, Godavari, Krishna, Cauvery, Narmada and Tapti. Out of 2.200 finfish species reported from the country, about 644 species (24.73%) inhabit warm freshwaters. Some commercially important groups of fishes of this ecosystem are:

Carps: these fishes belong to family cyprinidae and include prized species such as *Catla catla* (catla), *Labeo rohita* (rohu), *Cirrhinus mrigala* (mrigal), *Labeo calbasu* (calbasu), *L. gonius* (gonius), *L. bata* (bata), *L. fimbriatus* (fringe-lipped carp), *L. kontius* (Cauvery carp), *Cirrhinus cirrhosa* (White carp) and *C. reba* (reba).

Air-breathing fishes and featherbacks: Finfishes belonging to these groups are generally found in swampy areas. They are adapted to such waters with adverse conditions because of their accessory respiratory organs. Murrels and other important species of the group are: *Channa striatus* (Sol), *C. marulius* (Sol), *C. punctatus* (lata), *Clarias batrachus* (magur), *Heteropneustes fossilis* (Singhi), *Anabas testudineus* (koi), *Notopterus chitala* (chitala) and *N. notopterus* (foloi).

Catfishes: These are important group of fishes contributing significantly to the riverine catches. Some important species are: *Aorichthys aor* (aor). *A. seenghala* (seenghala), *Wallago attu* (boat), *Pangasius pangasius* (pangas), *Silonia silondia, Bagarius bagarius* (goonch), *Rita rita* (Rita) and *Eutropiichthys vacha* (vacha).

Hot Springs: Hotwaters of springs are clear, highly mineralized and generally devoid or very low in dissolved oxygen. Temperature of hotwaters ranges between 40 ^{0}C-45 ^{0}C. Most of the hotwater fishes are minnows and cichlids.

1.3 Brackishwater: The brackishwater (estuarine) regions are considered as transition zone between freshwater of the rivers and saline water of seas. The salinity of brackishwater ranges from 0.5 ppt to 30 ppt. The major estuarine systems of our country are: Hooghly-Matlah estuary, Mahanadi estuary, Godavari estuary, Krishna estuary. Cauvery estuary and other estuaries of east coast and west coast, Chilka Lake. Pulicat Lake and Kerla backwaters.

The important species contributing significantly to the brackishwater fishery are: *Mugil cephalus* (grey mullet), *Liza macrolepis* (borneo mullet), *L. tade* (tade grey mullet), *Liza parsia* (gold spot mullet) *Tenualosa ilisha* (hilsa), *Chanos chanos* (milkfish), *Etroplus suratensis* (pearlspot) and *Lates calcarifer* (bhetki).

The brackishwater also harbours lucrative shellfish species. Some of them are: *Penaeus monodon* (tiger prawn), *P. indicus* (white prawn), *Metapenaeus monoceros* (speckled prawn), *M. dobsoni* (flower-tail prawn), *M. affinis* (Jinga prawn) and *M. brevicornis* (yellow prawn).

1.3 Marine-waters: The sea water surrounding east and west coasts of the country having salinity more than 30 ppt is designated as marine water. The depth of the seas measures several hundred meters. The oceanic character being influenced by the Bottom Antarctic Drift as well as the Somali Current. The east coast, on the other hand, with many large rivers flowing into the Bay of Bengal and large number of tidal creeks, salt marshes, inlets and two large coastal lakes with feeble monsoon winds and lesser oceanic circulations, present markedly different condition.

About 1440 finfish species are reported from our marine territory which constitute 65.45% of the total available species in the country. A few commercially important groups are as follows:

Sardines: This is the most important group of clupeid fishes contributing significantly to the marine fishery. *Sardinella longiceps* is the most prized species. Other sardines are known as lesser sardines. Important species of the Indian marine waters are: *Sardinella longiceps* (oil sardine), *S. dayi* (Day's sardine), *S. fimbriata* (fringed-scale sardine) and *S. gibbosa* (gold-stripped sardine), *S. albella* (short-bodied sardine), *S. fimbriata* (fringed-scale sardine) and *S. girm* (spotted sardine).

Mackerel: the Indian mackerel, *Rastrelliger kanagurta* of Scombridae. Family is a much prized table fish. Mackerel supports fisheries on both the coasts though about three-fourths is from the west coast.

Bombay duck: Only single species- *Harpodon nehereus* of Synodidae Family is supporting a fishery of tremendous importance mainly in the west coast (Gujarat and Maharashtra).

Tunas and allied species: These fishes belong to the Family Scombridae and are distributed widely in tropic and sub-tropical regions. In Minicoy and Lakshadweep Islands, tuna fishery is well-organized. Some commercially important species are: *Katswonus pelamis* (skipjack tuna), *Euthynnus affinis* (little tuna), *Thunnus tonggol* (long-tail tuna), *T. thunnus orientalis* (oriental bluefin tuna) *Auxis thazard* (frigate mackerel) and *A. thynnoides* (frigate mackerel).

Carangids and allied species: These fishes form a significant proportion of marine catches on both the coasts. Some important species are: *Caranx carangus* (black-tailed travally), *C. sexfasciatus* (dusky trevally), *Decapterus russeli* (Russell's scad), *Selar crumenophthalmus* (big-eyed scad) and *megalospis cordyla* (hardtail scad).

Seer fishes: They belong to the Family Scombridae and are represented by two genera- *Scomberomorous* and *Acanthocybium.* The commercially important species are: *Scomberomorous commerson* (barred spanish mackerel), *S. lineonatus* (streaked Spanish mackerel), *Acanthocybium solandri* (Wahoo) and *S. guttatus* (spotted Spanish mackerel).

Silver bellies: Silver bellies occur along both the coasts of India. Some important species are: *Secutor reconius* (deep-pungnose ponyfish), *S. insidiator* (pungnose, ponyfish), *Leiognathus splendens* (splendid silver belly) and *L. equulus* (common ponyfish).

Polynemids: Threadfins are very important fishes available in Indian waters. They are: *Eleutheronema tetradactylum* (Indian salmon), *Polynemus indicus* (monk fish), *P. heptadactylus* (seven thread-finned) and *P. paradiseus* (mango fish).

Perches and allied species: Perches and perch-like fishes are more abundant in the coastal waters and especially around coral reefs and rocky bottoms of deep seas. Some of the prominent species of Indian waters are: *Lethrinus nebulosus* (starry pig-faced bream), *Psammoperca waigiensis* (Waigai sea perch), *Siganus canalicutlatus* (estuarine spine foot), *Lutjanus russelli* (Russell's snipper) and *Epinephlus diacanthus* (six-barred reefood).

Pomfrets: These are among the most prized marine species found in both the coasts of India. Some important species are: *Pumpus argentius* (silver pomfret), *P. chinengis* (White pomfret) and *Apolectis niger* (black or brown pomfret).

Catfishes: These are commercially important fishes available along both the coasts of India. A few important species are: *tachysurus sona* (dusky catfish), *Plotossus canius* (canine catfish eel) and *P. anguillaris* (stripped catfish eel).

Elasmobranchs: The important cartilaginous fishes of the group are: *Carcarhinus bleekeri* (blacktip finned shark), *C. dussumieri* (white-cheeked shark), *C. melanopterus,* (black-finned shark), *Scoliodon sorrakowah* (dog shark), *Sphyrnea zygaena* (round-headed/hammerhead shark), *Pristis microdon* (small-toothed saw fish) and *Rhinobatus granulatus* (granulated shovel-nose ray).

Crustaceans: Besides finfishes, several crustacean (shellfish) species of fishery importance are also available in the marine water territories of our country. Some of the economically important species are *Penaeus indicus, P. monoceros, M. brevicornis, M. affinis, Parapenaeopsis stylifera, Acetes indicus, Palaemon tenuipes, Panulirus polyphagus, P. versicolour, P. homarus, Scylla serrata* and *Neptunus pelagicus.*

Molluscs: Prized molluscan species also form sizable part of our marine fisheries resources. They belong to the classes Pelecypoda, Gastropoda and Cephalopoda. Some of the important mulluscs are:

Pearl oysters: *Pinctada fucata, P. margaratifora* and *P. anomioides.*

Edible oyster: *Crassostrea madrasensis, C. cuculata* and *C. discoides.*

Clams: *Meretrix meretrix, M. casta* and *Katelysia malabarica.*

Mussels: *Pema viridis* and P. indica

Cuttle fishes: *Sepia aculeata, S. pharaonis* and *Spiella inermis.*

Squid: *Loligo duvaucelli*

Octopus: *Octopus herdmani* and *O. globosus.*

1.4 Exotic Fishes in Inland Ecosystem: Apart from these native species, some exotic fishes have been introduced in the Indian waters for sport, food, vector control and ornamental purposes. A few important exotic species are:

Sport fishes: *Salmo trutta fario* (brown-trout) and *S. gairdneri* (*Oncorhynchus mijkis* rainbow trout).

Food fishes: *Cyprinus carpio* var. *specularis* (mirror carp), *C. carpio* var. *cummunis* (scale carp), *Ctenopharyngodon idella* (grass crap), *Hypophthalmichthys molitrix* (silver carp) and *Oreochromis mossambicus* (tilapia).

Larvicidal fishes: *Gambusia affinis* (mosquito fish) and *Lebestes reticulatus* (guppy).

Ornamental fishes: *Betta splendens* (Siamese fighting fish), *Xiphophorus helleri* (green sward fish) and *Carassius auratus* (goldfish).

2. Present Status

Though many indigenous species are common and wide-spread in Indian waters but due to various identified causative factors the fish genetic resources, in general, have been suffering from stresses. Some of the conventional fishing grounds have been showing dwindling trends, while some fish species are even endangered needing conservation. The ecosystem-wise discussion on status of their fish germplasm resources follows;

2.1 Coldwater fishes: As a result of cumulative effects of various anthropogenic and natural stresses, two group of native fishes schizothoracids and mahseers from upland waters have been reduced to a very low level. Amongst 18 valid schizothoracid species i.e. *Gymnocypris biswasi* is not encountered in the catch since long and 5 species namely, *Lepidopygopsis typus, Dyptychus maculatus, Schizopygopsis stoliczkae, Schizothoraichthys esocinus* and *S. longipinnis* have become rare. About 13 finfish species have been showing declining trends in the coldwater ecosystem of the north-east region of India.

2.2 Warmwater, fishes: In comparison to 1950's the average fish production at the middle stretch of the Ganga (Table-1), Godavari and Cauvery river systems have been showing declining trends.

Table 1. Decline in fish production from middle stretch of the Ganga river system (Modified after Chandra, 1989)

Year	Average (Kg/km)	Fish Production (Kg/ha)
1956-60	961.30	52.00
1961-70	944.42	50.00
1971-80	467.00	24.72
1981-87	629.83	33.33
1988-91	501.16	22.45

In Ganga river system, annual hilsa landings have declined from 19.30 to 1.04 t in Allahabad, 31.97 t to 0.60 t in Kanpur and 3.95 t to 0.68 Bhagalpur after commissioning of the Farakka barrage. Similarly, the prized Indian major carps have registered a sharp decline over the last few decades.

2.3 Brackishwater fishes: Due to slow changes in climatic and coastal oceanographic conditions, the estuarine ecosystem have undergone some changes, particularly with regards to sedimentation and sand bar formations. Anthropogenic interferences have also been causing a lot of ecological changes in the estuarine system resulting the alterations in the faunal composition and dominance of the species. Industrial, agricultural and domestic pollution is on the increase which would bring changes in the biota. The pearlspot, *Etroplus suratensis* which was quite prevalent in the peninsular estuaries, appears to have shrunken in its distribution. The spread of *Oreochromis mossambicus* might cause some threat to vulnerable species with low fecundity occupying the same ecosystem. Milkfish fry which was once abundant in the southern region has become scarce. Similarly, elvers of *Anguilla* have also suffered. *Setipinna taty, Mugil cephalus, Liza tade, Plotossus canius, Osteogeniosus militaris, Nematolosa nasus, Pangasius pangasius* and *Lates calcarifer* are under decline in estuarine waters.

2.4 Marine water fishes: Due to intensified fishing efforts in the inshore-waters of Indian seas, a number of prized fisheries resources are declining in number and size. The whale shark, *Rhiniodon typus,* off Gujarat, the catfishes of genus *Tachysurus* off Karnataka and the white fish *Lactarius lactarius* along the south-west coast of India have been reduced in abundance. The once existing fisheries of *Polynemus hasta, Otolithoides brunneus, Protonibea diacanthus, Congresox talabaniodes, Muraeresox cinercus* all off the Gujarat-Maharastra coast and *Platycephalus maculipinna* along the south-east and south-west coasts have become non-existent at present.

3. Impact of Stresses on Fish Biodiversity

Over-exploitation of the fish resources coupled with habitat destruction, result in the shrinkage of fish population. Due to these factors, a number of fishes in some conventional fishing grounds are declining rapidly and some have become endangered too.

As re-established, genetic variation is the raw material in species population which enables them to adapt to the changes in their environment. Any loss of genetic variation results in erosion of evolutionary flexibility. This leads to a poorer match of organisms to adopt to the environment increasing the probability of their extinction. The associated severe genetic problems in the small genetically effective population track the form of genetic bottlenecks, genetic drift and accumulation of homogygosity (inbreeding depression).

3.1 Genetic bottleneck: Genetic bottlenecks effectively sample (although not necessarily randomly) a few individuals from a larger gene pool, resulting in a permanent population with less overall genetic variability. Loss in genetic variability reduces the capacity of adaptation of the species in the changing environment ultimately making it unfit to survive. In a genetic bottleneck, loss of even 5% variability is observed in small population of 10 in one generation itself. In addition, a loss of about 3 rare alleles are also observed in such bottlenecks.

3.2 Genetic drift: It is a prolonged bottleneck leading to the repeated loss of variance until in days ultimate form all loci are fixed with complete absence of genetic variance. It is seen that longer the period of drift and smaller the population, greater will be the loss of variance.

3.3 Inbreeding depression: It is probably the most serious problem of endangered fishes with small population sizes. Inbreeding is defined as the mating of individuals related common ancestry, that is, those that share more genes in common due to descent than individuals randomly selected from the population. Inbreeding results in a predictable increase in homozygous genotypes differentially affecting different traits. In a Ne (effective population size), inbreeding depression to the tune of 5% is observed in the first generation itself. Eknath and Doyle (1990) observed 2 to 17% inbreeding depression in one year. The Ne ranging from 3 to 30 in a farm near Mysore (south India).

4. Need for Biodiversity

Maintenance of fish biodiversity alongwith other biotic resources can be viewed as prerequisite for the well-being of even the human beings. While several reasons can be ascribed to the need, there are four basic reasons for the maintenance of biotic resources:

i) Diversity or variability seems aesthetically pleasing in most environment. This is not only true in general but often applies to the specific species frequently encountered by man

ii) There is often local pride in population or species that are characteristic of an area. People often become disturb when some local form of animal is threatened by extinction and this concern is an important reason for conservation of atleast some species.

iii) It is generally agreed by ecologists and evolutionary biologists that species diversity and genetic variability are necessary for the long-term maintenance of stable, complex ecosystems and species.

iv) All the living beings co-evolve for their mutual benefits during the evolutionary process in an ecosystem. Any species getting extinct upsets the ecological balance to the detriment of each species and also the community as a whole.

5. Conservation strategies

Conservation of our entire fish genetic resources is a requirement and need of the hour. As far as conservation of fisheries resources are concerned, efficient and concrete strategies have already been initiated in this direction at National Bureau of Fish Genetic Resources, Lucknow and a few institutions which are being discussed under the following headings.

5.1 Checklist: A checklist of Fish Genetic Resources of India consisting of 2,200 fish species with information on taxonomy, habitat and distribution has been prepared by NBFGR and is ready for publication.

5.2 Catalogue: A catalogue on Fish Germplasm Resources of India is being prepared. The catalogue contains detailed information on taxonomy, distribution, bionomics, life-history, breeding behaviour, fishery, aquaculture, genetics and conservation status.

5.3 **Seminar on Endangered Fishes of India:** NBFGR has also conducted a National Seminar on the Endangered Fishes of India during April 1992. The major issues for discussion were status of fisheries in the major aquatic ecosystems of the country, major stresses affecting fish fauna in the conventional fishing grounds and conservation measures to be adopted for the recovery of the threatened species.

Based on the deliberations during the National Seminar and further sample surveys conducted by NBFGR and other organizations, the Bureau has prepared a provisional list of Endangered (28) and Indeterminate (70) fin-fishes.

Table 2. A provisional list of Endangered and Indeterminate fishes of India

Ecosystem	**Number of fish species**		
	Endangered	**Indeterminate**	**Total**
Coldwater	6	13	19
Warmwater	15	33	48
Brackishwater	5	9	14
Marinewater	2	15	17
Total	**28**	**70**	**98**

The coldwater fish, *Gymnocypris biswasi* designated as Extinct by some authors like Sehgal (1994), is not traceable since long time from its native habitat (Ladakh). However, as per the definition of FAO, the fish is only Endangered. The endangered fishes of India are listed below.

Coldwater fishes: *Gymnocypris biswasi, Schizothorax plagiostomus, S. progastus, S. richardsonii, Tor putitora* and *T. tor.*

Warmwater fishes: *Alia coila, Anguilla bengalensis, Bagarius bagarius, Eutropiichthys vacha, Labeo dyocheilus, Notopterus chitala, Ompok bimaculatus, O. pabda, O. Pabo, Pangasius pangasius, Puntius sarana, Semiplotus semiplotus, Tenualosa ilisha* (above Farakka), *Thynnichthys sandkhol* and *Tor khudree.*

Brackishwater fishes: *Etroplus maculatus, Lates calcarifer, Odon-tamblyopus rubicundus, Osteogeniosus militaris* and *Periophthalamus koelreuteri.*

Marinewater fishes: *Rhiniodon typus* and *Platycephalus maculipinna.*

5.4 Germplasm characterization: Strains of many fishes of the world have shown significant differences in growth rate, body composition and resistance to diseases. They also perform superior in culture conditions too over other strains. NBFGR carried out population genetic studies by screening 25-enzyme system using polyacrylamide gel electrophoresis (PAGE) of Indian major carps, air-breathing fishes and an endangered *Tor* species. Inter and intra-specific variations were recorded in Indian major carps and common carp using ultrathin isoelectric focussing (IEF, pH 1.5-9.5) of eye lens proteins and gradient sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE). Among the various cryogenetic techniques, NOR (nucleolar organizer region) banding of chromosomes has been useful in finding out polymorphism between and wihtin species. Distinct NOR patterns have been reported in seven fin-fishes by NBFGR. A detailed chromosomal atlas of Indian fish species has also been published by the Bureau.

5.5 Germplasm conservation

a) ***In situ conservation:*** *In situ* conservation of fish as land races and wild relatives is useful where genetic diversity exists and where wild forms are present. This is done through their maintenance within natural or man-made ecosystem in which they occur. The major advantages of *in situ* conservation are (i) continued co-evolution wherein the wild species can continue to co-evolve with other forms providing the breeders with a dynamic sources of resistance that is lost in *ex situ* conservation and (ii) national parks and biosphere reserves may provide less expensive protection for the wild relatives than *ex situ* measures.

In Himachal Pradesh, where the landing of prized mahseer fish is fast declining, the State Government has selected a few areas *viz.* Sedhpur and Machial in Mandi district. Renuka in Sirmaur district and Baizanath in Kangra district where mahseer fishing is banned for its *in situ* conservation. In order to develop feasible strategies on *in situ* conservation of endangered mahseer (*Tor putitora* and *T. tor),* NBFGR has taken up studies along the Ladhiya River in Kumaon Himalayas (U. P. hills). Population dynamics , the causes of decline in mahseer fishery and their magnitudes are under investigation. The programme for ranching of artificially-bred mahseer fingerlings in the Ladhiya river is underway. A similar rehabilitation programme has also been started by the Central Inland Capture Fisheries Research Institute, Barrackpore for *Hilsa (Tenualosa) ilisha* in the Ganga river system.

Marine ecosystems are being tempered with through commercial fishing, navigation and technological advancement which are detrimental to most habitats and ecosystems. Establishment of protected areas for *in situ* conservation of marine resources appears to be the only pragmatic approach. Establishment of marine parks is perhaps the best way for *in situ* conservation of marine.

b) ***Ex situ* conservation:** In this, the species are conserved outside their natural habitats either perpetuating sample population at Genetic Resource Centre or in the form of Genetic pools of gamete storage, germplasm bank (Gene Bank) etc. Establishment of gene bank by cryopreserved milt, eggs and embryos assures further availability of genetic materials of threatened categories and for intensive breeding programmes of economically important species. Long-term cryopreservation of milt of endangered as well as commercially important species like *Tor putitora, T. khudree, Labeo rohita, Cyprinus carpio var. communis* and *Salmo gairdneri gairdneri* has been achieved by NBFGR. However, work is in progress for the development of technique for cryopreservation of eggs and embryos of fishes.

NBFGR is going to set up a Gene Bank with cryopreserved milt of commercially important and endangered fish species during the current five-year plan itself. Further, the Bureau is also going to establish Resource Centres to cater the needs of marine, brackish water and coldwater ecosystems where breeding strategies endangered species are envisaged.

5.6 Androgenesis: It is sophisticated technique of biotechnology for production of the fish from male genome only avoiding the maternal genetic contribution altogether. Androgenesis is done by the destruction of female nuclear genome before fertilization and restoring diploidy by temparature shock. Even if an endangered fish gets extinct and its milt is available in the gene bank, it would be possible to reconstitute the fish from cryopreserved milt alone by employing this sophisticated technique. So far, androgenetic progeny has not been reported from any Indian fish. NBFGR has, however, initiated work in this direction.

5.7 Mass awareness programme: The success of environmental protection and biodiversity conservation efforts ultimately depend on the reaction of mass awareness and participation of local public. NBFGR has launched massive mass awareness campaign along the Ladhiya river catchments in U.P. hills for conservation of endangered mahseers. Three mahseer conservation committees have been constituted in upper, middle and lower stretches of the river involving villagers, fishermen students, Yuvak Mangal Dals, Gram Sabha members and officials. A series of lectures discussions and poster displays are being arranged by the Bureau in the Ladhiya and Sharda river catchments (Kumaon Himalayas) from time to time.

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ROLE OF PLANKTON IN PRODUCTION FUNCTION OF RIVER ECOSYSTEM

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Introduction

The surface run-off of waters plays the most important role in riverine ecology which determines the habitability and abundance of flora and fauna in its different sections. The rain water, precipitated on the earth, flows into depressions and follows the course of least resistance seeking its own level. The local variations in run-off waters depends upon the nature of soil (porosity and solubility), in slope gradient, its vegetation, the climatic conditions e.g. temperature, wind, humidity etc. and the volume and frequency of precipitation. Biotic communities specially plankton and invertebrates play an important role in production functions of river ecosystem as fishes are mostly dependent on these biotic communities for their food.

