Short Course Training
on
Fish Yield Enhancement in Open Waters based on Ecological Management

5th-14th May, 1999

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Central Inland Capture Fisheries Research Institute
(*Indian Council of Agricultural Research*)
Barrackpore-743101: West Bengal

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FOREWORD

The openwater environments, the mirrors of habitat degradation to a large extent following various omission and commission of human activities, have a decisive role in the sustenance of civilization on this planet. On a global basis an estimated population of more than 2 billion people depend upon the stability of these water bodies as regulator of climate & water supplies, accumulator of rains, and abode for a large number of animals and plants. Fish yield is a function of grazing chain and accordingly better & efficient the grazing chain better the fish production. In recent years, however, the stress factors in and around the aquatic systems are on the rise and in fact have been accelerated in the face of increased anthropogenic interferences. Environmental aberrations have become the order of the day specially in case of the rivers, where symptoms of impairments are more glaring prompted by large scale river valley as well as catchment modifications. The alarming decrease in production & productivity of fish biomass with sizeable threats on desirable biodiversity associated with human welfare are some of the manifestations of unholistic developmental activities carried-out in the vicinity of such water bodies. Pollution in riverine ecosystems and eutrophication of lakes are the resultant effect of man-induced irrational & over exploitation of resources, both physical as well as biological. In the present scenario of changing ecology of aquatic systems our thrust should be to conserve the endemic fish germplasm thriving in rivers through suitable corrective measures and by developing suitable management norms for reservoirs & floodplain wetlands so as to harvest required quality & quantity of bio-production from them on sustainable basis. However, to understand the whole gamut of production biology thorough understanding of various ecological variables is a sine-qua- non.

In the backdrop of the aforesaid *CIFRI* attach utmost importance on *HRD*, by sharing the knowledge acquired in this Institute over a long span of 50 years in fish & fisheries research of inland open waters, so as to provide the country the necessary trained manpower who can take the nation ahead by adopting pragmatic approaches for rational utilization of natural resources in future. I am sure the present training course would provide the participants enough exposure with regards to the status and future prospect of openwater fishery in India and will be helpful in their endeavour to up-grade the skill.

M. Sinha
Director

SCOPE OF FISH PRODUCTION IN INLAND OPEN WATERS OF INDIA

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1. Introduction

Since independence, fish production is increasing at a cumulative growth rate of 4.2% per year. It has outpaced many secotors involved in production of food items. The pace of development can be gauged by the fact that in 1951 country's total fish production stood at 0.752 million tonnes (mt) out of this 0.534 mt being marine and rest inland, it was shoot up to 4.94 mt (marine 2.707 and inland, 2.24 mt) in 1995-96. This phenomenal growth in fish production has enabled to the country to attain the honour of 7th largest fish producer and 2nd in inland production in the world. The export earning through fisheries products during this period has also crossed 1 billion US dollar mark.

The projected domestic requirement of the fish in the country by 20000 AD is 12 mt, a half of which has to be contributed from the inland sector. To attain, this national objective proper development/conservation of inland open waters is a must for which a scientific under standing of all types of inland fisheries resources is imperative to achieve their optimum sustainable exploitation.

Besides this open inalnd water fisheries being labour intensive activity, its development is bound to ameliorate the fortune of 0.49 million fishers who toil on these waters. However, there are as may avenues to augments the yield from inland waters as there are constraints which acts against them.