Biological activity in riverine ecosystem is influenced by climatic, edaphic and morphometric features. The geographical locations affects the metabolism of riverine stretches through food supply, shape of basin and the efficiency with which the climatic factors are able to act in the dynamic exchange. The measurement of plankton productivity, both at primary and secondary levels is essential to know its role in the production functions of riverine ecosystem. Many workers have suggested that an understanding of the production functions of invertebrates would facilitate management of fish stock. The success of biotopes and its productivity in riverine ecosystem will depend upon the suitability of the environment. The overall ecosystem health (environment) of a fluviatile waterbody can be known by comparing the important water quality parameters (DO, pH, free Co_2, nitrate, phosphate values) as well as the density and diversity of available biotic communities (plankton, benthos, fish). Thus, thorough understanding of ecology of riverine environment will reflect the role of plankton and invertebrates in the production functions of the aquatic system.

Ecology of Riverine Environment

The steep and torrential upper course of river generally having low temperature and turbulence though water is usually well oxygenated but shallow depth prevails. During floods, plankton is scanty, although during low water transient blooms may occur. Vegetation is restricted to some resistance forms attached to the rocks and too rooted, floating leaves or emergent forms in the pools. The assemblage of micro flora and fauna occur as mats of periphyton or of benthos, covering the bottom substrate. The fish fauna is entirely rheophylic. Fish fauna comprises small sized fishes provided with clinging apparatus (*Glyptosternum sp.* and *Glyptothorax sp.*) and other type having long sinuous shape (*Mastacembelus sp.*) and fishes (*Barbus & Salmo sp.*) capable of swimming sufficiently fast against the current.

The flat and slow flowing river course comprises lotic and lentic waters and its ecology is more complex than steep and torrential upper course. There is usually a well defined river channel flanked by floodplain. The main river, which may branch and recombine to form anabranches, generally consists of a regular succession of meander bends. Floating and emergent vegetation usually line the river banks and submerged vegetation may appear in its inner convex bank consists of sandy or sedimented areas which have slack current at low water while at high water these are submerged. The plankton population is closely related to flow conditions. Biotic factors of such river course has significant role in influencing the behaviour of fish communities. The growth of large areas of higher vegetation on the floodplain during the flood provide favourable breeding, feeding and nursery areas for most species of fish. Fish species show seasonality of behaviour whereby they breed early in the floods, feed and grow on the floodplain. Fishes of this river zone are also well adopted to survive in low water level and low oxygen concentration. They are characterised with complex breeding habits with multiple spawning and a great degree of parental care. The other category of fishes utilises the rich habitat provided by the floodplain during the floods but escape the severe dry season condition by lateral movement off the plain and longitudinal migration within the main river channel. According to Welcomme (1983) standing stocks and biological fish production from this zone of river course are difficult to calculate.

According to Welcomme (1979) and Holcick and Bastl (976) the nature of river-floodplain systems with reference to their fish populations is being recognised. Thus, indicating the role of biotic factors in governing their fisheries potentiality. There are considerable abiotic interactions, which influence biotic productivity based on hydrology and associated nutrient distribution. In floodplain the most nutrients released from newly-flooded ground, are directly contributed by river. The direct nutrient contribution by the river will depend on the degree of flooding. Production of plankton deriving nutrients from the water column appears to be more significant in river floodplains. In the inshore zones of river floodplains, nutrients appear to be mostly directly from the benthic substrate with larger concentration in the upper layers. Associated with the submerged parts of macrophytes are large quantities of periphyton and perizoon. The considerable biomass of detrital aggregate, derived mainly from the macrohytes, contains a high biomass of detrivores. According to Junk (1973) and Lim and Furtado (1975) the large water level fluctuations in floodplain probably increase the productivity of associated invertebrates resulting in large biomass. Direct input of dissolved nutrients from rivers into river-floodplain system is probably more important in the system for long term benefits, rather than controlling year-to-year production. Localised decanting of solids does, however, cause high phytoplankton production (Schmidt, 1973). The resulting zooplankton production may be important for young fish of many species. River floodplain systems having significant forest areas are regularly inundated and contribute to the production of larger individuals of many fish species which may be due to the allochthonous contribution of heavily forested streams.

Ecology of Estuaries

Biotic ecology of estuaries is greatly influenced because of its physical features due to water movements, the mixing processes and distribution of salinity. The interactions of these forces make the estuary a very turbulent and complex system of water circulation. The morphology of basin of the estuary and river channel modify and determine the stream and tidal dynamics. Stream flow varies seasonally with rainfall while tidal amplitude and current are linked with lunar effects and wind. Estuaries of arid regions differ from other estuaries being hypersaline but possess a moderate oxygen concentration at depths. Bottom mud is generally poor in organic content. The mangroves which has important role in estuarine ecosystem, represents country's 85% in Sunderbans. Role of biotopes in mangrove ecosystem play vital role in breeding and nursing phases of many riverine and marine organisms. Several of its creek are ideal for fish and prawn seed collection which sustains aquaculture in the region.

Plankton and Invertebrates in Food Chain of Riverine Ecosystem

Food-chain in the ecosystem involves the transfer of energy from one organism to the other in a systematic manner. The position of organisms in the food-chain is reflected by their trophic level. The producers constitute the base or the first trophic level of the food-chain. Herbivorous/phytoplanktivorous form the second trophic level while the carnivorous which feed upon the herbivores constitute the third trophic level or the level of secondary consumers. In the same sequence we may have the levels of secondary carnivorous or even the tertiary carnivorous. This depends upon the magnitude of the ecosystem.

Studies conducted based mainly on feeding habits and analysis of the gut contents show the involvement of the following series of organisms in the food-chain.

A. **Herbivorous** : *Daphnia carinata* (Cladocera), *Macrobrachium rosenbergii* (Crustacea), Nymphs or *Ephemerella sp.* (Insects), *Pila globosa* (Mollusca), and *Rhinomugil corsula* (Fish)

B. **Omnivorous** : *Catla catla* and *Clupisoma garua* (Fishes)

C. **Carnivorous** : Nymphs of *Mesogomphus lineatus* (Insects), *Rita rita*, *Glossogobius giuris* & *Wallago attu* (Fishes).

The above mentioned aquatic organisms were collected from the river Ganga.

Zooplankton (*Daphnia carinata*): The gut content analysis showed this cladoceran to be a herbivore which depends mainly on phytoplankton for its food. Members of Bacillariophyceae (36.5%), Chlorophyceae (48.5%) and Myxophyceae(12.0%) were identified, the rest were put under a separate category referred as other (3.0%). Chlorophyceae was the most preferred food of *Daphnia* (Figure 1).

Fresh Water Prawn (*Macrobrachium* sp.): Macrobrachium, being herbivorous, mainly feeds on Chlorophyceae and Bacillariophyceae. Besides, some Myxophyceae (*Anabaena* sp.); zooplankton (*Daphnia* sp.) and macrophytes were also found in the guts of *Macrobrachium* (Figure 2).

Gastropod (*Pila globosa*) : *Pila globosa* is essentially a herbivore. Members of Chlorophyceae alone constitute 54.8% of the total food intake of this gastropod, followed by Bacillariophyceae (23.8%), Macrophytes (19.0%) and Myxophyceae (2.4%).

Insecta (Nymphs of *Ephemerella sp.*) : Nymphs of *Ephemerella sp.* are primarily herbivorous by habit. Of the recorded dietary components, members of Chlorophyceae, Bacillariophyceae and detritus constituted the major fraction of food of the nymphs. The composition of various food items in the gut was : Chlorophyceae 32.2-61.0%, Bacillariophyceae 25.0-47.0% and detritus 3.5-12.0%. Besides members of Myxophyceae, flagellates were also observed. However, these formed insignificant percentage of food items.

Nymphs of *Mesogomphus lineatus* : The gut content analysis of these nymphs confirmed that they were carnivorous, feeding on microcrustacea (cladocera and copepoda), rotifers, protozoans, aquatic insects and fish fry. Members of the algal community belonging to Chlorophyceae, Bacillariophyceae and Myxophyceae were also recorded in small percentage during different seasons of the year. However, micro-crustacea, protozoans, rotifera and aquatic insects predominate in the gut.

Rhinomugil corsula : It is a surface dweller which moves in shoals. Filamentous algae and diatoms were found to be the main food items of this fish. However, decayed organic matter also contributed significantly. Sand grains and silt were consumed regularly along with decayed organic matter. Diatoms constituted 30.0% desmids and unicellular algae 10.5%, filamentous algae 20.0%, folliage and roots 29.8% and decayed organic matter 9.7%. Silt and sand grains were not considered as a part of food-chain. During the rainy season phytoplankton is not available and the fish thrives mainly on decayed organic matter alongwith sand grains and silt, aquatic leaves and roots. Such bottom feeding habit is also supported by the presence of an inferior mouth in this species (Figure 3).

Clupisoma garua : This catfish is essentially an omnivore based on its gut contents. It fed on a variety of food from different strata of the waterbody. The food contents included 43.3% plant matter consisting mainly the macrophytes and filamentous algae. The animal matter constituted of 4.8% crustaceans, 7.3% insects, 8.5% mollucs and fishes. Detritus and unidentified matter formed 8.6% and 5.0% respectively of the total food. In this fish, surface feeding takes place mostly during the rainy season and bottom feeding during the winter.

Catla catla (Figure 4) : It is an important and well distributed fish of India. Micro crustaceans, diatoms and filamentous algae are the main food items of this carp. The percentage composition of different food items determined on the basis of gut contents were : Micro-crustaceans (46.3%), Diatoms (20.8%), Chlorophyceae (15.5%), Macrophytes (9.7%), Rotifer (6.2%) and Protozoans(1.2%).

Rita rita : The catfish is a carnivore and bottom dweller. The fish shows its preference for molluscs which alone constitute 41.7% of the total food intake. In addition to it crustaceans (22.73%), fishes(15.7%) and insects(6.9%) were also recorded. Decayed organic matter, mud and sand together formed 13.03% of the total food.

Glossogobius giuris : This freshwater goby is a carnivore. The gut content analysis shows the predatory nature of this goby thus confirming its cannibalistic habit. Fishes and crustaceans were preferred and constituted 36.1% and 32.3% respectively of the total food. Besides, Molluscs and Insects contributed 16.2% and 11.8% respectively of the total food. No plant matter was detected.

Wallago attu : This catfish is a carnivore. Its gut content analysis confirmed it to be a piscivorous. Besides, it also feeds on the dead animal tissues and the decayed organic matter.

Food-Chain or Food-Web : On the basis of the food items of different aquatic organisms inhabiting the Ganga ecosystem, a food-chain/food web model shown in Fig. 5 has been prepared to elucidate the important role of plankton and invertebrates in the riverine environment.

Riverine Environment and Biotic Productivity

Environmental impact on riverine habitat governs the biotic interactions and functions in the ecosystem and accordingly productivity of biotopes is influenced. Riverine habitat loss has been observed in the exploratory survey carried out by the CIFRI during 1995-96 on the Ganga near its origin to sea. The present study on plankton indicates that its density has considerably decreased in the middle and lower freshwater stretches of the Ganga as compared to 1960 but the composition of plankton has not changed much. Moreover, the pollution indicator species were less in the lotic waters which indicates improvement in water quality of the Ganga. However, in the estuarine stretch there is in general an increase in plankton density than what it was before commissioning of Farakka barrage. This indicates positive role of increased flushing. Similarly considerable decline in the macrozoobenthic density was observed in freshwater stretches while many fold increase in its density was recorded in the Hooghly estuarine stretches. It was also observed that occurrence of pollution indicator groups such as Oligochaeta, members of Ephemeroptera and Trichoptera was very negligible which also indirectly reflects the improved water quality of the river Ganga.

But inspite of improved water quality in freshwater stretches of river Ganga, the plankton and invertebrate productivity could not accelerate due to loss in habitat. This appears to be mainly because of higher sedimentation and increased water abstraction resulting in substantial reduction in water volume in river Ganga. On the contrary the biotic productivity in downstream showed appreciable enhancement after commissioning of Farakka barrage which appears to have substantially benefited the fishery (specially the estuarine zone) as it has indicated continuous rise after 1975.

A community of hetroterophs can fix no more energy than the amount made available to them by primary producers, specially phytoplankton. The rates of production of zooplankton and benthos are positively related to food availability in the riverine ecosystem fixed through autotrophs. Thus, production of zooplankton and benthos is related to rates of primary production which depends upon nutrient conditions and alkalinity in the prevailing riverine ecosystem.

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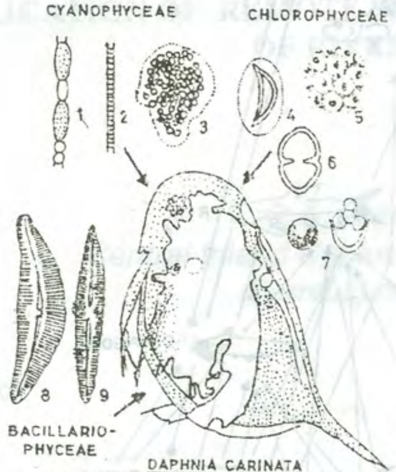

Figure 1 : Food Items of *Daphnia carinata*

1. *Anabaena,*
2. *Phormidium,*
3. *Microcystis,*
4. *Closterium,*
5. *Coelastrum,*
6. *Cosmarium,*
7. *Chlorella,*
8. *Cymbella*
9. *Navicula*

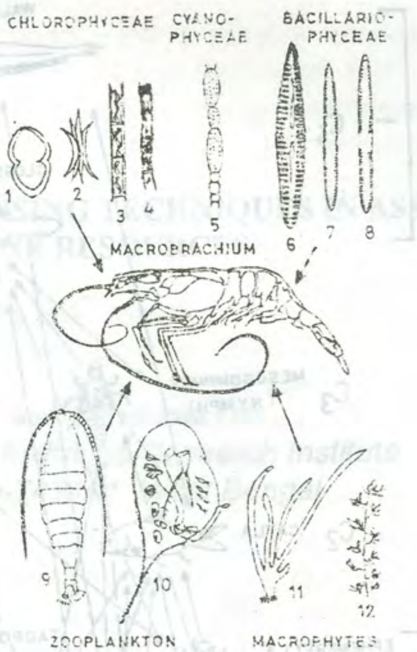

Figure 2. : Food Items of *Macrobrachium*

1. *Cosmarium,*
2. *Ankistrodesmus*
3. *Spirogyra.*
4. *Oedogonium*
5. *Anabaena,*
6. *Navicula,*
7. *Synedra,*
8. *Fragilaria*
9. *Diaptomus*
10. *Daphnia,*
11. *Vallisneria*
12. *Ceratophyllum.*

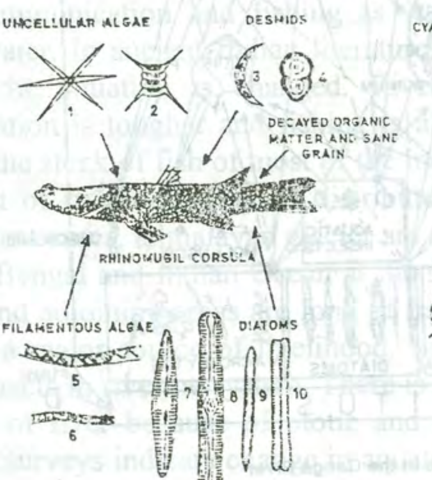

Figure 3. : Food Items of *Rhinomugil corsula*

1. *Ankistrodesmus*
2. *Scendesmus,*
3. *Closterium,*
4. *Cosmarium,*
5. *Spirogyra,*
6. *Oedogonium*
7. *Navicula,*
8. *Pinnularia*
9. *Synedra*
10. *Fragilaria*

Figure 4 : Food Items of *Catla catla*

1. *Oscillatoria,*
2. *Anabaena,*
3. *Synedra.*
4. *Fragilaria,*
5. *Navicula,*
6. *Diatoma.*
7. *Melosira,*
8. *Spirogyra,*
9. *Oedogonium*
10. *Cosmarium*
11. *Chlorococcum,*
12. *Daphnia,*
13. *Diaphanosoma,*
14. *Diaptomus.*
15. *Ceriodaphnia,*
16. *Brachionus.*
17. *Calyciflorus*
18. *B. caudatus* and
19. *B. diversicornis*

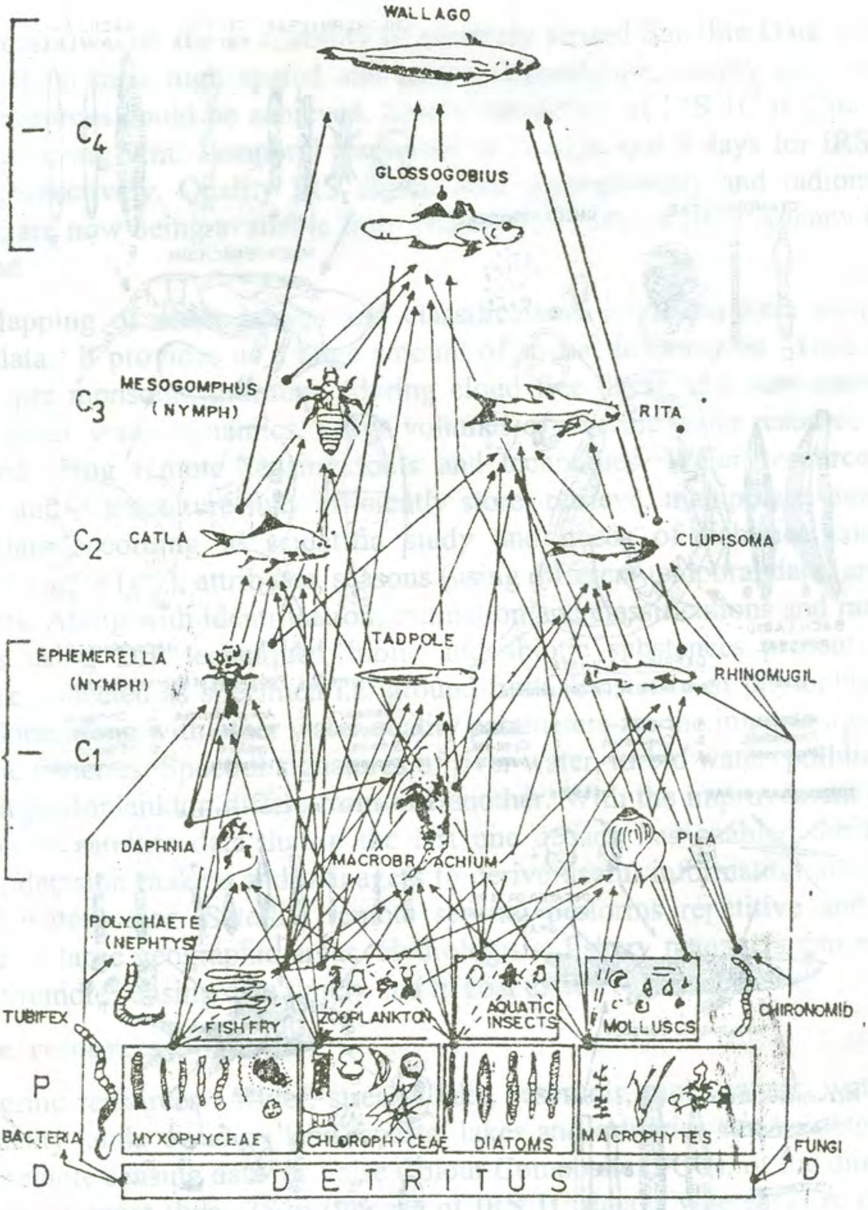

Figure 5 : Food-Web in the Ganga River

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APPLICATION OF REMOTE SENSING TECHNIQUES IN ASSESSMENT OF RIVERINE RESOURCES

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Introduction

Almost all human civilisations are originated on river side. River serves as a way of communication and fishing as well as a source of food, irrigation and drinking water. In ancient Indian literature river is considered as a mighty power. But now the situation is changed. Rivers get sedimented and silted, surface communication is tougher and fishing is aggressive and extensive. Recent studies show that the stock of fish of most of the Indian rivers is depleting. India has a quite high extent of riverine resources distributed evenly throughout all parts. In these areas, in most cases, Himalayan glacier are the main source of river water that flows to Bay of Bengal and Indian Ocean at the south. People living in the bank of river Hooghly and adjoining areas are fond of fish and a section of people is involved in fishing as a major source of livelihood. Large increase in population causes high human impacts in riverine system. There is a gradual change in geomorphology and hydrology of river because of biotic and abiotic factors associated with riverine resources. Surveys indicate change in aquatic community in recent times. Managing water resources of canals, tributaries and riverine water systems using conventional point survey techniques is time consuming and laborious. Monitoring of riverine resources i.e. water quality, primary producers, suspended and cohesive sediment concentration, effluent discharges and other pollutants and salinity etc. could be performed by remote sensing techniques in a cost effective manner.

Presently with the availability of remotely sensed Satellite Data of IRS 1C, IRS-1D, which have high spatial and temporal resolution, survey of estimating riverine resources could be achieved. Spatial resolution of IRS 1C is 25m whereas IRS-1D is having 9 m. Temporal resolution is 21 days and 9 days for IRS 1C and IRS 1D respectively. Quality IRS digital data, geometrically and radiometrically corrected, are now being available from National Remote Sensing Agency (NRSA), Hyderabad.

Mapping of water bodies and classifications could be done using digital satellite data. It provides us a huge amount of spatial Information. Data on multi dates i.e. pre monsoon, monsoon (during cloud free days), and post-monsoon are useful to study water dynamics. Large volumes of riverine water resource data can be derived using remote sensing tools and techniques. Water resource data in Fisheries and Aquaculture may efficiently store, retrieve, manipulate, analyse and display data according to scientific study and needs of fisheries community. Physical location (x,y), attributes, seasons (using different temporal data) are the key parameters. Along with identification, estimation and classifications and mapping of resources using DIP techniques, biotic and abiotic substances present in water bodies are collected as specimen i.e. ground truth. Existence of phytoplankton and zoo plankton along with other water quality parameters are the important constraints in riverine fisheries. Spectral signatures of river water, turbid water, pollutant, water with high phytoplankton differs from one another. With the improvement of spatial resolution of satellite data during the last one decade has enabled the scientists, planners, decision makers and managers to derive useful information about various types of waterbodies. Satellite remote sensing performs repetitive and synoptic coverage of large geographic areas. Hydrologists, fishery managers can effectively use these remote sensing data timely and in cost effective manner.

Riverine resources

Riverine resources : River, stream, lake, reservoir, tank, canals, water logged land, marshy land, swampy land, coastal lakes and estuaries can be detected from satellite remote sensing data or False Colour Composite (FCC), if the dimension of water-body is more than 25 m (in case of IRS 1C data), whereas 9 m (in case of IRS 1 D data). Rain water, melting water of glacier from great Himalayas which are the main sources of water can also be estimated by applying remote sensing techniques. In the past, survey method for assessment of riverine resources was oriented to point-source measurements and on site observations which may be a huge task. It become easier if we apply the recent techniques of remote sensing, although cost involvement of this study is high. Indian Remote Sensing Satellite provides remote sensing data with very high spatial resolution and repetitive scanning which effectively helps in estimating riverine resources available and also delineates the areas which has great prospect in fisheries. In contrast to reservoir fisheries, fishing exploitation in riverine system is much difficult. River management, particularly in relation to spawning and development of larvae and juvenile fishes are important. It is known that decline in fishery resources reflects decline in bio-diversity and productivity. Application of Remote sensing as a data source generates information of riverine system. This riverine information helps in decision making. This leads in execution of proper planning and developmental activities under the riverine eco-system.

Data Analysis in Remote Sensing

Data analysis in remote sensing for estimating and assessment of riverine resources includes detection of riverine resources, identification of riverine water resources, categorisation and measurement of resources. This also includes error assessment and accuracy assessment. It is being observed that accuracy in assessing riverine water resources may be acceptable at 90% level, further accuracy in estimating resource areas is more useful and desirable. Primary and secondary data of some riverine areas is some time useful as ground truth. The genuinity of primary data (as ground-truth) is highly deterministic factor in assessment of resources. Data analysis in remote sensing includes image display and enhancement contrast stretching, edge enhancement, density slicing, spatial filtering, data compression, image classification, multitemporal analysis and digital mosaics.

Remote sensing products

CCT and CDROM (with digital data of NRSA), FCC, Toposheet and photography are useful for analysing and assessing riverine resources. The digital data of NRSA is already pre-processed that includes radiometric and geometric correction.

Necessity of ground truthing

To verify the imagery/pixels values display on images for a given area of a water, sample data collection of ground truth is essential. Pixel value of a specific point may change time to time because of its' temporal variation, thus, seasonal changes of water quality and water dynamics can be studied. To observe the extent of change in resource areas, seasonal ground truthing i.e. water sampling is desirable. For determination of particular location GCP (ground control point) also to be noticed and geo-referencing is done, based on known latitude and longitudinal values of a few GCPs, which are known to us.

Remote sensing methods

Includes base map preparation of studied area, geo-referencing of studied area with remote sensing data considering latitude and longitude of a geographic location, Remote Sensing Data Interpretation, Visual interpretation interpretation of remotely sensed data based on grey level, computerised interpretation of grey values of pixels, super imposition of seasonal data, ground truthing and development of geographic information in database i.e. Geographics Information System (GIS)

Use of Micro Computer

Present day micro computer with Digital Image Processing (DIP) System Software become the important tool for analyzing the satellite remote sensing data because of its' high processing speed and huge memory capacity. A bare minimum, requirement of H/W platform to monitor water resources using satellite digital data can be INTEL 80386, Processor @25mhz, 80387 math co-processor, 4MB RAM, 720 MB HDD, VGA, VGA Card and V RAM of 2 MB. That indicates even a very old model of computer system can perform the job. These help in analysing and assessing bulk remote sensing data in less time. Due to rapid change in satellite and Tele-communication system, a vast geographic areas can be studied for easy decision making purposes.

Method of riverine classifications

Grey value is primary key to classify the waterbodies. In case of visual interpretation of satellite imagery identifying parameters for identifying surface topography may be **tone, texture, pattern, shape, size, shadow and association.** Classification could be done based on homogeneous characteristics with the aim of discriminate multiple entities from each others within the image. Using Computer Programming Language (of 4 GL), classification may be done as : Select [water bodies] from [all pixels] where grey values are equal to a specific value. High resolution remote sensing satellite data, using DIP techniques can be very much useful for identifying and estimating water resources for sustainable fisheries management. River, stream, lake, reservoir, tank, canal, water logged land, marshy land, Swampy land are main classes of water bodies and these include inland fresh water lakes, salt lakes, coastal lakes and lagoons whose resource can be monitored.

Potential Application of Remote Sensing

Glacial study

Himalayan glaciers are a good source of riverine water in India. Estimation of glaciers in high altitude of the Himalayas can effectively be done by remote sensing techniques. Amount of deposited ice can be estimated and its distribution is detected using spectral reflectance at NIR and MIR regions of electro magnatic wave.

Amount of riverine water

Area of water under riverine system is identified easily from coloured picture derived from digital satellite data. A synoptic view of remote sensing spatial information is more useful rather than traditional point information while estimating the resource amount. Depth of water body is studied using microwave remote sensing.

Water level Information

Water level information for shipping and boating purposes could be obtained from topographic information of water resources. A change in water level could be identified by remote sensing techniques.

Quantity of water

Quantity of resources be estimated from the function of depth and water area. Riverine depth is assessed by considering electro magnetic reflectances at upper and lower surface of waterbodies.

Seasonality study

Seasonal remote sensing data collected from IRS is very much informative in identifying the amount of riverine resource available at various seasons. Temporal change in surface water of river can provide a useful information on navigation, fisheries resource assessment and capture of fish at various seasons. Various survey reports suggest pre-monsoon and post monsoon capture is comparatively lesser because of depletion of water resources under riverine system.

Inundation

The river inundation area with the availability of multi-temporal satellite data is useful for monitoring large river like the Ganga and the Brahmaputra from space. Electromagnetic radiation of visible and microwave range can detect inundated area. Determination of inundated area in the Amazon river is estimated by Sippel, S.J. et al 1994; using SMMR 37 polarisation difference, and satellite remote sensing of river inundation area by Smith, L.C., (1997) using SAR (Synthetic Aperture Radar) Sensor which can penetrate cloud and also detect standing water.

Flood dynamics

Flood is common in river Hooghly. With the availability of pre-monsoon, monsoon and post-monsoon remote sensing data, water dynamics is studied for riverine resources estimation. The change in riverine surface water distribution reveals the extent of flood. Low land areas adjacent to riverine system is estimated using remote sensing data satellite imagery and digital data are useful in studying these application areas. The use of satellite imagery, FCC is most appropriate tool. Flood management in Punjab (India) by Sharma P.K. et al., (1997), is already reported by using LISS-1 data of IRS, FCC and European remote sensing satellite panchromatic images. Super imposition of false colour composite estimates the flood prone areas. The flood plain mapping and land cover estimation include the classification of land cover and the analysis of drainage areas.

Siltation and sedimentation

Siltation and sedimentation at the downstream of the riverine system could be identified using remote sensing data. As the navigation and capturing of fish is very much dependant on depth of river water, sedimentation and siltation at bottom area of river is important criteria in assessing riverine resource. Excessive sedimentation and clay deposition at lower course of river result in formation of island or delta. The amount of sedimentation and siltation could easily be studied by IRS Digital. Mapping of topographic area of surface water and delta formation process can be visually interpreted using FCC or digital imagery. In conjunction with data sets such as grain size, tidal currents and velocity parameters; determination of sedimentation in estuaries is possible. Estuaries of large rivers like Hooghly can be studied for deriving information on turbidity and algal biomass.

High and low tide

Extend of tide water can be identified by using multi-date remote sensing IRS data. This may be helpful in identifying the various possible fish-capture gears located at riverbanks and also helps in studying amount of coastal salinity area at coastal belt. At the lower part of Hooghly riverbank, a high density settlement greatly affected because of high tide of Hooghly river, could also be studied using temporal remote sensing data.

Bank Erosion

The use of terrestrial/aerial photography can be used as technique for measuring bank erosion under riverine system.

Turbidity / pollutant

Remote Sensing can detect the turbidity, suspended sediments and colour (chlorophyll) which are indicators of water quality: In case of water pollutants, some effluents have colour and hence can be identified through Remote Sensing Techniques. However, colourless pollutants can not be detected directly as their grey value differ significantly. By ground truthing Information can be gathered on dispersion of suspended sediment dynamics and their effect on phyto-plankton.

Phytoplankton

In case of Indian Remote Sensing Satellite Band-4, 0.77 mμ to 0.86 is suitable for delineation of surface water features. Based on spectral reflectance water bodies can be identified and estimated. Digital values (grey values) for water bodies exist within a range. Blooms of plant origin in water bodies rather suddenly may spread with great speed, sometimes changing the colour of the surface water into reddish green or hay colour. This modifies the optical properties of water and enables the detection of blooms through remote sensing. Mapping of algal blooms using digital multi -spectral image helps in study of bloom dynamics.

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BIOLOGY OF CERTAIN COMMERCIALLY IMPORTANT FISHES

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For better management of fish production or terminal production, knowledge of certain biological parameters viz., length-weight relationship food & feeding, age & growth and reproduction biology is of utmost importance. The above mentioned parameters in respect of commercially important riverine fish such as carps, catfishes, mahseers, anadromous hilsa, murrels and featherbacks are discussed in the present communication.

Length-weight relationship

Weight in fishes is generally considered a function of length, if form and specific gravity were constant throughout life. The relationship between weight and length can be expressed by the well known "cube law" which may be mathematically expressed as:

$$w = a\, L^3 \qquad \text{(i)}$$

where w and L are weight and length of the fishes a being a constant. The above equation has numerous practical applications in fishery biology such as (1) conversion of length into weight or *vice versa.* (2) fixation of onset of maturity and its duration in population (3) comparison of two or more monospecific populations inhabiting under similar or apparently different regimes of food, density and climate and (4) determination of the extent of utilization of food as manifested in feeding activity over an extended period or population changes attributable to alteration in supply of food as reflected in the gross nutritional balance of fish. However, subsequent workers found that obeying of cube law by fishes was rather an exception than a rule. Therefore, the inadequacy of cube law gave rise to formulation of another type of general equation which proved to be more satisfactory in describing length-weight relationship of the fishes. The equation may be described by a formula of the type.

$$\mathrm{w} = a\,\mathrm{L}^{n} \qquad \text{(ii)}$$

where w = weight of fish, L = length of fish, <u>a</u> is a constant and <u>n</u> an exponent usually ranges between 2.4 to 4.5 but for an ideal fish which maintains an uniform shape $n = 3$.

The length weight relationship may be derived from the equation

$$\mathrm{Log\ w} = \mathrm{Log}\ a + n\ \mathrm{Log} \qquad \text{(iii)}$$

The value of a and n are determined empirically by application of least squares method its value lies between 2.4 to 4.5 as described in the following formula:

$$\mathrm{Log} = \underline{\mathrm{a}} \qquad \frac{\mathrm{Log\ w.\ (Log\ L^{2}) - Log\ L\ (LogL.Logw)}}{\mathrm{N.\ (Log\ L^{2}){-}(LogL)^{2}}}$$

$$n = \qquad \frac{\mathrm{Log\ W{-}\ N\ Log\ a}}{\mathrm{Log\ L}}$$

N indicates total number of specimens

Condition factor or ponderal Index

Another important use of length weight relationship is condition factor 'K'. The above index is an indicator of general well-being of the fish. Often, it is employed to measure the effects of environmental factors. The condition factor can be computed by the following equation:

$$\mathrm{K} = \frac{\mathrm{W}}{\mathrm{L}^{3}} \qquad \text{(iv)}$$

(Where K = condition factor or condition index, W = weight of fish, and L = length of fish).

If the values are not in whole numbers, they are multiplied by 10 to bring it near unity. It has been observed that a fat fish of a given species indicates a higher condition factor than a thin fish of the same species, being equal in length. It has also been shown that the 'K' for fishes having cylindrical bodies, such as eel, is observed less than unity whereas fishes of more corpulent form register more than unity. For circumventing the above dissimilarity enunciated the concept of relative condition. Index (Kn) which may be derived from the equation (ii) after converting it into a logarithmic form (equation 3). The length weight relationship calculated from equation (ii) and (iii) is utilized to derive Kn in the following form:

$$Kn = W/w^{-}$$

Where W is observed weight of the fish and W mean weight calculated for each group. Therefore Kn is a measure of the deviation of a given fish from the average weight/length for its age-group size-group. On the otherhand, 'K' is by contrast, an individual deviation from an imaginary ideal fish shape.

Food and feeding habit of fishes

The food plays one of the most vital roles in the life history of fishes by way of controlling their growth, fecundity and migration. Variation in the seasonal and diurnal availability of the preferred food organisms of various species of fish in any region may govern the horizontal and vertical movements of the fish stocks.

Fishes are also known to change the food habits as they grow, accompanied by correlative changes in the digestive system. Another remarkable feature regarding the fish feeding is its seasonal variation in selection of food and intensity of feeding. The former is linked with the availability of the food in the biotope. Due to this, different dietary pattern of the same fish from various habitat have been reported.

The fishes may be broadly classified on the basis of their dietary habits as (1) Herbivorous, (2) Carnivorous and (3) Omnivorous.

Methods for studying the food of fishes

The gut contents` of fishes may be studied numerically, volumetrically gravimetrically and by occurrence method. The choice of the method will depend upon the type of the feed of the fish. Volumetric and occurrence methods would be adopted in all cases.

Procedure for quantitative methods

1. *Volumetric*

i) Determine the volume of gut contents in samples by water displacement
ii) Sort the samples to kind of items, species or group-wise.
iii) Obtain the volume of each kind of food item, that it forms in the total volume of food in the series.

2. *Gravimetric*

It is like volumetric except that instead of volume, weight of different food items is taken

3. *Numerical*

i) Sort the gut contents to kinds of items
ii) Count the individuals for each kind of food items in the sample.
iii) Summate each of them in series
iv) Compute numerical % of each item in the gross total

4. Occurrence Method

Method I

i) Count the number of fish in which each food item occurs.
ii) Express the above as percentage of the total number of fish examined

Method II

i) Summate the occurrence of each item.
ii) Find the percentage of individual occurrences (*i.e.* kind of items).

Index of preponderance

The volumetric, gravimetric and numerical methods of analysis emphasise only the quantitative aspects of the gut contents while occurrence method point out only the frequency of occurrence of food items. These methods individually are not suited in grading the food elements unless they are integrated into an index. Index of preponderance (Natarajan & Jhingran, 1961) is such a complete measure which take both of quantity and occurrence into consideration simultaneously.

If V_1 and O_1 are the volume and occurrence index of food item (i) for food may be presented as follows:

$$I_i = \frac{V_i . O_i}{\sum V_i . O_i} \times 100$$

Forage ratio

This provides an index as to how the bottom biota is consumed by fishes. Forage ratio represents the ratio of the percent that a given species/genus/group of organisms forms in the total stomach contents of fish sample to the percent that the same kind of organisms constitutes of the total population of food organisms in the bottom samples.

Age and growth

Studies on age and growth of fish are *sine qua* non for rational exploitation and effective management of the fisheries. Further, the age and growth studies also provide useful information on stock composition, age at maturity and mortality. The various methods employed for age and growth studies of a fish can be broadly classified as under:

a) Known method

b) Counting seasonal marks on the hard parts of the body of the fish such as scales and various bones and back calculating body length in the past year if the relation between growth of scale and growth of body is known.

c) Length frequency distribution or Petersen's method.

The first method gives the most authentic information on the age and growth However, the utility is restricted as this required ponds and various enclosures for raising the fish over a period of time and computing the fish growth by catching them back periodically.

The second method requires the study of scales, otoliths, vertebrae, spines, fin-rays opercula and cleithra. The easiest way of ageing scaly fish is through their scales. The seasonal changes are reflected in the form of growth zones or checks on the above mentioned hard parts of the fish. The growth may be of two types: narrow zones and wide zones. Under temperate conditions, most of the fishes have annual cycles of maximum growth corresponding to summer when temperature and food supply are most favourable but growth in these fishes slows down to a minimum during winter due to low temperature and scarcity of the food. Generally, a set of fast growing wide circuli and narrow zone circuli constitute an annulus. Contrary to this, in tropical waters, neither temperature nor food supply change considerably with the seasonal rhythm, and hence to presume that growth in tropical climate follows an annual pattern similar to that temperate waters, holds little ground save in certain belts where seasons are well-differentiated by marked fluctuation in the temperature regimen. Here, if the growth checks are formed on the hard parts, they require careful scrutiny and reasoning. The main causative factors in tropical waters are (1) Scarcity of food; (2) Maturity and spawning stress

Ageing of fish through scales

Accuracy of the scale method depends on three basic conditions 1) Scales must remain constant in number and retain identity throughout the life of that fish (2) growth of the scale must be proportional to the growth of fish and (3) annulus must be formed yearly and at the same approximate time each year.

Collection & preservation of scales

Scales for ageing of fish are invariably taken from the area above the lateral line and below the dorsal fin in case of soft rayed fish and at the end of pectoral fin in spiny rayed fishes. Regenerated scales must be discarded. Cleaning of the scales must be done with warm water or 5% caustic potash clean scales can sometimes be examined dry. But they tend to curl. To avoid this, clean scales may be kept between two glass slides and their ends tapped. A more recent and satisfactory technique is to prepare an impression of the outer surface of the scale on plastic materials. Scales or impressions can be examined through a microscope or a microprojector.

Types of rings or growth checks

Generally, two types of growth checks are found on the scales (1) annulus and (2) spawning ring

Characteristics of an annulus

Narrowly spaced bend or circuli immediately preceding more widely-spaced bands or circuli, the latter region being the new growth zone. The circuli are not broken or discontinuous and are generally found in immature fishes.

Spawning annuli

The annuli are characterised by concentric transparent bands in the form of grooves extending to the lateral posterior sides of the scale. In lesser pronounced rings they appear thin light bands.

The annuli are preceded by comparatively thinner and narrower ridges but followed by comparatively thicker and widely-spaced circle.

In the annulus or groove zone, the circuli appear discontinuous.

There is a tendency for the ridges (circuli) to flare out near the annular zone but are delimited being parallel to margin groove.

In the apical section of the annular zone, the circuli appeared to be closely approximated along their length.

False rings

Sometimes false rings appear along with true annulus due to certain adverse changes in fish environment. However, false rings may be identified by the following characters.

i) False annuli are incomplete and indistinct with irregularities of pattern
ii) By back calculating the intermediate lengths of fishes through their scales

Age determination through Petersen's method or length-frequency distribution

This is the simplest method for ageing the fish. According to this method the population of fish having a single restricted spawning; the individual length of each group is approximately normally distributed and the modes of length-frequency distribution of successive age-groups are separated along the length axis. This method has been known to be inadequate especially for determination of age of older size groups due to increasing overlap in length distribution and total absence of certain size groups due to gear selectivity.

Growth

Growth may be defined as an increase in size and fishes it is indeterminate. This is of two types (i) absolute growth and (ii) relative growth.

Absolute growth

It is the average total size of each age. The absolute growth rate may be determined as:

$$\frac{W_1-W_o}{t_1-t_o}$$

Where W_o = weight at any time t_o and
W_1 = weight at a later time t_1

Relative growth rate

It may be defined as percentage growth in which the increase in growth in each time interval is expressed as a percentage of the growth at the beginning of time interval. The relative growth curve rise slowly at first with an increasing slope followed by a decreasing slope assuming a 'S' shape curve. The point at which the growth rate changes from an increasing to decreasing rate has practical significance in fishery management. the relative growth rate may be calculated as:

$$\frac{(W_1-W_o)}{W_o\,(t_1-t_o)} \quad X\ 100$$

Calculation of growth

The rate of growth may be calculated by following methods:

1 By tagging or marking of the fish
2. By Walford growth transformation
3. By back calculation of the body lengths through scales
4. By length-frequency method.
5.

Reproduction in riverine fishes

The main commercially important fish fauna of Indian rivers comprise carps, catfishes, mahseers, murrels, the anadromous *Hilsa ilisha* and featherbacks. The mode of reproduction consists of maturity, fecundity and spawning.

Maturity can be defined as cyclic morphological changes which the female and male undergo to attain full growth and ripeness. Fishes have a very diversified reproductive behaviour unparallel to the other vertebrates. Some of the oviparous species (clupeoids) discharge millions of ova into the water and leave there for further development to the nature. The time of onset of maturity also varies considerably among different species. Generally, the attainment of maturity is related to acquisition of a particular size by the individual and as a rule, the slower the growth rate of the fish (Table. 1) the later the onset of sexual maturity and vice-versa.

The reasons for this diversified reproductive behaviour are attributable to the internal or introceptive and external or extroceptive factors (temperature, light, food, salinity, shoaling etc.) or to the cumulative effects of both.

A record of the state of maturity of fish examined is often required for many purposes e.g. in determining the proportion of the stock that is mature or the size of age at first maturity. it is sufficient to note whether or not the fish is going to spawn or has spawned in the recent spawning season by classifying into several maturity stages. The most popular classifications are given by Kesteven (1960) and Nikolskii (1963). The same are portrayed in Table 2.

Gonado-somatic index (GSI)

This is another useful method, other than the study of intra-ovarian ova-diameter Clark, 1934) for determining the maturity stages of the fish. It can be defined as the weight of the gonads as a percentage of the whole body or the gutted weight. Since the GSI has been reckoned as an indicator of the maturity of gonads. Its values should be higher in the breeding season and lower immediately after the completion of spawning. Similar results in the values of GSI have been obtained in fishes which spawn once a year and have a short spawning period like Indian major carps. On the other hand, the dynamic of the GSI is of quite different nature in fishes which reproduce almost round the year (*Oreochromis* spp. certain catfishes) and shed their eggs in batches, therefore, the value of GSI in the latter group does not vary much in different months.

Fecundity

The number of eggs contained in the ovary of a fish is termed individual absolute or total fecundity (Nikolskii, 1963). Bagenal (1967) modified the definition of Nikolskii by including the number of mature eggs laid in the life span of a fish.

The fecundity of the fishes has been related to body weight, body length and ovary weight and termed as relative fecundity. The concept of relative fecundity allows comparison of the fertility of animals of different species or different populations of the same species.

The rate of fecundity has been acknowledged by the biologists in understanding the population dynamics of fishes, as fecundity is one of the decisive factors in the formation of a new year class. It has been demonstrated by a few workers that fecundity can be used as a parameter of environmental suitability of the fish. A continuous deterioration in the environment produce qualitative and quantitative changes in the fecundity. On account of this, fishes become smaller in size and attain earlier maturity. The incidence of feeding, food density and feeding efficiency affect the strength of a year class during the critical period of larval stages. The fecundity has also been successfully used in delimiting various populations of the same species.

Spawning

The act of releasing gametes is called spawning. Kryzhanovsky cited by Nikolskii (1963) classified the fishes on the basis of spawning as: Lithophils, Psamophils, Pelagophils and Ostracophils. The spawning behaviour of some fishes is depicted in Table 3.