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

Table 1. Inland Fishery Resources of India (compiled)

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

2. Riverine fisheries

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

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

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

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

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

A survey of river Brahmaputra in the state of Assam brought to light a decline in the fishery of the middle and lower stretches of the river since 1972. The survey also revealed large-scale destruction of brood fishes and juveniles. A detailed survey conducted recently in the Godavari also indicated a depletion in fish yield. The production potential in lower Ganga was estimated at 198.28 kg/ha/yr, whereas the actual fish yield was 30.03 kg/ha/yr and thus, only 15.15% of the potential is harvested. In the middle stretch the utilisation of the potential is marginally better than the lower stretch. However, in general, the potential is not fully utilised and there is enough scope for further improvement. Unfortunately, the anadromous hilsa fishery has almost disappeared from the stretch of river Ganga above the Farakka barrage where it used to contribute a lucrative fishery upto 1,500 km up the sea mouth (up to Kanpur). Collapse of hilsa fisheries (Table 3) due to this river course modification has affected the lives of thousands of fishers along the riparian stretches in Uttar Pradesh and Bihar. Catadromous migrants like eels, freshwater prawn and *Pangasius* also seem to have been affected by such river course modifications.

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

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

Figures in parentheses denote % decline

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

3. Fisheries of estuaries and lagoons

The various estuaries and lagoons in the country (Table 4) form an important component of fisheries resources of the country. The fisheries of estuaries of India are above the subsistence level and contribute significantly to the production. The average yield is estimated to sway from 45 to 75 kg/ha. The Hooghly-Matlah estuarine system, Chilka lagoon, Adyar and Mankanam estuaries, Pulicat lagoon, coastal belt of East Godavari, Vembanad lagoon and Mandovi estuary have also been identified to be excellent sources of naturally ocurring fish and prawn seed for exploitation for aquaculture purposes.

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

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

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

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

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

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

4. Reservoir fisheries

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

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

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

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

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

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

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

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

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

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

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

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

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

5. Fisheries of floodplain wetlands

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

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

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

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

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

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

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

6. Major constraints in development of inland fisheries

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

6.1. Biological constraints

The extraction of fish riches from the rivers, based on the principle of maximum sustained yield, has not been possible in the Indian context. Fishing has been guided by the principles of economic profit rather than biological principles. The intensity of fishing, nature of exploitation and species orientation in the characteristic artisanal fisheries of Indian rivers are governed by *(1) seasonality of riverine fishing activity; (2) unstable catch composition; (3) conflicting multiple use of river water; (4) cultural stresses leading to nutrient loading; (5) lack of understanding of the fluvial system and infirm data base; (6) fragmentary and outmoded conservation measures lacking enforcement machinery; (7) inadequacyy of infrastructure and supporting services; (8) defective marketing and distribution systems ; (9) demand directed by availability; affordability, and palatability, and (10) socio-economic and socio-cultural determinants.* Infirm database of inland fisheries resources has been another serious constraint plaguing the development process. Even market intelligence statistics suffered from various drawbacks due to disposal of appreciable quantity of fish that passed directly from the primary producers to consumers. Through a Central Sector Scheme on Inland Fisheries Statistics, launched during Seventh Plan by Union Ministry of Agriculture, CIFRI has been able to evolve a methodology for data collection on inland fisheries. It is expected that in years to come the database in this field would also be firm.

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

6.2 Environmental constraints

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

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

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

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

6.3 Socio-economic constraints

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

Socio-economic milieu under which the inland fishermen operate is not conducive enough to attract credit and infrastructure support for required modern crafts and gear from traditional banking and financial Institutions. A sector's ability to attract finance and specially loanable funds depends largely on evaluation of risk elements by prospective funding agencies. The migratory character, seasonality of fishing activity and unstable catch composition of capture fishery does adversely effect investment appraisal and assessment of funding possibilities because of various reasons. There is an inescapable need to evolve some distinct criteria for financing the capture 10and culture based capture fisheries of inland open waters where the input-output relations are relatively less precise. This would need evolving a new set of criteria for the creditworthiness and repaying capacity of such fishers.

6.4 Legal constraints

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

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

7. Conclusions

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

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

METHOD OF ESTIMATION OF FISH POPULATION IN OPEN WATERS

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There has been fast development in the methods of estimation of population parameters in fishery science. These methods have undergone transformation from traditional methods to advance methods based on scientific guidelines . Some of these methods are largely of historical interest.

Before proceeding to discuss estimation methods, I would like to mention four important technical advances that are relevant to population estimation. The first is the development of very small radio transmitter tags. Although transmitter failure is still a problem, one can foresee the day when these tags will be so small, cheap and reliable that they can be used in large numbers. The second development is in remote sensing such as thermography where animals are detected by the heat they radiate. The third development relates to the use under water accoustics. The fourth and most important advance is the wide spread availability of computers with associated statistical techniques such as simulation, Monte Carlo inference, the Jackknife and bootstrap. Computers have also made it possible to examine the robustness of many techniques.

Reasonable results can be obtained by considering stock size to be propotional to fishing success (cpue) and eliminating the effect of recruitment by using a short time scale. This type of computation first applied to a population of rats by Leslie and Davis (1939). An improved form was introduced by Delury (1947) and refined by Braaten (1969) . The natural logarithm of the catch per unit effort($\frac{C_t}{f_t}$) is plotted against the cumulative effort (E_t) to the mid point of each interval

$$log(\frac{C_t}{f_t}) = log_e (q\,No) - q\,E_t$$

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

Any fishing success method implies two rather severe conditions :

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

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

Derzhavin's biostatistical method

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

Marking methodology in estimation of population parameters in an exploited fishery

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

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

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

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

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

v) Survival rate is constant over the experimental period.

The success of these methods, therefore, depend largely on the type of tag and methods of application. Various types of marking methods have been used so far but they lack at one or the other count. some of the common marking methods used for this purpose are mentioned below :

Types of Marking :
- i) Use of vital stains
- ii) Fin-clipping
- iii) Use of fluorescent pigments
- iv) Printing ink

Types of Tagging :
- i) Internal tags
  - a) Stainless steel or nickel-plated iron tags
  - b) Transmitter tags
- ii) External tags
  - a) The Peterson Disc
  - b) The Lea tag
  - c) The plastic flag tag
  - d) The spageth tag
  - e) Plate tags
  - f) Dart tags like Streamer & Anchor tags

The success of estimation methods depend on the efficiency of the tags and their application. It has to be ensured that the efficiency of tagging is such that the following features of the models are satisfied.

- i) There should not be any initial tagging mortality.
- ii) Complete reporting of tags should be ensured through various measures.
- iii) The loss of tags between release and last recapture should be minimum.
- iv) Tagging should not force any extra mortality
- v) The catchability for tagged and untagged specimens should be same. ie., tagged should not make the fish more vulnerable to gear as compared to untagged fish.
- vi) Tags should not affect the growth, physiology, behaviour and survival of the tagged fish. i.e., without any detrimental effect upon swimming stanu.. or buoyancy regulation.

Methods of estimation

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

i) Estimation of parameters from a single tagging experiment.
ii) Estimation of parameters from a multiple tagging experiments.

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

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

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

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

which leads to the well known Peterson estimate

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

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

Here let m_i be the marked fish out of n_i in the i-th sample and y_i be the ratio of m_i and n_i (ie $y_i = \frac{m_i}{n_i}$) ; then the estimates of survival rate can be obtained as ;

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

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

$$S = \frac{X}{(\sum y_i + X - y_k)}$$ [Robson and Chapman (1961)]

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

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

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

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

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

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

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

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

$$\log n_i = -Z' T i + \log (\frac{FNo}{Z'}) + \log (1-e^{-Z'T}) \quad \text{where } Z' = F+M+X$$

F,M & X are losses due to fishing mortality, natural mortality and extra losses due to loss of tags, deaths due to tagging and migration out of the area. No. is the total no. of fish tagged.

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

$$\log n_i = b\, i + a \quad \text{where } b = \text{slope} = Z'T$$

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

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

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

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

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

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

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

Source : Fisheries Mathematics Edited by J.H. Steele, Academic Press, p-78.