Prabhu (1956) stated that fishes exhibit four types of spawning described as below:

Type A : Spawning taking place only once a year during short period.
Type B : Spawning taking place once a year but with a longer duration.
Type C : Spawning twice a year.
Type D : Spawning throughout the year.

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Table 1. Growth of commercially important fishes (mm) at different ages

Species	**Age in years**								
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**
C. catla	295	514	716	813	917	-	-	-	-
C. mrigala	276	473	622	732	815	877	957	-	-
L. rohita	310	500	650	740	800	850	890	940	960
L. calbasu	207	311	401	489	557	619	722	765	802
Tor tor	249	320	380	440	490	533	580	-	-
C. marulius	385	533	653	766	825	-	-	-	-
M. aor	333	448	618	751	840	889	941	983	1020
M. seenghala	311	433	544	649	743	833	911	964	1023
Hilsa ilisha	355	415	455	485	505	525	-	-	-
N. notopterus	101	155	215	269	314	331	345	-	-

Table 2. Two generalized classifications of maturity stages in fishes with approximate correspondence between them

From Kesteven (1960)	From Nikolskyii (1963a)
I. Virgin Very small sexual organs close under the vertebral column. Testes and ovaries transparent, colourless to gray. Eggs invisible to naked eye.	*I. Immature* Young individuals which have not yet engaged in reproduction, gonads of very small size.
II. Maturing virgin Testes and ovaries translucent gray-red. Length half or slightly more than half, the length of ventral cavity. Single egg can be seen with magnifying glass.	*II. Resting stage* Sexual products have not yet begun to develop, gonads of very small state eggs not distinguishable to the naked eye.
III. Developing Testes and ovaries opaque, reddish with blood capillaries. Occupy about half of ventral cavity. Eggs visible to the eye and whitish granular	*III. Maturation* Eggs distinguishable to the naked eye; a very rapid increase in weight of the gonad is in progress, testes change from transparent to a pale rose colour.
IV. Developing Testes reddish white. No milt drops appear under pressure. Ovaries orange reddish. Eggs clearly discernible opaque. Tesstes and ovaries occupy about two-thrid of ventral cavity.	*IV. Maturity* Sexual products ripe; gonads have achieved their maximum weight, but the sexual products are still not extruded when light pressure is applied.
V. Gravid Sexual organs filling ventral cavity. Testes white drops of milt fall with pressure. Eggs completely round some already translucent and ripe	*V. Reproduction* Sexual products are extruded in response to very light pressure on the belly, weight of the gonads decreases rapidly from the start of spawning to its completion
VI. Spawning Roe and milt run with a light pressure. Most eggs translucent with few opaque eggs left in ovary	*VI. Spent condition* The sexual products have been discharged; genital aperture inflamed; gonads have the appearance of deflated sacs, the ovaries usually containing a few left over eggs and the testes some residual sperm
VII. Spawning/spent Not yet fully empty. No opaque eggs left in ovary	-
VIII. 1. Spent Testes and ovaries empty, red. A few eggs in the state of reabsorption	-
VIII 2. Recovering spent Testes and ovaries translucent, gray-red. Length half or slightly more than half, the length of ventral cavity. Eggs can be seen with magnifying glass.	*vii. Resting stage* Sexual products have been discharged; inflammation around the genital aperture has subsided; gonads of very small size, eggs not distinguishable to the naked eye.

Table 3. Spawning time, periodicities of spawning and fecundity of certain commercially important riverine fishes.

Species	Time of spawning	Periodicity of spawning	Absolute fecundity	Relative fecundity
C. catla	Monsoon months	Once a year	2,30,831 to 42,02,250	676 to 987
C. mrigala	Monsoon months	Once a year	1,81,695 to 18,09,536	1309 to 1837
L. calbasu	Monsoon months	Once a year	1,40,078 to 4,40,859	1438 to 1463
M. seenghala	Summer and early monsoon months	Prolonged and multiple spawner	1,31,800 to 4,28,376 (on the basis of 4 spawning bursts)	
Tor. Tor	Monsoon months	Prolonged and multiple spawner	6,677 to 40,000	-
N. notopterus	Monsoon months	Once a year	250 to 1377	58 to 96
C. punctatus	Monsoon months	Prolonged and multiple spawner	3000 to 26000	-
C. marulius	Monsoon months	Prolonged and multiple spawner	2000 to 40,000	-
C. striatus	Monsoon months	Prolonged and multiple spawner	3000 ato 30,000	-
H. ilisha	Monsoon and winter months	Twice a year	40,000 to 1325,500	828

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TREND OF SPAWN AVAILABILITY IN THE GANGA RIVER SYSTEM

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With the introduction of high yielding technologies of aquaculture, the demand for fish seed is increasing day by day. Rivers used to constitute the major source of the fish seed of the country till sixties, contributing 91.6% of the total fish seed production (365 millions in 1964-65). The contribution of rivers declined to about 30% in early seventies probably because of environmental deterioration and overfishing . Now a days induced breeding and bundh breeding have taken a lead among the sources of fish seed production but riverine source still continue to contribute substantially in meeting the country's seed requirements. The riverine carp spawn yield from Ganga river system, which formed the main source of the quality seed, has gone down both in quality and quantity .

GANGA RIVER SYSTEM

Ganga river system covers the states of Haryana, Delhi, Uttar Pradesh, Madhya Pradesh, Bihar and West Bengal. Fish seed in this river system is collected in the form of eggs, spawn, fry and fingerlings. The following definitions were adopted by the fish seed committee in 1966 for the purpose of obtaining uniformity of usage throughout India.

Spawn - hatchlings upto 8 mm in length.
Fry - fish seed, above 8 mm and upto 40 mm in length
Fingerling - Fish seed, above 40 mm and upto 150 mm in length.

EGG COLLECTION

The eggs collection is possible only when location of breeding grounds are known and easily accessible but from the places which are not well connected, eggs are collected in the down stream of breeding grounds. The collection of eggs, both from the breeding grounds and down stream, is done by the fisheries department in Madhya Pradesh, where breeding grounds have been located in Banumore (Gwalior) and Jhansi fields (Morena), which are inundated by the flood waters linking these centre with rivers Sank and Asan, tributaries of Chambal. Eggs are collected from one to two feet of deep water by disturbing the bottom and scooping them with gamcha. At Goharganj, drifting eggs are collected by fixing shooting nets in Garua nala, tributary of Betwa river. The advantage of egg collection is that one can be sure of its quality.

Fish seed of Indian major carps are obtained from three sources, *viz.* (1) from natural condition in suitable rivers, (2) Bundh breeding and (3) Artificially induced breeding and hatching .

Indian major carps usually do not breed in confined waters. They breed under suitable riverine condition, when attain sexual maturity during monsoon months. The mature female fish lays eggs in shallow inundated area, followed by males which throw milt on these eggs and fertilise them. Thus, the fertilization of carp eggs takes place outside the body of the female fish. In about within 18 hours the embryo breaks the egg case with jerking movement of the tail and comes out. These hatchlings drift with the slow current. Fish seed at this stage is collected by fixing shooting nets in shallow areas of the rivers.

SPAWN COLLECTION

The collection of spawn on commercial scale is prevalent in Bihar, West Bengl and Uttar Pradesh. A survey of the existing spawn collection centres in these states show a large concentration of such centres on the main Ganga, yielding quality spawn. About 75 important spawn collection centres are registered with the Uttar Pradesh Government on the Ganga, Yamuna, Betwa, Gomti, Ramganga, Rapti,Ghagra and a few other smaller streams.

In the Ganga system, major carp spawn are available from May to September. The 1st appearance of spawn in India occurs in the Kosi due to flood caused by melting snow in mid May or early June. The other rivers viz. Ganga, Gomti, Yamuna which experience spawning only after having been flooded by heavy rains. Kursela centre, situated just below the confluence of the Kosi with Ganga, has an additional advantage in that it first receives spawn from Kosi, followed by that of Ganga.

Spawn prospecting investigations, originally initiated by the CIFRI in 1949 and intensified in 1964, helped in establishing many productive centres in Ganga river system. The Institute also undertook an extensive programme of carp seed prospecting through the All India Coordinated Research Project initiated in 1971. Investigations by CIFRI on spawn prospecting have been helpful in establishing excellent source of quality fish seed at Sapori (Tank) on the Banas, Anwara (Agra), Dhumenpur (Etawah), Kishanpur (Fatehpur), Mahewa Jamunapur (Allahabad) on the Yamuna; Salempur (Lucknow) on the Gomti. The list of investigated sites during 1964-1973 is given in table 1 alongwith seasonal indices of spawn quality and quantity. Of all the centres, where investigations were conducted on the Ganga system, some of the centres were declared unsuitable as they yielded spawn of minor carps only. In lower stretch of Ganga and its tributaries in Bihar and West Bengal, spawn is collected by private fishermen on a very large scale and there exists a private trade.

QUANTITATIVE AND QUALITATIVE POTENTIALITY OF INVESTIGATED SITES

Midnapore type shooting net (1/8" meshed) was adopted as the standard net for assessing the relative quantitative potentiality of the various investigation sites. The quality of collected spawn was determined both by analysing microscopically as well as by rearing. Making use of these , seasonal indices of spawn quality and quantity were derived for the various centres.

The total catch of desirable spawn taken by one standard net in a course of the entire season, generally based on the average of several.(upto 5) standard nets, is taken as the seasonal index of quantity. Percentage of major carps in the season's total catch of desirable spawn, as derived from rearing is considered as the seasonal index of quality.

The seasonal indices of quantity and quality for the various investigation sites are shown in table-1.

FRY AND FINGERLING COLLECTION

The established fry and fingerling collection centres are quite few viz. those at Majhawali (Gurgaon), Ali, Chills, Okhala, Razapur and Wazirabad (Delhi) on the river Yamuna, Bithoor, Gangaghat and Golaghat (Kanpur) on the Ganga; Lamti (Gonda) on the Ghaghara, Jarwal Katli (Bahraich) on the Sarjoo and Chopan (Mirzapur) on the Sone in Uttar Pradesh. The collection is made usually by cast and drag nets.

RECENT STATUS OF RIVERINE SEED

Investigations on the trend in the availability of quality and quantity of spawn was undertaken at Mahewapatti/Mandhuka centre on river Yamuna from 1976 till 1997. Similar work was done at Agra during 1991 to 94. Observation on the yield of spawn at Mandhuka centre during last three decades have shown progressive decline both in quality as well as in quantity. The indices of quality and quantity at this centre declined from 7385 ml and 85.3% in 1964 to 315 ml and 39.5% in the year 1996 (Fig.1). At Agra the index of quality and quantity also declined from 593 ml and 59.8% (1991) to 258 ml and 36.6% in (1994).

The spawn collected on Ganga at Buxar, Patna and Bhagalpur from 1984 to 1990 also indicate the deterioration in the quality and quantity of Gangetic spawn. (Table-2). The exploitation of juveniles and spawners is, however, considered to be seriously jeopardising spawn abundance. It has been estimated that only 80 t of spawners are sufficient to produce 4000 million spawn. Most of the researchers have suggested various measures for management of the fisheries of Ganga river systm for improving spawn yield as well as the major carp fishery. These measures in respect of Indian major carps include imposition of closed season for spawners and minimum size limit, declaration of deep pools as sanctuaries, adoption of measures for water abstraction and regulation, provision of spawning facilities, stocking of selected stretches of river and abatement of pollution.

With the rising demand of fish seed for aquaculture practices the fishermen barricade the nallahs during the rising phase of the rivers with the help of a screen, so that the fry and fingerlings remained in the nallah. When the flood recedes the stock of fry is collected with the help of drag net and sold to private fishermen for aquaculture. This practice has also adversely affected the recruitment of major carps in the river system.

Recent years indicated that the spawn of Indian major carps from Ganga river system alarmingly depleted. In view of declining trend in spawn availability recycling of stock is suggested.

Table 1: Seasonal indices of spawn quantity and quality, 1964-1973

Year	Centre	River	State	Quality	Quantity
1964	Kishanpur	Yamuna	U.P.	7356	83.5
	Mahewa Jamunapur	-do-	-do-	4402	72.3
	Tajpur	Ram Ganga	-do-	3351	2.8
	Sardanagar	-do-	-do-	966	5.9
1965	Anwara	Yamuna	-do-	3493	81.0
	Dhumanpura	-do-	-do-	2200	35.0
	Bansi	Rapti	-do-	4715	77.7
	Dhundha	Sone	Bihar	637	3.5
	Dhangwar	-do-	-do-	2417	25.2
1966	Majhawali	Yamuna	Haryana	784	18.6
	Mant	-do-	U.P.	173	26.3
	Ghagraghat	Ghagra	-do-	228	7.4
1967	Nethla	Yamuna	-do-	6006	7.0
	Salempur	Gomti	-do-	1374	26.4
1968	Nanamau	Ganga	U.P.	808	76.3
	Deolan	Yamuna	U.P.	239	83.7
1969	Mahewapatti	-do-	-do-	1098	52.2
	Bahiara	Sone	Bihar	252	88.5
	Tilauthu	-do-	-do-	-	80.0
	Dighwara	Ganga	-do-	-	-
1970	Ahirauli	-do-	-do-	552.0	85.49
1971	Daryapur	Ganga	Bihar	282	40.3
	Mahewapatti	Yamuna	U.P.	135	45.4
1972	Jahangira	Ganga	-do-	324.6	70.28
	Kishenpur	Yamuna	-do-	100.0	77.9
1973	Sukhsenagh	Ganga	-do-	880	79.9

Table 2: Seasonal indices of spawn quality and quantity

Year	Centre	River	State	Quality	Quantity
87	Patna(Fatuha)	Ganga	Bihar	15.0	-
88	-do-	-do-	-do-	11.0	-
89	-do-	-do-	-do-	12.4	-
90	-do-	-do-	-do-	25.0	-
87	Bhagalpur	-do-	-do-	65.0	-
88	-do-	-do-	-do-	50.0	-
87	Buxar	-do-	-do-	20.0	-
91	Agra	Jamuna	U.P.	59.6	593
93	-do-	-do-	-do-	51.0	231
94	-do-	-do-	-do-	36.7	258
88	Allahabad	Ganga	-do-	45.5	80
89	-do-	-do-	-do-	38.0	100
90	-do-	-do-	-do-	21.0	132
91	-do-	-do-	-do-	26.0	110

ROLE OF STOCK ASSESSMENT IN DECISION MAKING PROCESS

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Introduction

Resource Assessment is the basic technique for provision of biological advice on fisheries management. In the process of resource evaluation one makes an assessment of the long-term and short-term potential of the biological resource as a whole as well as of its various components and the interrelationships of these components.

In the decision making process one need to consider all aspects such as biological, social, economical and political. Biological advice concerns harvesting the resource in such a way that no more is removed from the resource on an average than can be replaced through growth and recruitment. Economic advice relates to harvesting the resource in such a way that benefits to society at large and various components are optimised.

In other wards biological-social-economical advice together ensure that the resource is utilized in such a manner that the socio-economic benefits to society is optimised while at the same time the continued biological productivity of the resource is ensured.

On the basis of resource assessment scientists advise on the consequences of manipulating various ways of biological system through fisheries intervention. To a large extent the success or failure of fisheries management hinges on the quality of biological advice your advice. Continued removals above the upper limit defined by the biological system will inevitably lead to collapse of the resource. Thus, the biological advice , your advice, must be the first consideration on which overall advice to fisheries management is based.

What resource assessment does:

The role of resource assessment is to describe and explain in quantitative terms variations in fish stocks and the effect of fishing providing a basis of knowledge for the control of fisheries in a manner which optimises the benefits obtainable from the removal. Hence, resource assessment is largely concerned with the productivity of species stocks or in other words the growth of fish in the species stock. To describe the effects of fisheries on fish stocks, it is not only necessary to know a great deal about fish stocks, but also to have an intimate knowledge of the fisheries themselves. It is necessary to know the quantities of each species removed, the time and location of removal and the size and age composition of the catch.

Thus the first priority to describe the life history of stocks. Stock identification studies are conducted by tagging large number of fish at various locations and inferring their movements from information in locations of recapture. Studies are conducted to describe the seasonal distribution of the various life stages of fish and associated environmental conditions, describing spawning areas, feeding habits and diseases. Methods are validated for determining the age of individuals of particular species. Once a method of ageing has been established, the growth of fish in the species stock can be described.

To describe the effect of fisheries on fish stock, it is necessary to know the quantities of each species removed, the time and location of removal and the size and age composition of the catch.

Information on the amount of fishing effort is obtained by maintaining inventions.

Armed with the information described above, we are in a position to describe the pattern of events in the environment, in fish stocks and in the fisheries based on them. We then develop the ability to describe the factors critically and to predict the productivity of fish stocks.

Now we turn our attention to various techniques available to control the exploitation of fish stocks. For the purpose of discussion, a resource is either under - , fully or overexploited in relation to its potential biological productivity. The under exploited stock is one where a further increase in exploitation will increase yield ; the fully exploited is one in which the level of exploitation will harvest the potential yield without endangering future catch ; and an over exploited stock is one where exploitation has resulted in a shortfall on the potential yield. We shall distinguish between two types of overexploitation or overfishing ; growth overfishing and recruitment over fishing. The earliest formulates of the effect of fishing were concerned with the loss in weight by catching fish before they had time to grow. Thus problem of growth overfish was addressed by the yield per recruit approach. Recruitment overfishing occurs when recruitment declines as a result of a reduction of the breeding stock. For example, that four great pelagic fisheries had disappeared through recruitment overfishing, the HOKKaido herring, the Japanese Sardine, the Norwegian herring and the California Sardine.

Let us take up the investigations on the fishery of the Ganga river in the middle stretch in and around Allahabad and probe in what way these stock assessment studies empower us to provide management options. As made out by number of studies, the fishery of the Ganga river has declined in the past and the fishing has become unremunerative due to appreciable loss in fish stocks of the system due to overfishing in the past. The stock assessment conducted by the workers on five commercially important species estimated number of parameters and the results obtained by them are presented below:

Species	**Z**	**F**	**M**	**E**	**MSY (tons)**	**(Fmsy)**	**Catch (1986) (tons)**
C. catla	1.20	0.90	0.30	0.75	4.48	(0.59)	4.26
C. mrigala	1.09	0.74	0.35	0.68	7.97	(1.01)	9.40
L. rohita	0.74	0.44	0.30	0.59	3.63	(2.76)	2.87
L. calbasu	1.19	0.85	0.34	0.71	33.66	(0.64)	23.82
M. aor	0.68	0.34	0.34	0.55	13.95	(0.56)	12.20

The study further reveals that the average size in the catch has gone down significantly and the qualitative character of the fishery has also undergone change as some of the species have been replaced by others. The results presented above indicate that the fishery of species *C. catla, L. calbasu* and *M. aor* are overexploited whereas *L. rohita* is unde exploited. The fishery of mrigal seems to be closer to sustainable levels.

The management of such fishery needs appropriate biological advice for its sustainable exploitation in relation to available biomass in order to reap long-term benefits without further harming it. Various management options available for regulating such declining fishery need to be evaluated in the light of above investigations. Some such options available to the managers are listed below:

Various options available to regulate the fishery in order to check the declining trend are listed below and may be evaluated for their effectiveness for the present fishery in the light of available field conditions.

(i) Size of mesh of fishing nets;
(ii) Establishment of open or closed seasons;
(iii) Establishment of open or closed areas
(iv) Improvement and the increase of living resources;

(v) Regulation of total catches by species, groups of species;
(vi) Control of the amount of fishing through regulation of effort and allocation of catch quotas.

The idea of first regulation is to control the capture of small fish to avoid growth overfishing. Such measure needs to be suggested as mostly small mesh size nets are regularly operated in the area. The objective of controlling the amount for fishing is too control the fishing mortality to ensure that the desired level of fish mortality is applied. Due to the fact that the nature of the resource comes under the category of common property resource such measures are difficult to enforce. Establishment of closed or open seasons are indirect methods of controlling the amount of fishing and such measures have proved effective in this river. The remaining measures seems to be inappropriate in the prevailing situations.

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MODELS FOR MONITORING FISH STOCK ABUNDANCE BASED ON CATCH AND EFFORT DATA

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A fishery resource is a self renewable living natural resource in a dynamic habitat. In the absence of exploitation the abundance or biomass of the population will tend to increase, since it is a living resource, it will balance itself by adjustment of its inherent biological characteristics like growth, recruitment and mortality. When fishing exploits a resource, it can still recover by growth and new recruitment and retain the original level, but it changes mortality and may alter all the biological characteristics and its behaviour pattern. As fishing activities have intensified during the past few decades, it has become essential to predict catches and particularly the effects on catches due to change in the fishing activity with a view to proposing steps to ensure that increasing fishing intensity (effort) will continue to give sufficiently increasing returns. The fish stock assessment may be described as the fish search for exploitation level, which in the long run gives the maximum yield in weight from the fishery. For a given fishery resource there is, however, a largest average catch or yield that can be continuously taken from a stock under existing environmental conditions so that the stock remains un-effected. Therefore, ultimate objective of management programme of a given fishery resource is to assess this maximum yield or what is term as maximum sustainable yield .

Objectives of the fish stock assessment

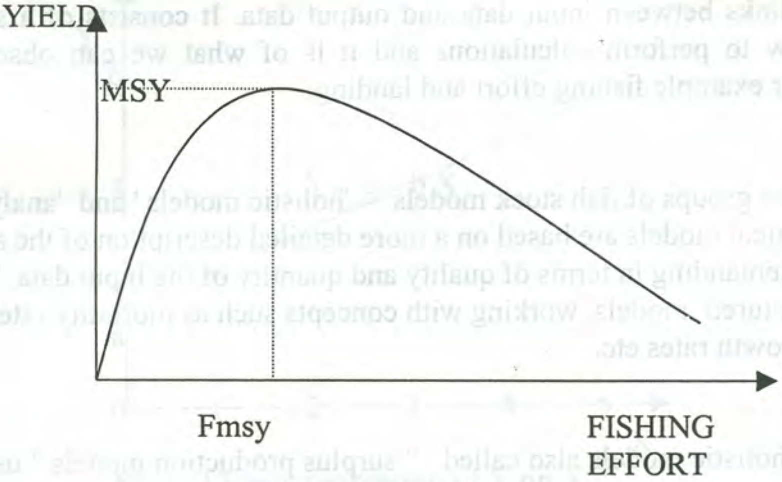

Fig 1 : The basic objective of fish stock assessment

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

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

Models

A description of fishery consisting of three basic elements :

1) the input (the fishing effort)
2) the output (the fish landed)
3) the process which link input and output (the biological processes and the fishing operations).