Code No. (x_i)	Days since tagging	Number returned (n_i)	$\log(n_i)$ $=(Y_i)$	Beverton & Holt regression Method
-	0	501	-	$\Sigma xy = 34.373$
1	10	270	5.598	$\Sigma x^2 = 60$
2	20	133	4.890	$b = -0.5729$, $a = 5.8848$
3	30	177	5.176	ie $Z'T = 0.5729$
4	40	55	4.007	$Z' = 20.805$
5	50	96	4.564	$F'T = 0.073$
6	60	17	2.833	$F = 2.664$, $M = 18.141$
7	70	27	3.296	
8	80	2	0.693	Chapman(1961) $\hat{F_e} = 4.3833$
9	90	4	1.386	$\hat{M_e} = 17.79$
				$\hat{Z} = 22.1733$

Multiple Tagging

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

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

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

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

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

Jolly - Seber Method

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

T_i	=	number of fish released on i-th occasion (newly tagged + previously tagged)
r_i	=	the total no. of fish recaptured during the experiment that were last released in the i-th sampling occasion
q_i	=	the no.of fish last liberated before the i-th occasion which are not captured on the i-th occasion but which are captured after the i-th occasion
I_i	=	the no. of tagged individuals in the population immediately prior to the taking of the i-th sample.
I_i-m_i	=	tagged fish in the waterbody prior to i-th occasion.

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

r_i out of T_i are captured during the experiment

Then by simple proportional theory

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

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

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

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

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

Robson's method

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

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

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

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

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

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

Example: Estimation of survival rate

Table 3 Jolly - Seber Method

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

Value of q

1	2	3	4	5
0	69	180	188	83

Value of S

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

Table 4 : Robson Method

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

Value of q

1	2	3
0	63	117

Value of S

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

Estimation of population size :

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

$$N_i = \frac{n_i q_i ' T_i '}{m_i r_i} + n_i$$ (Jolly-Seber Method)

$$N_i = \frac{n_i q_i ' T_i '}{m_i r_i '}$$ (Robson Method)

Table : 5 Jolly -Seber Method

Basic data calculation for table 3

	T_i	q_i	r_i	m_i	Ii	n_i	N_i
1	1000	0	129	-	-	-	-
2	2060	69	267	60	592	16000	157867
3	1656	180	260	156	1302	10000	83462
4	1252	188	234	252	1258	7000	34944
5	2339	83	193	339	1345	5500	21822

Table 6 : Robson Method

Basic data calculation for table 4

	T_i	q_i	r_i	m_i	I_i	n_i	N_i
1	1000	0	123	0	0	16000	-
2	2000	63	210	60	600	10000	160000
3	1500	117	135	156	1300	7000	83333

EVALUATION OF PRODUCTIVITY IN OPEN WATERS WITH SPECIAL REFERENCE TO NUTRIENT CYCLE

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Introduction

Rapidly growing population of the world has resulted into growing demand for food, drinking water, energy and livable environment. The problem of food has become more acute in developing countries due to their low productivity, poor animal husbandary, and fisheries as these countries occupies 55% of the geographical area while carrying over 75% of the world population. In terms of food requirement, aquaculture perhaps stands next to agriculture. The continued environmental degradation caused due to indescriminate resource depletion ultimately lead to disastrus situations instead of bringing in prosperity and self sufficiency to the region.

Inland fish production in India has registered a phenomenal increase during last about four decades. As against 0.2 million t produced in 1951, the production of inland fish in the country during 1995-96 is estimated at 2.2 million ton. The projected domestic requirement in the country by 2000 AD is 12 million t, a half of which has to come from the inland sector. To achieve this national goal, proper development/conservation of inland open waters is a must for which a scientific understanding of all types of inland fisheries resources is imperative to back up their optimum exploitation.

Inland fishery resources of India, comprising vast expanse of rivers, canals, estuaries, lagoons, reservoirs and flood plain wetlands (lakes) are recorded for their variety as well as their rich population potentiality (Table-1). A large number of river valley project have been built and commisssioned since independence, as a part of our developmental activities, resulting in a chain of new aquatic resources like irrigations canals and reservoirs. Extensive areas under flood plain wetlands in the form of mauns, beels, chaurs, jheels are available in eastern U.P., Northern Bihar, West Bengal, Assam, Tripura, Manipur, Arunachal Pradesh and Meghalaya. These are shallow nutrient rich water bodies formed mainly due to change in river courses and offer ample scope for culture-cum-capute fisheries. The end of saline areas of the river systems, known as estuaries, and lagoons also form an important component of fishery resources of the country.