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

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

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

Basic concepts on simple linear regression

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

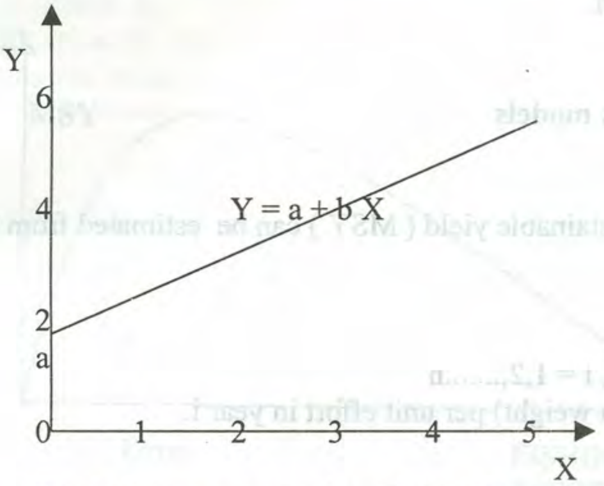

Fig 2: Linear regression of Y on X

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

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

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

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

The Schaefer and Fox models

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

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

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

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

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

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

which can also be written as

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

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

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

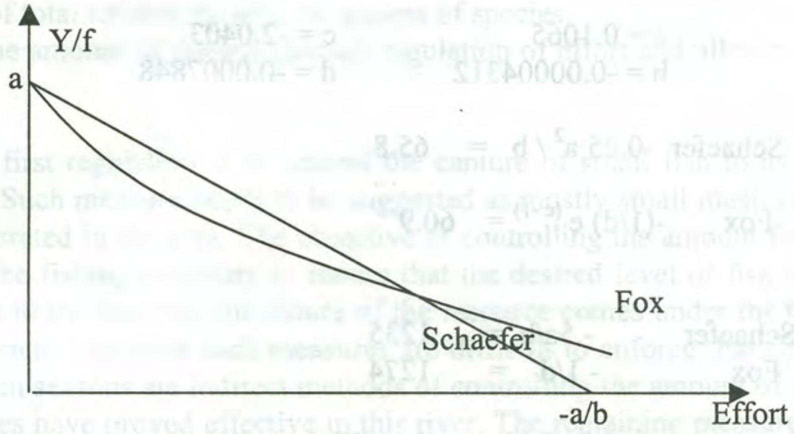

Fig 3: Schaefer and Fox model

The Schaefer's model can be written as

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

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

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

and the corresponding yield

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

The Fox model can be written as

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

$$f_{msy} = -\ 1/d$$

$$MSY = -\ (1/d)\ e^{(c\ -1)}$$

Year	Yield Y(i)	Effort f(i) X	Schaefer Y(i)/f(i) Y	Fox log{Y(i)/f(i)} Y
1969	50	623	0.080	-2.523
1970	49	628	0.078	-2.551
1971	47.5	520	0.091	-2.393
1972	45	513	0.088	-2.434
1973	51	661	0.077	-2.562
1974	56	919	0.061	-2.798
1975	66	1158	0.057	-2.865
1976	58	1970	0.029	-3.525
1977	52	1317	0.039	-3.232
Mean		923.22	0.0667	-2.7648

$a = 0.1065$ $c = -2.0403$

$b = -0.00004312$ $d = -0.0007848$

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

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

f_{msy}

Schaefer $-.5a/b = 1235$

Fox $-1/d = 1274$

Relative response-model of Alagaraja (1984)

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

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

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

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

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

Example

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

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

Solution

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

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

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

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METHODS FOR ESTIMATING GROWTH AND MORTALITY PARAMETERS BASED ON SIZE FREQUENCY DATA

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Growth

The study of growth means basically the determination of the body size as a function of age. Therefore, all stock assessment methods work essentially with age composition data. In temperate waters such data can usually be obtained through the counting of year rings on hard parts such as scales and otoliths. These rings are formed due to strong fluctuation in environmental conditions from summer to winter and vice versa. In tropical areas such drastic changes do not occur and it is therefore very difficult, if not impossible to use this kind of seasonal rings for age determination.

Only recently methods have been developed to use much finer structures, so called daily rings, to count the age of the fish in number of days. These methods, however, require special expensive equipment and a lot of manpower and it is therefore not likely that they will be applied on a routine basis in many places.

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

The growth of fishes of a given stock is generally expressed by an equation known as von Bertalanffy Growth Formula(VBGF)

$$L_t = L_\propto (1-e^{-k(t-to)})$$

Where $L_{\propto}$ is the mean length the fish would reach, if, they were to grow to a very old age (indefinitely, in fact).
K is a growth co-efficient t_o is the 'age' the fish would have had at length zero, if, they had grown according to the equation (t_o generally has a negative value)
and where L_t is the length at age t.

The biological data, which can be used to obtain information ("growth data") from which growth parameters can be estimated, are of three basic types.

1. Tagging - recapture data on (or direct observation of the growth of) individual fishes.
2. Periodic markings (annual, or daily) on skeleton parts such as scales, otoliths or other bones.
3. Size-frequency data, most commonly length frequency data.

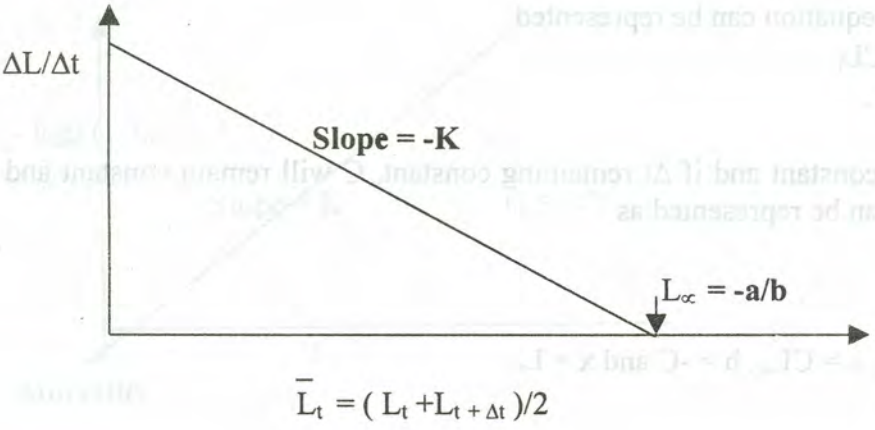
   Growth parameters can be derived from data by graphical methods or plot, which are always based on a conversion to a linear equation.

(a) The Gulland and Holt plot.

The equation used for this plot is written as

$$\Delta L/\Delta t = K(L_{\propto} - \bar{L}_t)$$

where $\bar{L}_t = (L_t + L_{t+\Delta t})/2$
using $\bar{L}_t$ as the independent variable and $\Delta L/\Delta t$ as dependent variable, the equation can be written as $\Delta L/\Delta t = a + b\ \bar{L}_t$
The growth parameters K and $L_{\propto}$ are obtained from :
$K = -b$ and $L_{\propto} = -a/b$.



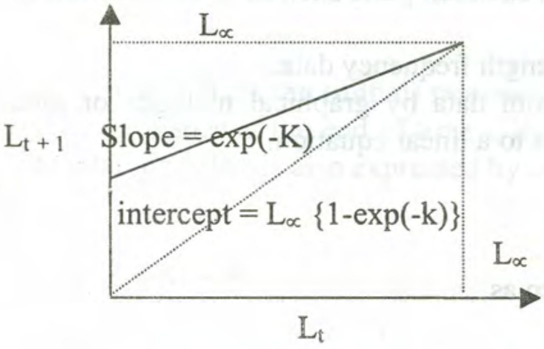
b) The Ford-Walford plot

The method most commonly used for estimating the parameters $L\propto$ and K of VBGF in the "Ford-Walford plot" which essentially consists of a rewritten version of the VBGF of the form.

$$L_{t+1} = a + b\,L_t$$

Where $L_\propto = a/(1-b)$ and $K = -\log_e b$

and where Lt and L_{t+1} pertain to length separated by a constant time interval (1 = year, month, week etc)



c) Chapman's method

This method is applicable when we have pairs of observations based on constant time interval Δt

(t, Lt), $(t + \Delta t, L_{t+\Delta t})$, $(t + 2\,\Delta t, L_{t+2\Delta t})$ etc.

The von Bertalanffy equation can be represented
$L_{t+\Delta t} - L_t = CL_\propto - CL_t$
where $C = 1 - e^{-K\Delta t})$

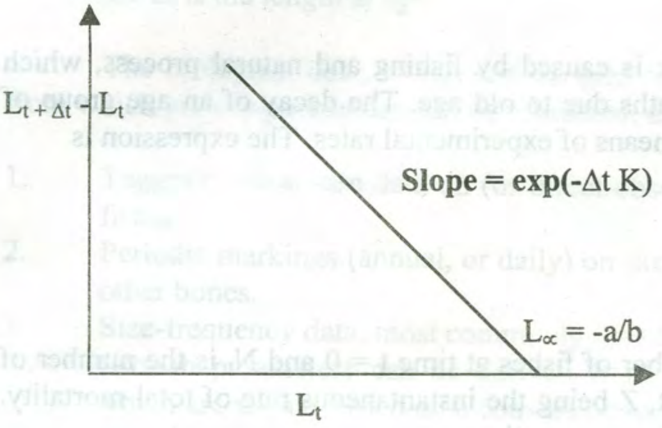
Since K and $L_\propto$ are constant and if Δt remaining constant, C will remain constant and the above equation can be represented as

$$Y = a + bx$$

where $Y = L_{t+\Delta t} - L_t$, $a = CL_\propto$, $b = -C$ and $x = L_t$

The growth parameters are derived from

$K = -(1/\Delta t) \log_e (1 + b)$ and $L_{\propto} = -a/b$ or a/c



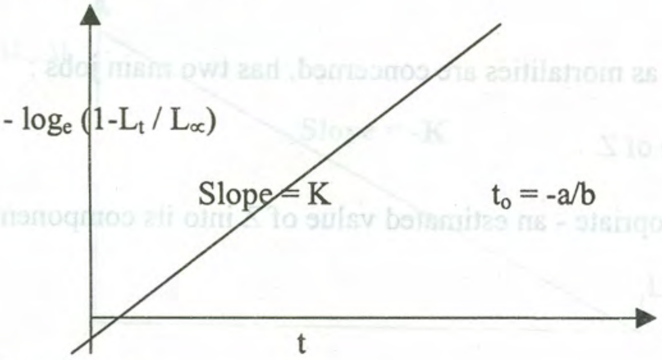
d) The von Bertalanffy Plot

It can be used to estimate K and t_o from age/length data, while it requires an estimate of $L_{\propto}$ as input.

The von Bertalanffy growth equation can be rewritten

$$-\log_e (1-L_t / L_{\propto}) = -K\ t_o + Kt$$

With the age, t, as the independent variable (x) and the left-hand side as the dependent variable(y) the equation defines a linear regression, where the slope b = K and the intercept $a = -K\ t_o$



Mortality

The growth is the positive aspect in the dynamics of a fish stock, while death process is the negative counterpart. The growth is described by mathematical model. The death process can also be derived by mathematical expression and the key parameters are called the mortality rates.

The mortality of a fish stock is caused by fishing and natural process, which includes production, disease and deaths due to old age. The decay of an age group of fishes through time is expressed by means of experimental rates. The expression is

$$N_t = N_o e^{-Zt}$$

where N_o is the (initial) number of fishes at time $t = 0$ and N_t is the number of remaining fishes at the end of time t, Z being the instantaneous rate of total mortality. The total mortality is also expressed by an equation

$$Z = M + F$$

where M is the instantaneous rate of natural mortality and F is the instantaneous rate of fishing mortality. Obviously, when

$$F = 0 \text{ then } Z = M$$

which means that natural and total mortality have the same value when there is no fishing (in an unexploited stock).

The fishery biologists, as far as mortalities are concerned, has two main jobs :

(a) To estimate the value of Z

(b) To split - where appropriate - an estimated value of Z into its component part M and F.

Estimating Total Mortality

Total mortality from the mean size in the catch can be estimated adopting different methods. Some of them are presented below.

(a) When a large number of length frequency data have been obtained from a given stock by a given gear, Z can be estimated from the mean length(L) in the catch from a given population by means of

$$Z=K(L_\propto-L)/(L-L')$$

where $L_\propto$ and K are parameters of the von Bertalanffy growth equations, L is the mean length in the catch, and “L is the smallest length of animals that are fully represented in catch samples”.

(b) Another equation which can be used to estimate Z from the mean length in the catch is

$$Z=\frac{n.K}{(n+1)\log_e\{(L_\propto-L')/(L_\propto-L)\}}$$

where $L_\propto$, L, L' and K are defined above while n is the number of fishes used for the estimation of L. It will be noted that when n is large, the term n/(n+1) tends towards unity and hence can be neglected.

(c) The above equation corresponding to weight (when growth is isometric)

$$Z=\frac{n.K}{(n+1)\log_e\{(\sqrt[3]{W_\propto}-\sqrt[3]{W'})/(\sqrt[3]{W_\propto}-\sqrt[3]{W})\}}$$

where $W_\propto$ and K are parameters of the von Bertalanffy growth function for weight growth, which has the form

$$W_t = W_\propto\,(1-e^{-k(t-to)})^3$$

where $\overline{W}$ and W' are the weight corresponding to $\overline{L}$ and L' as obtained (along with W_∞) from conversion from length to weight, by means of appropriate length-weight relationship.

(d) Another method of estimating Z consists of sampling a multi-aged population of fishes, then plotting the natural logarithm ($\log_e$) of the number of fishes in the sample(N) against their age(t) or

$\log_e N = a+bt$

where the value of b, with sign changed, provides an estimate of Z. This procedure is known as catch curve method.

Several requirements must be met for the values of -b to be good estimate of Z. Among these we may mention:

(i) Only those values of $\log_e N$ must be included which pertain to age group of fishes fully vulnerable to the gear in question.

(ii) Recruitment must have been constant within the period covered, or have varied in random fashion only.

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MARKING METHODS FOR THE ESTIMATION OF FISH POPULATIONS

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Estimation of fish population abundance is essential to understand the changes in population, yield estimation and for fishery resource management. Broadly, estimation methods can be grouped into two:

1. Direct methods
2. Indirect methods

Tagging or marking falls under the category of indirect methods. Estimation through marking methods depends on a ratio. The marking methods were first employed by Laplace in 1783 to estimate the population of France using birth records. In case of fish, tagging or marking them by mutilating some part of the body was employed to trace their waterways and migration. Petersen was first to use the tagging to estimate the fish population living in a closed water body. These methods are generally known as

1. Sample census,
2. Estimation by marked numbers,
3. Mark-and-recapture method,
4. The Petersen method, or
5. The Lincoln index.

In such studies, a sample of fish is taken from the population and the fish are marked or tagged for future identification and then returned to the population. After allowing time for marked and unmarked to mix, a record is then kept of the total number of fish caught out of it during a year or another interval, and the number of marked ones among them. Then using the proportion of marked to unmarked, estimate for initial population is derived.

Assumptions

For such studies, the following assumption should be fulfilled:

1. the marked fish become randomly mixed with the unmarked,

2. the natural mortality is same for marked and unmarked specimens,

3. the marked fish are as vulnerable to the fishing as are the unmarked ones,

4. marked fish do not lose their marks during the course of investigation,

5. it is expected that the marks are recognised and reported on recovery to the concerned authorities, and

6. only a negligible recruitment is made to the catchable population during the investigation period.

Procedures

Single census (Petersen type)

In this procedure fish are marked only once; subsequently a single sample is taken and examined for marked specimens. Caution should be taken in respect of time. Marking should be done in short interval, and the subsequent sampling may be taken over a quite long period.

Multiple census (Schnabel type)

Fish are marked and released over a considerable period. During the course, samples are taken and examined for recaptures. In this procedure samples should be replaced, otherwise the population is decreasing and the population estimate cannot refer to any definite period of time. If the sample size is negligible fraction of population, the condition of replacement may be violated.

Point censuses

Samples for marking and for obtaining recoveries are made at three or more periods or points in time. The first sample is made for marking only, the last is for recoveries only, and the intermediate one or ones are for marking and recovery. In this procedure a different mark is used each time, and subsequent sampling takes cognisance of the origin of each mark recovered.

Following the above procedures, there are number of procedures for getting second or census sample. The important ones are as follows.

Direct census

Here, the size of the sample or samples taken is fixed in advance. This is the most common procedure.

Inverse census

In this case, the number of recaptures to be obtained is fixed in advance, and the experiment is stopped as soon as that number is obtained.

Notations

Let N denotes the initial population

M denotes the number of fish marked

C denotes the catch or sample taken for census

R denotes the number of recaptured marks in the sample

$\hat{N}$ denotes the estimate for initial population N

$V(*)$ denotes the variance for argument *

Here, only two simple methods of estimation will be discussed and for detailed discussion, the reader may consult the books referred in the end under suggested readings.

Petersen method

It is the simplest method for marking/tagging studies. A sample of M fish is taken from a water body and after marking the specimens are released. During the course of fishing in a year or other time interval, the total number of fish caught were C, out of which R specimens were marked ones. Then an unbiased estimate of the reciprocal of initial population N is given by

$$\frac{1}{\hat{N}} = \frac{R}{MC} \tag{1}$$

The sampling variance of (1) is given by

$$V\left(\frac{1}{\hat{N}}\right) = \frac{R(C-R)}{M^2C^3} \tag{2}$$

The reciprocal of (1) provides a consistent estimate of N and estimate of N is given by

$$\hat{N} = \frac{MC}{R} \tag{3}$$

The sampling variance of $\hat{N}$ is given by

$$V\left(\hat{N}\right) = \frac{M^2C(C-R)}{R^3} \tag{4}$$

Although expression (3) provides a consistent estimate of N, *i.e.*, it tends to provide correct value as sample size is increased, but it is not the best estimate. The formula was further modified as

$$\hat{N} = \frac{M(C+1)}{R+1} \tag{5}$$

(5) provide an almost unbiased estimate of N. The large-sample sampling variance for (5) is given as

$$V(\hat{N}) = \frac{M^2(C+1)(C-R)}{(R+1))^2(R+2))},$$

substituting the value of $\hat{N}$ from (5)

$$V(\hat{N}) = \frac{\hat{N}^2(C-R))}{(C+1)(R+2))} \tag{6}$$

All the expressions given above are applicable whether the fish captured are removed from the population, or whether they are returned to it.

Sometimes a slightly different form of (5) is used for estimation purposes and is given as

$$\hat{N} = \frac{(M+1)(C+1)}{R+1} \tag{7}$$

In case of inverse sampling, a slightly better estimator is given by

$$\hat{N} = \frac{C(M+1)}{R} - 1 \tag{8}$$

The approximate asymptotic variance is given as

$$V(\hat{N}) = \frac{(M-R+1)(\hat{N}+1)(\hat{N}-M)}{R(M+2)} \tag{9}$$

Schnabel method (Multiple census)

The Schnabel or multiple-census procedure for estimating population is somewhat like a series of Petersen estimates but using all accumulated data for one estimate. In this procedure a sample is taken from the population, marked and returned to the population. A second sample is taken, marked fish are noted, and unmarked fish are marked. All are released. The same procedure is repeated for as long as feasible. In this procedure it is assumed that no mortality takes place during the course of investigation and there is no recruitment. However, the procedure may still be useful if these assumptions are not fulfilled.

Let

M_t	denotes the total marked fish at large at the start of the t th day (or other interval), *i.e.*, the number previously marked less any accidentally killed at previous recaptures.
M	denotes the total number marked, *i.e.*, $\sum M_t$
C_t	the total sample taken on day t
R_t	the number of recaptures in the sample C_t
R	the total recaptures during the experiment, *i.e.*, $\sum R_t$
N	the population present throughout the experiment.

Then, estimator for N is given by

$$\hat{N} = \frac{\sum_{t=1}^{n} C_t M_t}{\sum_{t=1}^{n} R_t} \tag{10}$$

Again, the estimates of the reciprocal of N are more normally distributed and it is better to use for determining confidence limits. The formula is given as:

$$\left(\frac{\hat{1}}{N}\right) = \frac{\sum_{t=1}^{n} R_t}{\sum_{t-1}^{n} C_t M_t}, \tag{11}$$

which has an approximate large-sample variance:

$$V\left(\frac{\hat{1}}{N}\right) \cong \frac{\sum_{t=1}^{n} R_t}{\left(\sum_{t=1}^{n} C_t M_t\right)^2} \tag{12}$$

The confidence interval for the estimate of 1/N will be given by

$$\frac{1}{\hat{N}} \pm 1.96\sqrt{V\left(\frac{1}{\hat{N}}\right)} \tag{13}$$

In the following an example taken from Everhart *et. al.* (1975) is cited to show the computational procedure.

Sample	Total catch *(C)*	Total number of marked fish at large *(M)*	Number of marked fish recaptured *(R)*	*CXM*	Number of fish marked from the sample
1	100	0	0	0	100
2	120	100	12	12000	108
3	90	208	19	18720	71
4	150	279	42	41850	108
Total			$\sum R = 73$	$\sum CM = 72570$	

Using formula (10) the estimate for N is obtained as

$$\hat{N} = \frac{72570}{73} = 994\,,$$

and

$$\frac{\hat{1}}{N} = \frac{73}{72570} = 0.00100593$$

Using the expression (12)

$$\hat{V}\left(\frac{\hat{1}}{N}\right) \cong 1.386 \times 10^{-8}$$

Thus, the 95 percent confidence interval for 1/N will be given as

$$P\left(0.000775 \le \frac{1}{N} \le 0.001237\right) = 0.95\,,$$

and for N:

$$P(809 \le N \le 1290) = 0.95\,.$$

Fish marking

Fish can be marked in two ways:

a) mutilating the fish in some manner, as by removing a fin or part of the maxillary bone,

b) or by tagging, which involves the insertion, attachment, or injection of a foreign object or substance.

An ideal mark should have the following characteristics

1. Remain unaltered during the life time of the fish,
2. Have no effect on fish behaviour or make the fish more available to predators,
3. Not tangle with weeds or nets,
4. It should be inexpensive and easily available,
5. Fit to any size fish with little alteration,
6. Be easy to apply without anaesthesia and with little or no stress to the fish,
7. Create no health hazard,
8. Cause no harm to fish as food to aesthetics,
9. Be easy to detect in the field by untrained individuals,
10. Cause no confusion in reporting
11. Remain unaffected by preservation.

For a comprehensive account for fish marking, the reader may consult Everhart *et. al.* (1975).

Suggested books for further reading

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Summer School on ***Ecology, Fisheries and Fish Stock Assessment in Indian Rivers***
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FISH STOCK ASSESSMENT- YIELD PER RECRUIT MODEL

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Mathematical models play a vital role in prediction of future yields and stock biomass levels. These models can be used to forecast the effects of increasing or decreasing effort, changes in fishing pattern such as increase or decrease in mesh size. Thus, these models form a direct link between fish stock assessment and fish resource management.

Before going into details, it should be clear that a comprehensive assessment of the long-term effects of any pattern of fishing is difficult, and is likely to be subject to inaccuracies. But when we consider the fate of a brood or year class or cohort of fish once they have been recruited to the fishery, situation is considerably brighter. After recruitment to fishery, many of the uncertainties, such as, influence of adult stock size or environmental factors on recruitment are circumvented. There may be a change in growth rate and natural mortality, but after recruitment these changes are comparatively small, and reasonable estimates for growth rate and natural mortality can be obtained. Thus, on the basis of yield per recruit the scientist/advisor can give a clear answer to questions such as "what pattern of fishing will give the maximum yield from the year-class of fish that has just been recruited". These answers are very important in themselves and provide a solid foundation on which advice can be given, and tentative conclusions are attained. Thus, calculation of yield from a given recruitment – usually expressed as yield per recruit – is a basic element in the assessment of any fish stock.

The first prediction model was given by Thompson and Bell in early forties, known as "Thompson and Bell model", involving a large number of calculations. Based on rigorous assumptions in 1957, Beverton and Holt's "yield per recruit model" came into picture and due to involvement of less number of calculations, it became very popular among fishery workers for fish stock assessment. Here, we shall discuss only the yield per recruit model of Beverton and Holt and for other models and details reader may refer to books referred in the end under suggestions for further reading.

Yield per recruit model of Beverton and Holt

Basic assumptions

1. Recruitment is constant, yet not specified.
2. All fish of a cohort are hatched on the same date.
3. Recruitment and selection are "knife-edge".
4. The fishing and natural mortalities are constant from the moment of entry to the exploited phase.
5. There is complete mixing within the stock.
6. The length-weight relationship has the exponent 3, *i.e.*, $w = al^3$.

Notations

t_r	age at recruitment
t_c	age at first capture
F_t	fishing mortality coefficient
M	natural mortality coefficient
Z	=F+M, total mortality coefficient
K	von Bertalanffys' growth parameter
t_0	calculated age when length of fish is supposed to be 0
W_∞	asymptotic body weight
W(t)	average weight of an individual fish at age t
L_∞	asymptotic body length
R	number of survivors at age t_r, *i.e.*, recruitment to the fishery
N(t)	number of fish alive at age t

Now, further it is assumed that

1. At age t_r all fish belonging to a cohort recruit to the fishing grounds at the same time.
2. From age t_r to t_c the cohort is not exposed to any fishing mortality. Thus, during this period they suffer only natural mortality, M, which is assumed to be constant throughout the life span of the cohort. Thus,

$$F_t = 0; \qquad t \le t_c$$

$$F_t = F = constant; \qquad t > t_c$$

In terms of the above notations, the number of survivors at age t_r is the recruitment R to the fishery and

$$R = N(t_r)$$

Now, the number of survivors at age t_c will be:

$$N(t_c) = Re^{-M(t_c - t_r)} \tag{1}$$

Similarly, the number of survivors at age t ($t>t_c$) will be given by

$$N(t) = N(t_c)e^{-(M+F)(t-t_c)}, \tag{2}$$

substituting from (1) in (2)

$$N(t) = Re^{-M(t_c - t_r)-(M+F)(t-t_c)} \tag{3}$$

Thus, the fraction of the total recruitment $N(t_r)$ or R, surviving until age t will be given by

$$\frac{N(t)}{R} = e^{-M(t_c - t_r)-(M+F)(t-t_c)} \tag{4}$$

The equation (4) gives the number of fish at time t "per recruit" *i.e.* as the fraction of each fish that recruited to the fishery.

Now, we shall proceed to Beverton and Holt's per recruit model. Let us consider a small time interval dt, then the catch in the small interval dt, *i.e.*, from time t to t+dt will be given by

$$C(t,t+dt) = F.N(t).dt \tag{5}$$

To convert the catch to weight, we will multiply the catch by W(t), the average weight of a fish of age t and the yield will be given as

$$Y(t,t+dt) = F.N(t).W(t).dt \tag{6}$$

It is assumed here that W(t) follows the von Bertlanffy's growth equation which is given by

$$W(t) = W_\infty[1 - e^{-K(t-t_0)}]^3 \qquad (7)$$

Now, in expression (6), dividing both sides by R

$$\frac{Y(t+dt)}{R} = F\frac{N(t)}{R}W(t)dt, \qquad (8)$$

where N(t)/R is given by the equation (4). The model (8) is the Beverton and Holt model for a short time period. To get the total yield per recruit for the entire life span of the cohort, Y/R, all the contributions defined by (6) must be summed up, and finally after mathematical manipulations and ignoring the ineffective terms it leads to

$$\frac{Y}{R} = Fe^{-M(t_c-t_r)}W_\infty\left[\frac{1}{Z} - \frac{3S}{Z+K} + \frac{3S^2}{Z+2K} - \frac{S^3}{Z+3K}\right], \qquad (9)$$

where

$$S = e^{-K(t_c-t_0)} \qquad (10)$$

Equation (10) is the Beverton and Holt's yield per recruit model. A number of computer programmes exists for this, and similar expressions. The results of the model are expressed in units of yield per recruit (grams per recruit).

Although, this equation contains several parameters, several of those, for instance W ∞, only appear as a constant factor. Since, in considering yield-per-recruit, we are mainly interested in changes or relative yield-per-recruit at different levels of fishing mortality or age at first capture, these constant factors do not matter. Using (9), we can calculate Y/R with varying inputs of the different parameters, such as F and t_c and then assess the effect of various inputs on the yield-per-recruit of the species under investigation. Here, the parameters F and t_c are the parameters which can be controlled by fishery managers. Thus, we can say that Y/R is a function of F and t_c. The yield-per-recruit can be expressed either as a function of fishing mortality F, keeping the age at first capture, t_c, as constant, or as a function of t_c, keeping F constant. In each case the present value of F or t_c should be clearly indicated. The yield per recruit curve keeping t_c as a constant often has a maximum, which gives the "maximum sustainable yield".

The expression (9) can be expressed in a different form using the exploitation ratio, ratio of fishing to natural mortality, *i.e.*, F/M and the relative size at first capture, expressed as

$$c = \frac{l_c}{l_\infty} = 1 - e^{-K(t_c - t_0)} \tag{11}$$

Then, substituting the value of c in (10), we get

$$S = 1\text{-}c, \tag{12}$$

and with slight mathematical manipulations, we can write

$$e^{-M(t_c - t_r)} = e^{-M(t_0 - t_r)} e^{-M(t_c - t_0)}$$

$$= e^{-M(t_0 - t_r)} (1 - c)^{M/K} \tag{13}$$

Using (13), expression (9) can be rewritten as

$$Y = FRW_\infty e^{-M(t_0 - t_r)} (1 - c)^{M/K} \sum_{n=0}^{3} \frac{U_n (1 - c)^n}{F + M + nK}, \tag{14}$$

where, U_0=1, U_1=-3, U_2=3 and U_3=-1.

Now, taking out constant term characteristic of the stock but independent of F and c, we can write

$$Y = Y'\left[RW_\infty e^{-M(t_0 - t_r)}\right], \tag{15}$$

and

$$Y' = E(1 - c)^{M/K} \sum_{n=0}^{3} \frac{U_n (1 - c)^n}{1 + \dfrac{nK}{M}(1 - E)} \tag{16}$$

Looking on expression (16), we find that it contains only E, c and M/K. The values have been tabulated by Beverton and Holt for a series of values of M/K from 0.25 to 5.00. For each value of M/K the tables can be used directly as a yield-isopleth diagram, giving a number proportional to the yield per recruit, as a function of c (*i.e.* size at first capture) and E (a measure of intensity of fishing). From this the effects of different actions on the fishery can be easily determined, though some care should be taken in interpreting the effects of changes in the amount of fishing at high values of E. This is because if E is large (>0.5), quite small changes in E correspond to large changes in F.

Suggestions for further reading

Beverton, R. J. H. and S. J. Holt (1957) On the dynamics of exploited fish populations, *Min. Agric. and Food (U.K.), Fish. Invest.* Ser. II, 19.

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A METHOD FOR DETERMINING GEAR SELECTIVITY AND ITS APPLICATION

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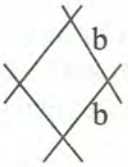
In any fishery the composite length ranges (or age ranges) of fish or shell-fish are not always under full exploitation. Most fishing gears, for example trawl gears, are selective for the larger sizes, while some gears (gill nets) are selective for a certain length range only, thus excluding the capture of very small and very large fish. This property of fishing gear is called "gear selectivity". It needs to be taken into account when we want to estimate the real size (or age) composition of the fish in the fishing area. At the same time, it is an important tool for fishing managers who, by regulating the minimum mesh sizes of a fishing fleet, can more or less determine the minimum sizes of the target species of certain fisheries. Gear selectivity is strongly related to the estimation the total mortality, Z, the analysis of trawl survey data vis-a-vis commercial fisheries and production of future yield.

Estimation of trawl net selection

In trawl net the fine meshed end of the net where the catch is collected is called the cod-end. The "mesh size" of the cod-end determines, to a large extent, the selectivity of trawl gear.



The "mesh size" is usually defined as the length of the "stretched" whole mesh. The mesh size of the netting shown here is 2b, where b is the length between two knots.

It is possible to determine the amount and size of fish that escape through meshes of the cod-end by covering the cod-end with a much larger bag with much finer meshes.

The selectivity of the gear then be determined by comparing the sizes of the fish in the cover. The results can be expressed as the proportion of fish at each length entering the net which are retained in the cod-end. When their proportions are plotted against length, the selection curve of the net for the species concerned is obtained. This curve is called "gear selection ogive". The easiest mathematical expression to describe the gear selection ogive is the so called "logistic curve".

$$S_L = \frac{1}{1+\exp(S_1 - S_2 * L)}$$

$$\text{where } S_L = \frac{\text{number of fish of length L in the cod-end}}{\text{number of fish of length L in the cod-end and in the cover}}$$

and L is the length interval mid point(mid-length), S_1 and S_2 are the constants.

The above equation can be rewritten as
$\log_e (1/ S_L - 1) = S_1 - S_2 * L$
which represents a straight line, where $S_1 = a$ and $S_2 = b$.

So, the observations of the fractions retained can be used to determine the logistic curve that fits to the observations. The estimated logistic curve (S_L est) can then be used to calculate the fractions that correspond to the curve.

By applying a few algebraic manipulations it follows that there is a one-to-one correspondence between S_1 and S_2 and $L_{25\%}$, $L_{50\%}$ and $L_{75\%}$, the length at which respectively 25%,50% and 75% of the fish are retained in the cod-end. The length range from $L_{25\%}$ to $L_{75\%}$, which is symmetric around $L_{50\%}$ is called the 'selection ogive'

The formulae for calculating $L_{25\%}$, $L_{50\%}$ and $L_{75\%}$ are

$L_{25\%} = (S_1 - \log_e 3)/S_2$
$L_{50\%} = S_1/S_2$
$L_{75\%} = (S_1 + \log_e 3)S_2$

S_1 and S_2 can be derived form $L_{75\%}$ and $L_{50\%}$ using the following formulae

$S_1 = L_{50\%} \text{ x } \log_e (3) /(L_{75\%} - L_{50\%})$
$S_2 = \log_e (3) /(L_{75\%} - L_{50\%}) = S_1/L_{50\%}$

The regression analysis is done over a length range between zero (0) and full(1) retention, thus excluding those length intervals where no or full retention was obtained .

As the probability that a fish escape through a mesh depends on its shape, and in particular on its body depth composed to the mesh size, it is natural to assume proportionately between $d_{50\%}$ (the body depth at which 50% of the fish are retained) and the mesh size.

$d_{50\%} = A \text{ x (mesh size)}$

where A is a constant. As body depth is approximately proportional to body length the above equation Implies that a similar expression holds for the length of a fish :

$L_{50\%} = SF \text{ x (mesh size)}$

Where SF is called the “selection factor”

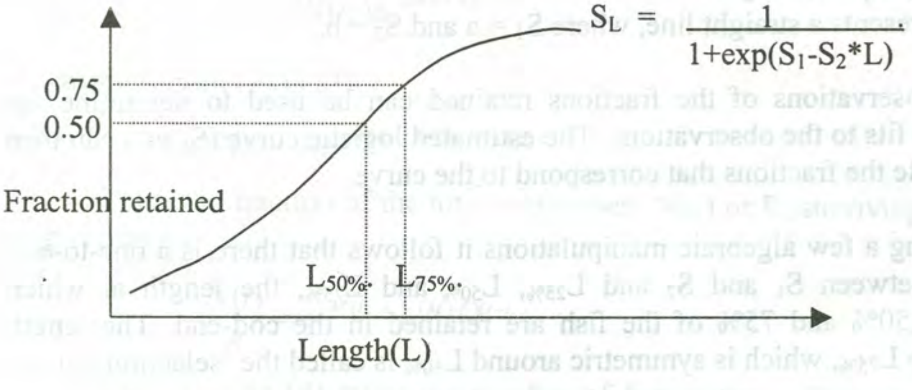


Fig 1: Gear Selection Ogive

With the known parameters $L_{50\%}$ and $L_{75\%}$ for the gear currently in use we are in a position to calculate a new length-based selection curve for new values of $L_{50\%}$ and $L_{75\%}$. From the new selection ogive, and the Fm of the current fishery, we can calculate a new array of fishing mortality.

$F_1 \text{ new} = F_m \text{ x } S_L \text{ new.}$

Example :- One experiment was conducted on the threadfin beam, *Nemipterus japonius*, which is caught with a trawl net with a cod-end mesh size of 4 cm and a cover of much smaller meshes. The typical catch of one trawl hand is given in table below in the form of two length-frequency tables for the cod-end and the cover respectively.

A	B	C	D	E	F	G	H
Length interval $L_1 - L_2$	Number in codend	Number in cover	total number	Fraction retained S_L observed	$\log_e (1/S_L - 1)$ (y)	Mid length $(L_1 + L_2)/2$	Fraction retained S_L est
9 - 10	0	1	1	0	-	-	-
10 -11	1	6	7	0.14	1.82	10.5	0.13
11 - 12	2	7	9	0.22	1.27	11.5	0.23
12 - 13	2	4	6	0.33	0.71	12.5	0.38
13 - 14	7	5	12	0.58	-0.32	13.5	0.56
14 - 15	30	13	43	0.70	-0.85	14.5	0.72
15 - 16	61	8	69	0.88	-1.99	15.5	0.84
16 - 17	27	3	30	0.99	-2.20	16.5	0.91
17 - 18	7	0	7	1.00	-	17.5	0.96
18 - 19	4	1	5	0.80	-	18.5	0.98

Intercept = a = $S_1 = 9.4875$ -Slope = -b = $S_2 = 0.7193$

$S_L \text{ est} = 1/(1+\exp(9.8745 - 0.7193*L))$

$L_{50\%} = S_1 / S_2 = 13.2$ cm $L_{75\%} = (S_1 + \log_e 3)/ S_2 = 14.7$

$L_{25\%} = (9.4975 - \log_e 3)/0.7193 = 11.7$

$L_{50\%}$ = SF*(mesh size), in our case for a mesh size of 4 cm the selection factor is SF = 13.2/4 = 3.3

This selection factor can be used to determine $L_{50\%}$ for different mesh sizes, for instance of *Nemipterus japonicus* when using mashes of 3 would be

$L_{50\%} = 3.3*3 = 9.9$ cm

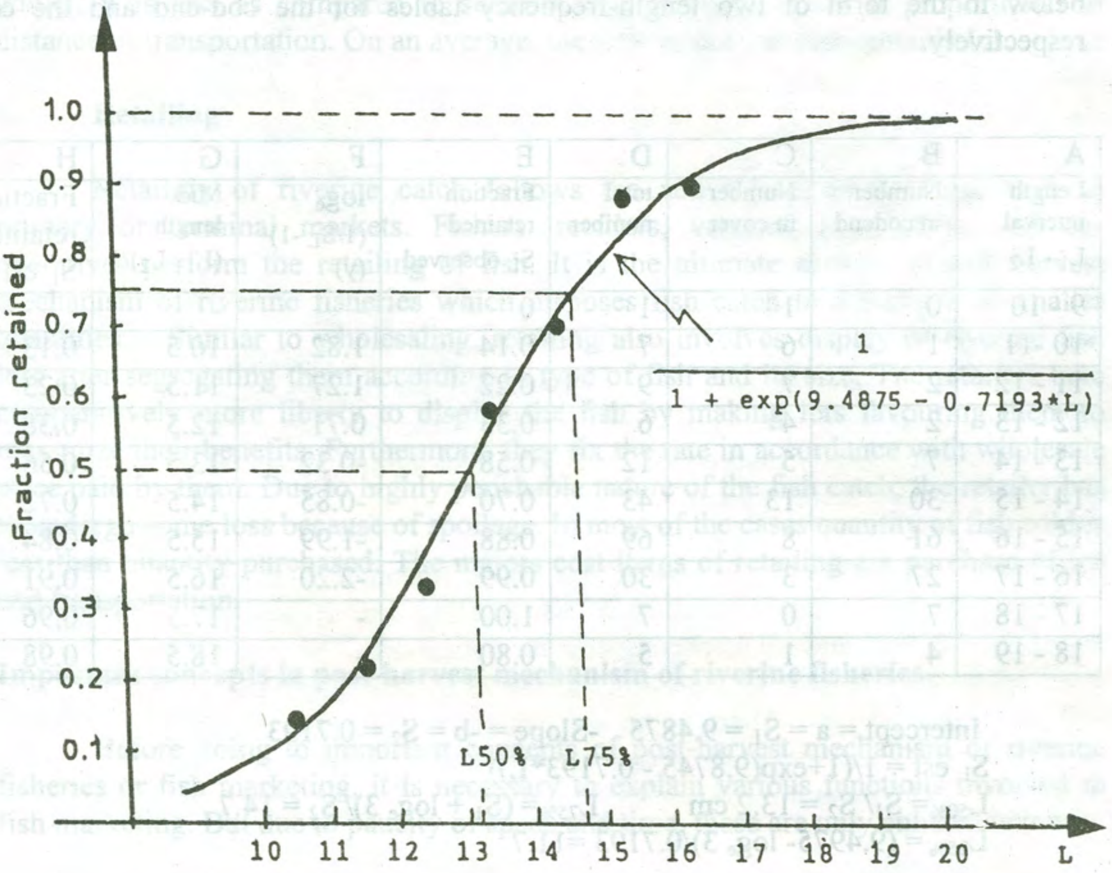


Fig 2:-Gear Section Ogive for *Nemipterus japonicus* caught by a trawl with a codend mesh of 4 cm

POST-HARVEST MECHANISM OF RIVERINE FISHERIES IN INDIA

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The returns for a production activity are the function of its production and marketing efficiencies. The efficiency of production may be measured in terms of cost effectiveness and quantity and quality of final output. The efficiency of marketing means that how best the marketing process passes the consumer price to producers. These concepts are also applicable to riverine fisheries. The riverine fish production process primarily includes capture fishing and in certain stretches collection of fish spawn also. In India, rivers are natural, enormous, unmanageable common property resources with open access. These have multiple uses, viz. irrigation, sand industry, water transport, drain house for industrial and municipal wastes, etc.; besides, capture fishery operations. The rivers are also subjected to water abstractions, dam construction, river training and sedimentation. Furthermore, the riverine fish harvest has been observing declining trend for past few decades. The above-cited factors constrained the prospects to improve efficiency of riverine fish production. Therefore, the efforts for enhancing their fish business income through production activity have limited scope to uplift socio-economic status of the fishers. It has shifted the emphasis of these efforts to post-harvest operations. The literature on post harvest mechanism of fisheries in general and riverine fisheries in particular is very scanty. In this context, it is pertinent to elaborate these aspects in detail. Therefore, present lecture is devoted to investigate post harvest mechanism of riverine fisheries in India and some important concepts for its appraisal.

Post- harvest mechanism of riverine fisheries

The post-harvest process of riverine fisheries describes the fishery operations conducted by fishers or other concerned people after completion of fishing or fish production process. It means that once the fish harvest or catch is in the hand of fishers, the functions performed by him or other related persons constitute the post-harvest mechanism of riverine fisheries. In India, most of the riverine catch is consumed in fresh form. A negligible quantity of it is either dried and processed by traditional methods or used for non-edible purposes. Therefore, the post-harvest mechanism becomes a synonym for fish marketing. The marketing or post-harvest mechanism of riverine fisheries includes following operations.

1. Disposal of fish catch by fishers;
2. Transportation of catch to landing centre / wholesale or retail market;
3. Wholesaling;
4. Packaging; and
5. Retailing.

1. Disposal of the catch by fisher

The unmanageable and vast magnitude of rivers resulted in diffused riverine fishing operations over varying lengths of different riverine stretches. After completion of fishing operations, the next step is disposal of catch. The disposal of catch depends mainly on type of fishing property regime in the stretch, quantum of catch and social and financial compulsions of fishers. Under different fishing rights there the probable options for disposal of catch are:

i) If fishing rights are exclusively with some contractor or co-operative, the fishers have to dispose their catch to these agencies.
ii) If river fishing rights are in common property regime with open access, the fisher has to undertake decision making process for: i) where to dispose; ii) how to dispose; and iii) to whom to dispose the riverine fish catch.

The disposal of catch in the option i) is prefixed, while for ii), it depends on a) quantum of fish catch; b) distance to the fish market; and c) type of fish marketing intermediaries. If quantum of catch is small, fishers prefer to dispose it locally to local dealer or fellow fisher. In case large quantum of catch, depending upon his experiences and prior fixtures, the fishers may dispose it i) locally to consumer / local dealer; ii) at nearby wholesale / retail fish market; and iii) directly to consumer as vendor.

2. Transportation of catch to landing centre / wholesale or retail market

Location and distance of landing centre / wholesale and retail market are the prime factors influencing frequency and quantum of riverine catch transported from fishing site to fish market. If the fish market is very near to fishing sites or fishers villages, the frequency of transportation of catch to market will be higher, as comparatively, smaller quantity of catch is also disposed at the market. The agency bringing catch to market are individual fisher, contractor, co-operative or local dealer. The fish catch is either packed in gunny or plastic bags or buckets to transport to landing centre or fish market. The mode of transport of catch depends on the distance to market and means of transport available. It may be on foot, by auto rickshaw, bus, etc. In case of contractors or co-operatives the assembly of catch may be at fishing site, the quantity of catch assembled may be large. It may be transported in vehicle. The other option is, contractor or co-operatives having the fishing rights, may ask the fishers to bring their catch to specific place, e.g. fish market or landing centre, so, the fishers have to transport it to prefixed place. A study conducted for rivers Ganga and Yamuna revealed that fishers generally prefer the nearest landing centre or fish market to dispose the catch, instead of taking it to bigger distant market. Therefore, in case of river Ganga, the riverine catch has been transported at Daraganj, Teliar ganj and Katra fish markets, while for river Yamuna mostly it has come to Sadiapur, Guaghat and Naini, fish markets. It confirmed the hypothesis of fisher preference of disposal or transportation of fish catch to the nearest fish market. Almost similar observations have been made for other rivers.

The individual fishers are generally following their traditional custom to transport their catch to particular market and market functionary, unless there is any payment or personal problem. In number of cases the fishers have to transport their catch to particular market functionary due to financial bindings also. The transportation costs included the to and fro fares, octroi and some miscellaneous expenditures in terms of kind and money, paid by the fishers for smooth transport of their catch.

3. Wholesaling

The next step in post-harvest mechanism of riverine fisheries is wholesaling. In most of the wholesale markets, the market functionaries act as wholesaler cum commission agent or as wholesaler or commission agent. For majority of them, it is an ancestral occupation. In case of the riverine stretch leased out for fishing, the contractors may act as wholesaler cum commission agent or wholesaler. Once the catch reaches wholesale market, it is displayed after segregation according to species, size & weight of fish and individual fisher to whom it belongs. The wholesaling includes auctioning of the riverine catch for local consumption and packaging for transport to terminal or outstation fish markets.

A. Auctioning of riverine catches

The auctioning process starts, when the catch is ready for display to the buyers e.g. retailers, vendors or bulk consumers. There are two systems of auctioning:

i) Auction by lots without weighing

In this system, whole of the segregated lot of fish is auctioned by bidding either for whole lot or on per unit basis, i.e. per kg. In case of bid for whole lot, the highest bid price will be paid by the bidder, but, for per unit bid price, the lot is to be weighed after bid. The amount payable by bidder is calculated as the product of weight of lot and highest bid price.

ii) Auction by lots after weighing

The process for auction and calculation of payable amount by the highest bidder is same as without weighing. The only difference is that the lot of fish to be auctioned is weighed before beginning of auction process.

The auctioning is generally done in the early morning hours, when most of the retailers, vendors and bulk consumers come to buy the fish. After the completion of auctioning process, the wholesaler cum commission agent or commission agent deduct their commission from the amount paid by the buyer and give the balance to the fishers. The rate of commission varies from place to place. For the studied rivers, it ranged between 6 – 10%. At certain places, a practice of providing discount to buyers is prevalent. It is in the form of 5-10% reduction in weight of the lot auctioned. This deduction is termed as "katta". It varies according to species, size and weight of fish, but there is no standard method for its deduction.

B. Transport to terminal markets

For local distribution of riverine catch, the functionaries at wholesale market act as commission agent, but for outstation or terminal markets, they perform the functions of wholesaler. With the immense experience, they can guess the probable local and outstation market prices for particular type of riverine catch. Accordingly, they segregate the catch for local auction and transport to outstations. The transportation of riverine catch to outstation markets primarily depends on the consumer preferences or the prices expected for different fish species at respective places. But, the most potential terminal or outstation market is Calcutta, where riverine catch is transported from all over India. Nowadays, the increased consumer preferences for large sized catfishes have diverged the transportation of their riverine catch towards northern India, particularly in the states of Punjab, Haryana and Delhi, while for remaining fishes it is still directed to West Bengal.

A good information and documentation system is noticed between wholesalers of assembly and outstation fish markets. The business between the two is based on trust. Sometimes the outstation market wholesalers finance their primary market counterparts by paying advance money, while on other occasions, it may be vice versa. The primary market wholesalers collect money, much later than dispatch of catch to the outstation market.

The real profits in wholesaling are due to fluctuations of prices at outstation markets. The major items of costs of wholesaling are: i) procurement costs; ii) establishment cost; and iii) marketing cost for outstations. The major share of cost of wholesaling goes to procurement costs followed by marketing costs for outstations and establishment cost. There is no set pattern of the costs of wholesaling. The variation in different items of cost at different centres is very high, which gives impression that wholesaling of riverine fish catch is not standardised.

4. Packaging

The handling of a highly perishable commodity like fish involved greater risks, particularly in transportation to a distant place, with greater demand supply fish deficit and comparatively much better prices than local markets. It needs proper packaging and transportation facilities. After the decision for transportation of riverine catch to outstation markets, next step is packaging. It should be with minimum loss due to decay of fish during transportation. The fish price varies significantly according to freshness and condition of fish; so, packaging should be given much-needed attention, to minimize these losses and to fetch the best possible price. Most of the riverine fish is transported either in bamboo buckets or in wooden boxes covered with gunny bags. The adequate quantity of ice and proper packing materials are the crucial inputs for proper packaging of fish. Further, it is packed after segregation for different categories and sizes of fish, so, as to fetch better prices at outstation markets. The major components of packaging costs are ice, packing material and labour. The maximum share of this cost is for purchase of ice. The quantity of ice varies according to season and the distance of transportation. For winter, it is less as compared to summer. The quantity of ice is proportional to distance of transportation. On an average, the ratio of ice and fish remains 1:1.

5. Retailing

Retailing of riverine catch follows the activity of wholesaling, both at primary or terminal markets. Fishers, retailers, vendors, contractors, and co-operatives perform the retailing of fish. It is the ultimate activity of post-harvest mechanism of riverine fisheries which disposes fish catch to consumer in smaller quantities. Similar to wholesaling, retailing also involves display of riverine fish lots after segregating them according to type of fish and its size. The retailers take comparatively more liberty to display the fish by making lots favouring them to maximize their benefits. Furthermore, they fix the rate in accordance with wholesale price paid by them. Due to highly perishable nature of the fish catch, the retailer has to undergo some loss because of spoilage. In most of the cases quantity of fish sold is less than quantity purchased. The majors cost items of retailing are purchase of ice and transportation.

Important concepts in post-harvest mechanism of riverine fisheries

Before going to important concepts of post-harvest mechanism of riverine fisheries or fish marketing, it is necessary to explain various functions involved in fish marketing. But due to paucity of space and time, these are only enlisted below:

A. **Exchange functions**: Assembly / buying; demand creation; price determination; and selling and disposal of fish.
B. **Physical functions**: Transportation; processing; and storage;
C. **Facilitating functions**: Standardization and grading; packing; financing; risk bearing; market intelligence; market information

Various operations of post-harvest mechanism of riverine fisheries are described above, but the very purpose of study is defeated without making a mention of some of the important basic concepts utilise to appraise it. Some of these concepts are:

1. Marketing surplus;
2. Market intermediaries;
3. Marketing channels;
4. Marketing costs;
5. Marketing margins;
6. Price spread; and
7. Fish marketing efficiency.

1. Marketing surplus

The term marketing surplus may be defined as total quantity of riverine fish catch, harvested by the fishers. Since, the fishers keep some proportion of catch for their own consumption or for some miscellaneous requirements, so, whole of fish marketing surplus may not actually reach the fish market. It is of two types

i) Marketable surplus

The quantity of riverine catch, the fishers willing to dispose in the market or available for disposal is termed as marketable surplus. This quantity may be equal to or more than the fish catch actually disposed by the fishers. It may also be equal to or less than actual riverine fish production.

ii) Marketed surplus

The quantity of fish catch actually reached the fish market is called marketed surplus. Since, it is not necessary that the quantity available for disposal or fishers willing to dispose would actually reach the market, so, the marketed surplus must be equal to or less than marketable surplus. It is equal to difference between marketable surplus and quantity of riverine retained by fishers for self-consumption and other miscellaneous purposes.

These concepts are important to estimate the total riverine fish production at a centre and actual fish landings at assembly centres and fish markets. These also depict the share of fish harvest utilised for self-consumption and other miscellaneous purposes.

2. Market intermediaries

The term market intermediaries is used for the market personnel involved in riverine fish marketing or who performs post-harvest or fish marketing operations. These are also called market functionaries. In the process of riverine fisheries, the market intermediaries are include local dealers, wholesalers, wholesaler cum commission agents, commission agents, contractors, co-operatives, retailers, vendors and the fishers performing the marketing operation (s).

3. Marketing channel

The marketing channel is defined as the path through which the riverine catch passes, starting from fisher to the ultimate consumers. It includes all the market intermediaries, which handle and pass on the catch. The most prevalent riverine fish marketing channels are presented in table 1.

Table 1 The fish marketing channels in riverine fisheries

1	Fisherman → Wholesaler cum commission agent → Retailer → Consumer
2	Fisherman → Retailer → Consumer
3.	Fisherman → Local dealer/ Local dealer cum commission agent →Consumer
4.	Fisherman → Local dealer → Wholesaler cum commission agent → Retailer → Consumer
5.	Fisherman → Local dealer cum retailer → Consumer
6.	Fisherman → Contractor/ Contractor cum wholesaler → Retailer → Consumer
7.	Fisherman → Co-operative society → Contractor / Contractor cum wholesaler → Retailer → Consumer
8.	Fisherman → Co-operative society → Wholesaler cum commission agent → Retailer → consumer
9.	Fisherman → Co-operative society →Consumer
10.	Fisherman → Consumer

4. Marketing costs

The costs of riverine fish marketing include all the expenses incurred by the market functionaries and the fishermen for purpose of disposal of fish catch. These are the charges on/for i) handling of catch at fishing area; ii) assembling; iii) grading; iv) packing; v) transport; vi) storage; vii) finance; viii) commission agent; ix) market charges, e.g. octroi, etc.

These costs may be incurred at all the stages of marketing channel starting from fisherman to consumer. To have an overview, these are described at fishermen and market level.

i) At fisherman level, marketing costs are in the form of commission paid to wholesaler cum commission agent / commission agent / local dealer /co-operative / contractor and transportation cost of fish catch to landing centre or fish market.

ii) At market level the expenditure done by different market intermediaries on various market operations like procurement, storage, grading, packing, loading, unloading, transportation, commission paid to wholesaler-cum-commission agent, octroi, market fee, postage, telephone charges, etc. form the costs..

5. Fish marketing margins

The fish marketing margins are the remuneration received by different riverine fish market intermediaries towards performing different functions. These may be of following types

i) Gross margins (GM)

The gross margins for ith intermediary (GM_i) are the difference between price received and price paid by him. It is calculated as

$$GM_i = PR_i - PP_i$$

Where PR_i = price received by ith intermediary;

PP_i = price paid by ith intermediary;

ii) Net margins (NM)

The net margins for ith intermediary (NM_i) are the difference between his gross margins and marketing cost. It can be computed as

$$NM_i = GM_i - ME_i$$

Where ME_i = Market expenditure incurred by ith intermediary.

6. Price spread

The price spread indicates the distribution of consumer's rupee among market intermediaries and the fisher. This is very important indicator of operational efficiency of any marketing system. It estimates the percentage share of different intermediaries in consumers' rupee. By comparing their share in consumer rupee or retail price and function performed, we can assess the operational efficiency of fish marketing system. It may be calculated as

$$S_i = \frac{GM_i}{RP} \text{ X } 100$$

Where S_i = percentage share of i^{th} intermediary in retail price
RP = Retail price per kg

7. Fish marketing efficiency (E)

The fish marketing efficiency indicates the movement of fish from fisherman to consumer at lowest price, in accordance with the provision of services desired by the consumers. For various markets and marketing channels it may be computed as

$$E = \frac{RP - ME}{RP} \text{ X } 100$$

Where $ME = \Sigma ME_I$

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BIONOMICS OF SUSTAINABLE FISH HARVEST

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Introduction

The fish has been an important source of food and other products for human beings. Although, the gross domestic product (GDP) and employment in fisheries sector observed significant growth rate, but it has negligible share in GDP of most of the countries. Yet, commercial fisheries can be extremely important source of employment in specific region, in less developed countries (LDCs), particularly, where it get relatively more importance than developed countries. India being a developing nations, is in no way an exception. The fish production of our country has a significant growth rate, but capture fisheries, both for inland and marine sectors is indicating a declining trend. These facts put an accent on sustainable exploitation of natural fisheries waters including the vast network of rivers. To frame the sustainable fish harvest policies for these natural waters, it is necessary to have an idea about the basic concepts of sustainable harvest. This article is devoted to bionomics or model for sustainable fish harvest.

The Setting

In the present context, fishery can be thought of as a stock or stocks of fish and the enterprises having the potential to exploit them. For stock(s) of fish crucial variables are its size and growth rate. The growth of stock is dependent on reproduction, individual growth of fish and mortality. For enterprises, total fishing efforts, catch and the costs and returns associated with them are the preliminary variables.

Before going to the bionomics or the model of sustainable fish harvest, it is necessary to understand the following key issues in fisheries and the concept of sustainability.

I Fish being a living creature has its own biological production function. On one side, it can not be produced like material goods and on the other it can not be cultured as agriculture, as its habitats - lakes, rivers and oceans, mostly have larger areas. The users have very limited control over these natural resources and consequently on the fish reproduction and growth. Therefore, to understand commercial fishing, one must be familiar with the biological characteristics of fish stock (s) and their interaction with the habitat.

II The second major issue is effect of property rights, which influences the economics of harvesting a fish population. Since, most of the fishery waters are in open access, it gives rise to host of problems – over fishing leading to even extinction of fish species, inefficient use of factor inputs, low returns to fishing industry, etc.

Sustainability

Sustainability of a system means the ability of a system to perform various functions over time without any external biological, chemical, physical and any other kind of subsidization. It means that over the time, given fishing effort would yield the same fish harvest. There are two major rules for sustainability

I Using use renewable natural resources (fish) in such a way that the harvest rate (h) is not greater than natural regeneration rate (y). It may be represented as

$$h \leq y$$

II Keeping the waste flow (W) to the environment at or below the assimilative capacity (A) of the environment, therefore,

$$W \leq A$$

If, these rules are observed renewable fish stock and its assimilative capacity can be sustained. These stocks will be available for exploitation in any future period as today.

Model of the fishery

A fishery consists of different activities. The characteristics associated with fishing include type of fish harvested, crafts or vessels used and gears operated. The number of riverine fish species is many which may be surface, column or bottom feeder. Fish being a biological creature, it can reproduce, grow and die, so, is termed as a renewable resource. There are various stages of exploitation of renewable resources. It may be exploited partially or fully. The bionomics or model of sustainable fish harvest can be elaborated under:

I Simple biological dynamics;
II Bionomic equilibrium; and
III Sustainable fish harvest under common property regime or open access;

I **Simple biological dynamics**

Most of the fish species follow a typical growth curve for its stock, which depends on its size i.e. population or biomass. With small population, birth rate will tend to out number natural mortality, because of sufficient food supply and space. It would result in increasing growth rate for fish stock. But after certain sufficiency level, the death rate begins to rise with increase in biomass or stock size. It is because of diminishing food and space availability per fish. As a result the growth rate of fish stock will also decline and reach to a stage where the death rate equals the birth rate, with zero growth rate. All this biological dynamics may be summarised graphically and mathematically.

Let X(t) be the fish stock at time t and dX(t)/dt denote the change in stock over a short interval of time t. Let the instantaneous growth of biomass before any harvesting is

$$\frac{dX}{dt} = F(X) \qquad (1)$$

F(X) is the instantaneous growth rate for the biomass of fish population. It can also be considered as biological production function or mechanics. For each stock or biomass X, it indicates the net increase over a small instant time in the natural size of population. This net natural growth is due to increase in the biomass – new fish entering the stock through birth, physical growth of fish existing in the stock at each time t, minus decreases in the population through natural mortality. F(X) is often represented by logistic function, i.e. a function which yield a parabola when plotted against X starting from a stock size zero. The function (1) can be represented as

$$F(X) = rX(1 - X/k) \qquad (2)$$

Where, represents the intrinsic instantaneous growth rate of biomass and is equal to the rate of growth of stock X, when it is close to zero, k is the carrying capacity of the habitat, *i.e.* maximum biomass or population that a habitat can support. We assume r and k as the fixed values given by biologists.

Starting at a small but positive stock (Figure 1), the biomass will at first grow fast, the growth will reach maximum, then decline till the biomass reaches its carrying capacity. The net growth of the population is identical at various levels of growth, i.e. X_1 and X_2. At X_1 the birth rate > death rate, because the population is small and food and space is ample, while at X_2 it is vice versa. From this figure we can define the biological equilibrium as the value of fish stock X for which there is no growth in fish population i.e. $dX/dt = F(X) = 0$. There will be no growth when $X=0$ or $X=k$. In the latter case biomass equals to carrying capacity of habitat. It is called the biological equilibrium.

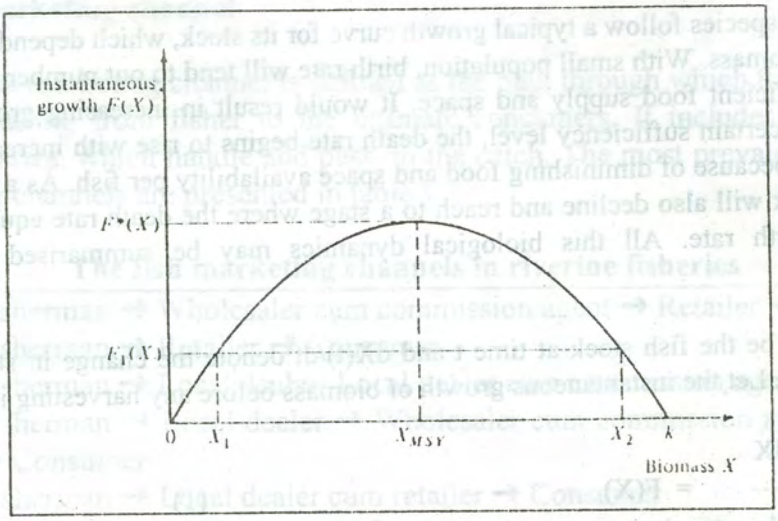

Figure 1 Growth of fish stock

II Bionomic equilibrium

Upto now we have not introduced any economic decision making in the model. Now, let us examine the role played by economic activity of harvesting assuming, it is a cost less activity. An equilibrium that combines the biological mechanics with economic activity is called bionomic equilibrium.

Let us, consider three different annual rates of harvest H_1, H_2 and H_3 (Figure 2). Assuming biological equilibrium at k at these rates of harvest the fish population will behave as under:

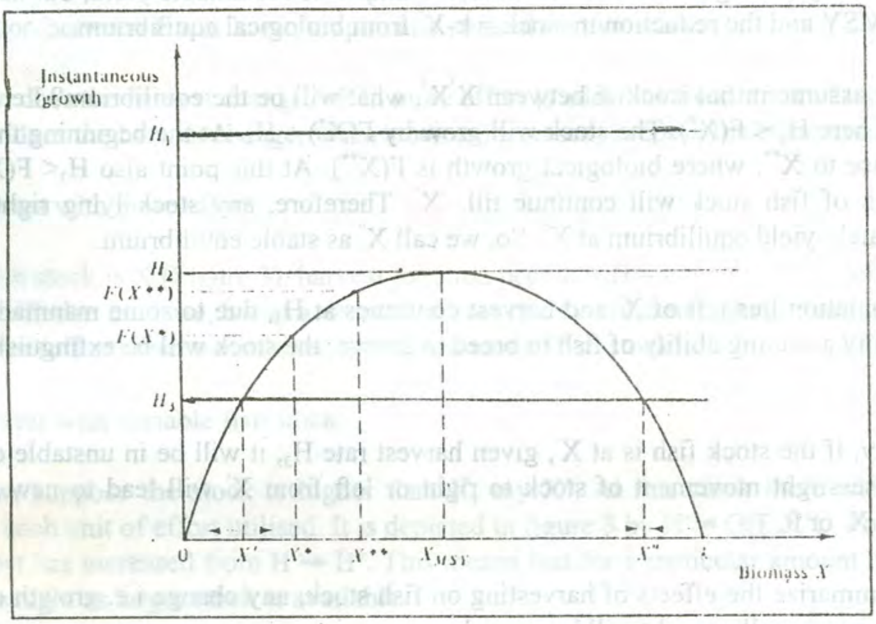

Figure 2 Effect of three different annual harvest rates on fish stock

i) The harvest level H_1 lies above biological growth function F(X). It means that more fish are harvested than recruitment or growth of stock at each point in time. It is evident that no fish population can survive for long under such conditions. It will lead to extinction.

ii) The harvest rate H_2 touches F(X) at maximum point. X_{MSY} is the maximum sustainable yield from the population. It is the point at which net growth is at its maximum. If population is initially at k $dX/dt = 0$ and H_2 kg of stock are harvested and this level of harvest is maintained, the stock will gradually fall to X_{MSY}. The remaining biomass will grow at maximum rate, because food and space are ample than at k. At this stage maximum sustainable harvest or maximum sustainable yield (MSY) will occur. The process of catching H_2 kg of fish per unit time can continue indefinitely (as long as no exogenous change will occur). But this equilibrium generally is not economic optimum. If the initial stock is left of X_{MSY}, H_2 harvest level will deplete the stock e.g. at X^* net growth will be less than harvest, so, X^* can not be sustainable.

iii) At harvest level H_3 kg, there are two possible equilibrium, as H_3 intersects growth curve F(X) at X' and X''. Now the question is which one is likely to occur? Assuming the initial stock at k, and harvest rate at H_3, X'' will reach from right side as at k, F(X) = 0 and harvest exceeds the growth, so, population decline from k to X''. But once the point X" is reached H_3 = net growth. This is another example of sustainable yield, but harvest is less than MSY and the reduction in stock = k-X'' from biological equilibrium.

If, we assume initial stock in between $X'X''$, what will be the equilibrium? Let the stock is at X^*, here $H_3 < F(X^*)$. The stock will grow by $F(X^*) - H_3$. At the beginning the stock will increase to X^{**}, where biological growth is $F(X^{**})$. At this point also $H_3 < F(X^{**})$, so, the growth of fish stock will continue till X''. Therefore, any stock lying right to X' will ultimately yield equilibrium at X''. So, we call X'' as stable equilibrium.

If population lies left of X' and harvest continues at H_3, due to some manmade of natural calamity affecting ability of fish to breed or spawn, the stock will be extinguished, as $F(X) < H_3$.

Finally, if the stock fish is at X', given harvest rate H_3, it will be in unstable equilibrium, because slight movement of stock to right or left from X' will lead to new equilibrium either X'' or 0.

To summarize the effects of harvesting on fish stock, any change i.e. growth or reduction in fish stock over a small period t will be given by

$$dX/dt = F(X) - H(t)$$

It is the difference between F(X) and H(t), where H(t) is the harvest in time t. The equation can be solved for equilibrium, where F(X) = H. This is called steady state of bionomic equilibrium. At the point X_{MSY}, $H_2 = F(_{XMSY})$ is called steady state maximum sustainable yield, a bionomic equilibrium.

III Sustainable fish harvest under common property regime or open access

In the above discussion the principles of steady state equilibrium in fishery were reached, when economic and biological factors interact. Each equilibrium was bionomic equilibrium. No assumption was made about economic nature of fishing or how the harvest rate was chosen. Now, let us introduce property rights in the model. The most prevalent property regime in riverine fisheries, is common property or open access. It means that rivers are any one's property or open for fishing purpose, i.e. any fisherman can fish anywhere.

To reach at any equilibrium, first of all we have to define the harvest function H(t), i.e. level of harvest at time t. The harvest function basically depends upon two inputs : the fishing effort E(t) and the fish stock X(t) at time t. Therefore the harvest function may be expressed as

$$H(t) = G\,[\,E(t), X(t)]$$

The interaction between E and X can graphically studied in two ways

i) how does the harvest change, when more effort is added to fixed stock of fish;
ii) how does the harvest change, when stock is increased, keeping the effort constant.

i) Harvest with more effort

If fish stock is X (Figure 3), harvest function becomes H = G(E,X). As the effort increases, the harvest will also increase, but at a decreasing rate due law of diminishing marginal product of variable factor (effort) that is combined with fixed factor (fish stock).

ii) Harvest with variable fish stock

Now, suppose the stock is higher than X, say X'. At this stock there will be a greater harvest fior each unit of effort utilised. It is depicted in figure 3 by H' = G(E,X'). For given effort E^0 the harvest has increased from $H \rightarrow H'$. This means that for a particular amount of effort, more fish can be caught as larger stock is available.

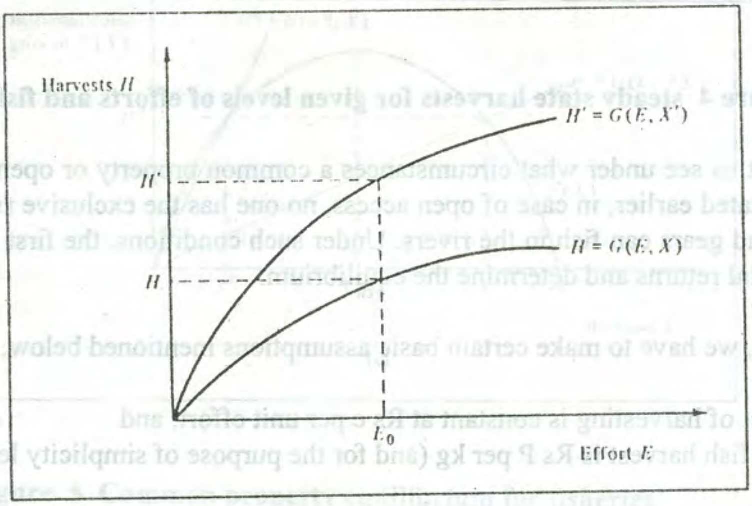

Figure 3 Harvest functions at different levels of efforts and fish stocks

Suppose the fishing starts in biological equilibrium k, with virgin stock (Figure 4). Now some fishermen enter and start fishing. We reach at point X with harvest H. Now as the fishing effort increases the harvest function will pivot upwards and for a while more effort yields greater harvest. But this increase in effort decreases the stock. Because of the shape of F(X) curve, harvest will increase till X_{MSY} and thereafter decreases. As more and more stock is caught, the fish stock size diminishes, and it becomes difficult to catch the remaining, so, catch per unit effort will decreases. Another way to look at it is, when the stock size is larger, less effort is needed to catch same number of fish, so it is inefficient for the fishermen to operate in the left of X_{MSY}.

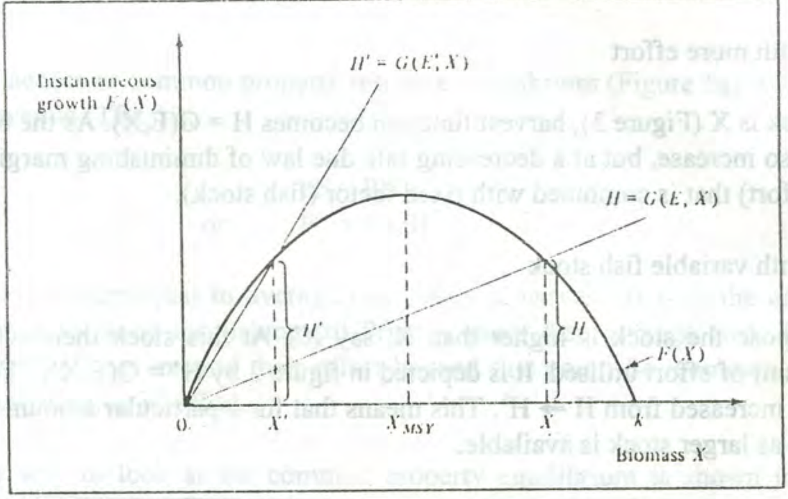

Figure 4 steady state harvests for given levels of efforts and fish stocks

Now, let us see under what circumstances a common property or open access equilibrium will occur. As stated earlier, in case of open access, no one has the exclusive rights to harvest, any one with boat and gears can fish in the rivers. Under such conditions, the first step is to define the total cost and total returns and determine the equilibrium.

For this purpose, we have to make certain basic assumptions mentioned below:

i) Unit cost of harvesting is constant at Rs c per unit effort; and
ii) Price of fish harvest is Rs P per kg (and for the purpose of simplicity let P = 1).

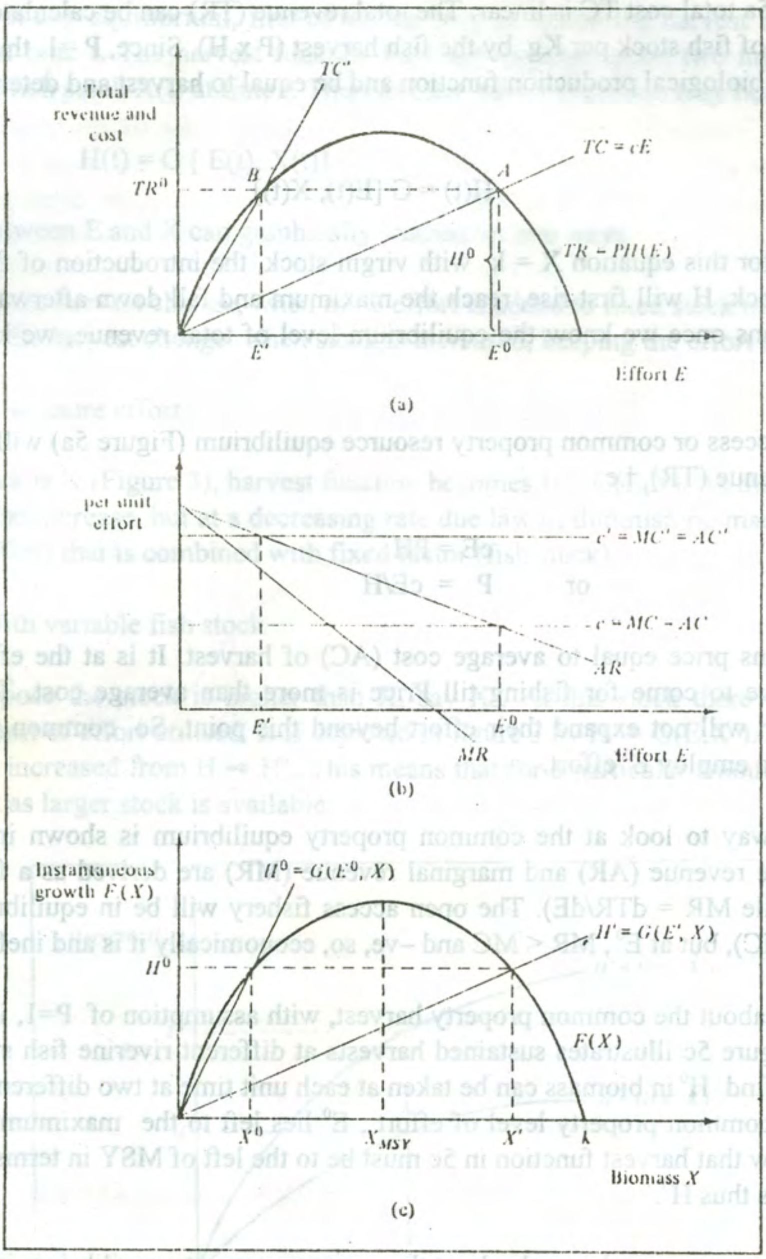

Figure 5 Common property equilibrium for fisheries

In figure 5a total cost TC is linear. The total revenue (TR) can be calculated by multiplying price of fish stock per Kg by the fish harvest (P x H). Since, P =1, thus TR will be exactly similar to biological production function and be equal to harvest and determined by equilibrium

$$H(t) = G\,[E(t), X(t)]$$

Suppose for this equation X = k with virgin stock, the introduction of fishing effort will reduce the fish stock. H will first rise, reach the maximum and fall down afterwards. At P =1, TR = F(X). This means once we know the equilibrium level of total revenue, we know equilibrium harvests.

In open access or common property resource equilibrium (Figure 5a) will be at Total Cost (TC) = Total Revenue (TR), i.e.

$$cE = PH$$

$$\text{or} \qquad P = cE/H$$

That means price equal to average cost (AC) of harvest. It is at the effort E^0 . So, the fishermen continue to come for fishing till Price is more than average cost. The economically rational fishermen will not expand their effort beyond this point. So, common property or open access equilibrium employ E^0 effort.

Another way to look at the common property equilibrium is shown in figure 5b, here industry's average revenue (AR) and marginal revenue (MR) are derived as a function of effort (AR = TR/E, while MR = dTR/dE). The open access fishery will be in equilibrium when AR = Marginal Cost (MC), but at E^0, MR < MC and –ve, so, economically it is and inefficient situation.

To know about the common property harvest, with assumption of P=1, it is given by TR^0 in fish 5a. But figure 5c illustrates sustained harvests at different riverine fish stocks. Measuring H^0 vertically, we find H^0 in biomass can be taken at each unit time at two different stock levels, X^0 and $X^{'}$. Because common property level of effort , E^0 lies left to the maximum sustainable total revenues, we know that harvest function in 5c must be to the left of MSY in terms of biomass. Our harvest function is thus H^0.

To summarize, two points can be made about the common property equilibrium in the fishery.

I Common property equilibrium occurs, where TR = TC, which implies that average revenue = average cost of effort (Figure 5b). Thus marginal revenue (MR) is less than marginal cost (MC) of effort.

II Common property equilibrium may be both economically and bio-economically inefficient. It is economically inefficient because efficiency requires that MR = MC, but we have MR < MC. Bio-economic efficiency can be interpreted as any equilibrium which is to the left of the maximum sustainable yield (MSY) in terms of biomass (or to the right of the maximum total revenues). If equilibrium occurs to the left of the MSY biomass, it indicates that the same harvest can be taken at a higher sustained biomass.

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ROLE OF EXTENSION FOR THE GROWTH OF RIVERINE FISHERIES SECTOR IN INDIA

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1. Introduction

Rivers have been the harbinger of prosperity and many a civilizations have flourished on their banks. The rivers and their tributaries comprise a major share of the inland fisheries resources. Maximum sustained yield of fish from river waters and assurance of recurring bountiful harvest of fish without depleting the resources and wastage of fishing effort are necessary for the nation. During the post independent era, river basins witnessed an expeditious pace of industrialization, agricultural development and urbanisation. These developmental activities along with flood control measures have adversely affected the riverine habitat and its fisheries. The remunerative capture fisheries of the yester years no longer exists. Ecological aberrations have adversely affected the spawn availability which used to be the prime source of stocking material for aquaculture.

Though Indian fisheries act of 1897 is a land mark in the conservation of fishes of India, no remarkable impact in this regard has yet to be established. Hence, there is an immediate need to introduce appropriate measures towards management including conservation on riverine fishery resources of the country. Apart from biological, ecological and environmental objectives, the actual users of the resources *viz.* fishermen, entrepreneurs, fish traders etc. are required to be taken into account in arousing mass awareness and activate their participation in the activities related to growth of riverine fishery. Many factors in this process may play their roles of which research and education system backed by effective extension service will be most vital.

2. Role of extension towards development of riverine fishery

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 domains. It aims at causing planned change or progress in the target field as per the greater sociological and economic changes designed by the political will of the people. In view of its crucial role, the fish conservation programme planning for fisheries 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 its components like research, clients and support. This role becomes even more important when it comes to the question of influencing the adoption behaviour of resource poor fishermen who constitute a sizeable number in the country. Right from generation of developmental programmes, 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 from such information, the research system should be engaged in the development of management policy *vis-à-vis* conservation plan in close association with the extension system as well as client's system. The riverine fishery development programme, thus generated will be tailor made to the conditions of the clientele. The extension system has to translate fishery developmental measures into the form of messages understandable to the target group and organise a strategy, so that they are disseminated through the utilization of appropriate media. As the target groups operate under resource constraints and become victim of underemployment while adopting conservation measures, the 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. The success of extension system on riverine fisheries development not only depends upon its capability in safeguarding fishery resources through adoption of conservation measures but also its ability to provide relevant technological and management base to various categories of fishing population operating under divergent resource endowments and aqua-ecological characteristics.

3. Scope and relevance of extension education *vis-à-vis* human resource development in the growth of riverine fishery

The human resource development in riverine fisheries sector through extension education needs an individualistic approach rather than a purely technological approach. Extension education is a science dealing with the transfer of technology and behavioural changes involved in the process of technological transfer and adoption. The technology development and transfer system depend on the behavioural pattern of the clients. This involves the clients, their interests, attitudes, motivations, aspirations, norms, traditions, value systems, customs and resources. Extension education based on a two-way-flow system of communication, would help to work out and convey these aid in the development of appropriate technology. Meaningful utilization of technology by the client system in turn would lead to the desired level of human resource development. Evolving a technology alone won't lead to its utilization. It requires the awareness and the need for a change from the existing pattern on the part of the client system. In other words, adoption occurs only when there exists an imbalance between a person's needs and his actual situation. The role of an extension specialist here is in creating the awareness of the existing system if it is below the mark and help people to achieve the level of self-actualization through adoption of improved technologies. According to the study on inland fishermen only 21% of them had education upto primary standard, 7% secondary and 2% continued studies above secondary level. Various studies (Haque and Ray, 1983, Balasubramaniam and Kaul, 1985) have shown that fishermen are mostly low in literacy and usually belong to the poorer section of the society. Fishermen of India who form the backbone of the riverine fishing industry are characterised by low socio-economic status resulting from poverty, remoteness of dwelling places, lack of creidt and low productivity of traditional fishing implements. This backwardness of fishermen often impedes their access to innovations and participation in welfare programmes. Building up opinion leadership which help in two-step-flow of communication may be the best approach in this context. Conducting non-formal education programmes and adult education campaigns will be helpful in building up leadership.

It is the fact that there are two major objectives of extension service on riverine fisheries. The first and major goal is the welfare of people in fishing communities. The second goal is the management, conservation and efficient exploitation of the fishery. The first goal refers to socio-personal development while the second means technological development. The fulfillment of the first goal is a pre-requisite for the second.

Human resource development through transfer of technical ideas and skills comprises improved management measure, fish conservation, better infrastructure for marketing system, credit facilities and above all dissemination and efficient utilization of information at the grass-root level. The major fishery activities are discussed below for facilitating better understanding of the type and extent of extension needs.

a) Development

For maximum exploitation of the resources, fishermen should be equipped with modern crafts and gears for fishery operations. In agreement with findings on agricultural innovation, it is found in fisheries sector too that higher investments and higher returns are associated with higher adoption in capture innovations (Balasubramaniam and Kaul, 1985). It was observed that qualitative variables were having better contribution than quantitative variables regarding variance in adoption. Hence, in order to achieve the technological development in this area the social variable should be paid proper attention. Fishermen being low in the socio-economic ladder and being mostly localite persons, need reinforcement of the information as the adoption period is usually very long. Hence, this area invites special attention of extension personnel who can convince at least the local leaders about the relative advantage and other benefits of the innovations in fisheries.

b) Fish handling and processing

Fish being easily perishable, has to be carefully handled once captured until it reaches the consumer. Progress has been made in the development of post-harvest technologies involving efficient handling, preservation and product development. However, there are many constraints at the implementation level. It is not the lack of needed infrastructure like ice plant, cold storage and processing factories alone but also the lack of extension work for creating better understanding and climate which contribute to the constraints.

c) Marketing

Another impediment to the development of riverine fisheries is the high fluctuations in the demand and supply of fish. Timely information service regarding demands for various types of fishes, wholesale and retail prices, storing and transport facilities can help to maintain a regulated market. To get rid of the exploitation by middlemen, Co-operative sector should step in a big way to purchase fish at the landing centre itself. The fishermen are lured by the immediate gains if he sells fish to the middlemen. So, proper extension work may educate the fishermen about the advantages of selling of the fishes to the Co-operatives for sustained income and short & long term benefits.

d) *Credit and finance*

In fishery industry especially in the small scale fisheries, middlemen and local money lenders play a very vital role in financing the fishermen. The transaction is based on mutual trust but the rate of interest is usually very high. Fishermen borrows money during the lean season and pay back whenever they get good catch. This often leads him into a vicious trap of borrowing and paying back. Hence, extension personnel has an important role here to educate the fishermen on the credit facilities available to him through approved financial agencies and the procedures to be followed in such transactions which may often look complicated to them. They may be also educated about various developmental programmes schemes like IRDP through which they can avail subsidies and benefits for purchase of crafts and gears. Developmental communications would help to make the fishermen aware of the financial benefits accessible to him and to project his needs to the concerned authorities.

4. Status of extension in fisheries sector

When the community development programme was launched in 1957, the organisational set up for extension did not include an extension officer for fisheries and extension officer for agriculture or animal husbandry was considered to be responsible for giving advise to fishermen and fish farmers. It was the Balvant Rai Mehta Commission of 1957 that focused attention on the need for separate extension officers and village level workers in fisheries also. Considering the need, a number of fisheries extension units were established by Govt. of India to train village level workers and field staff of the departments of fisheries. Fisheries extension continues to be one of the weakest links in fisheries development in the country and the existing service is inadequate resulting from lack of trained man-power, confusion among different agencies involved in development regarding responsibilities and lack of clear understanding the concept of fisheries extension among the fishery experts.

In compared to agriculture and animal husbandry, the challenges of fisheries sector are much more complex. The application of a fertilizer or sowing operation of a particular seed or animal husbandry practices like feeding, breeding and management of cattle can be convincingly shown to the farmers through lecture-cum-demonstration methods, field days and exhibitions. These types of exposures are quite difficult in fisheries sector. The impediments are the uncertainty of catch, site of work mostly in deep and vast water bodies beset with nature's fury and the socio-economic backwardness of the clients. Fishermen are one of the most improvised groups, perhaps because of out-moded practices and old techniques. Fishermen require better organisation, better management and better technology.

Widening the area of Co-operation, diversification of fishing, motorisation of country crafts, implementation of efficient harvest and post-harvest technologies provision of better shore facilities, cold chains and marketing channels are some of the ways for increasing fish production and improving its utilisation. In all these spheres extension support is essential. So far as the artisanal fishermen are concerned they are very much under-employed during the lean fishing season. They could take up culture of fish and prawns during the off-season wherever feasible. Blending of capture and culture fisheries would go a long way in generating employment enhancing production and increasing income. But intensive extension education programmes are essential for promoting these activities.

Dissemination of the available information on various fishery resources, their exploitation and utilisation should be given priority. This should not be done indiscriminately. First the target population is to be identified, their needs should be analysed and then the right type information is to be provided. To the extent possible this should be followed up by demonstration. In culture fisheries demonstrations are comparatively easier. But in the capture fisheries demonstrations are difficult, cumbersome and costly as the operations are in the large open waterbodies. However, effective audiovisual aids which may give a realistic view, can be developed for the benefit of fishermen. All the developmental programmes should have a built-in-extension component for better utilization of the human resources. Extension programmes not only adds to the promotion of the current developmental programmes but also provides a wealth of feed-back data essential for planning methods/procedures for further improvement in the technology and its implementation. Proper extension education and linkages may accelerate growth of riverine fishery in the country.

5. Communication planning for arousing mass awareness for the development of riverine fisheries

The prime objectives of the riverine fishery developmental programmes can not be achieved unless communication is taken as an important component and ingredient towards development (Bhaumik & Saha, 1998). The constructive application of communication for riverine fishery development calls for proper planning that takes equal note of the national priorities & needs, preference of individual and social priorities. An essential ingredient of such communication planning is an understanding of the specific assets and limitation of different media. It may be appropriate to have an idea of the impact of each of these on the society. The different types of communication modes are given below:

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

2) The case studies may come from all the areas of extension activities on the riverine fishery. The case studies may be on achievements/activities of individual worker and experience of fishermen. The information can be compiled to give upto-date data.

3) Information on fish conservation measures could be widely circulated in the form of circular letter, handout, leaflet, pamphlet, mimeograph etc.

4) Joint field visits of researcher and extension worker will enable them to understand about success of the fish conservation programme and to identify the constraints.

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

6. Use of audio-visual aids for mass awareness of the target group

Audio-visual aids play important role in effective communication of information on riverine fishery management. The extension functionaries working in riverine fishery developmental programmes must be equipped with audio-visual equipment. Radio and Television have a great potential as a medium of mass communication. The authorities concerned with Radio and TV may be co-opted to ensure that they plant their programme to broadcast/telecast information on the subject regularly form mass awareness of the target group to strengthen efforts towards growth of riveirne fishery.

7. Participation of target group 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 conservation and other management measures. They have a major responsibility in explaining the same and in setting up good systems of dialogue so that the members of the target group get full opportunity to express their opinion 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 the fact 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 fishermen and extension personnel involved in riverine fishery management. In general much of the communication will be organised in the villages in an informal level, although there will be also regular programmes on group meetings, field days, training sessions etc. The people's participation in the programmes have demonstrated that participation in the riverine fishery improvement 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. The most efficient means of achieving this objective are small, democratic and informal group of 8 to 15 like minded fishermen. All the programmes on riverine fishery improvement aiming at ecological restoration and socio-economic development would have better chances of success if people think as their own activity. The riverine fishery improvement movement necessarily involves both individual and group actions. In fact, participatory approaches are indispensable for successful fish conservation programmes.

8. Conclusion

Towards the growth of riverine fishery it would involve a two pronged strategy, namely creating the right type of attitude and atmosphere through extension education and improvement of production through application of appropriate management. Extension system has to meet great challenges in identifying the problems and constraints in riverine fisheries sector through well organised and continuous action research. These would help in accelerating the growth of riverine fishery *vis-à-vis* uplifting socio-economic status of the fishermen.

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