Table 1. Inalnd fishery resources of India

Rivers	45,000 km
Reservoirs	3.15 million ha.
Estuaries	2.7 million ha.
Lagoons	0.19 million ha.
Flood plain wetlands	0.24 million ha.

Factors influencing fish yield

The studies undertaken by CIFRI in the past revealed that, environmental abervations like sandification of river bed, blanketing the river bed productivity, and marked reduction in water volume due to increased sedimentation (caused due to deforestation in the catchment areas) and increased water abstraction, accompanied with river course modifications and irrational fishing practices appear to be key factors responsible for decline in fishery. Flood control measures, sedimentation and increased water abstraction also effect the flood regime and inundation of grounds needed for feeding and breeding. In the Ganga basin, 33.5 billion m^3 of water is presently held in storage reservoirs behind the weir and barrages apart from 18 major canals net workes diverting the water to irrigate 7 m ha of agricultural land.

Productivity indices

Climate, edaphic and morphometric features

Biological productivity of any water body is influenced by climate, edaphic and morphometric features. The climate (Air temperature, Wind Velocity, and Rainfall) have great bearring on productivity. The wide seasonal variation in air temperature, with low values during winter and high during summer have great influence on the thermal features of the sub-tropical water bodies although in southern peninsular India the seasonal differences are narrow. The incident solar radiation on the water surface also shows considerable variations with the location (latitude).

Water level, depth, shore development, volume

The water level, depth, water discharge (both in and out), shore development, volume development (morphometric factors) etc., also have great bearing on the circulation of nutrients and energy in the aquatic biotopes. Climate and edaphic factors provide essential source of energy and nutrients as such they are very important morphometric factors which serve as modifications which determine heat and nutrient characteristics are second in order of importance. Rawson (1952) observed inverse relationship between mean depth and productivity based on the fact that shallower water bodies provide better circulation of nutrients. North cote and larking (1956) recorded that waters with high dissolved solids (TDS) are more productive than those with low values and recorded a direct relation between TDS (edaphic characters) and productivity in Morpho-Edaphic Index (MEI) which is the ratio of an edaphic character (dissolved solids) and mean depth, a morphometric character, and this is used in index of productivity.

Productivity and chemical constitutents

The water in an aquatic system consists of two fundamentally different regions one below the other as per biological productivity in which opposing processes take place. These are the regions of photosynthetic production (the trophogenic-zone) over the regions of breakdown (tropholytic-zone), in photosynthetic zone carbon-di-oxide is taken up by the photosynthetic organisms, resulting in decrease in bicarbonates and increase in carbonate and pH ($2HCO_3 = CO_2 + CO_3 + H_2O$). Oxygen is liberated and increase in concentration ($6CO_2+6H_2O = C6H_{12}\ O6+6O_2$). In the tropholytic zone oxygen is consumed, carbon dioxide is liberated, carbonate is converted to bicarbonate ($C6H_{12}\ O6+ 6O_2 = 6CO_2+6H_2O$ $CO_2+H_2O = 2HCO_3$) and pH decreases with increase in hydrogen ion concentration ($CO_2 + H_2O = H2CO_3 = H+HCO_3$).

At night when there is no photosynthesis, the reactions at trophogenic and tropholytic zones are the same. If the rates of reactions in the two phases are high the water body will show sharp variations in the chemical parameters either with the progress of the day (dial-variations) or in depth profile during stagnation period in deep waters the two zones are separate (in case of reservoirs) but in shallow waters variation in the chemical parameters reflect the intensity of reactions in both the zones. As the rate of above reactions are directly related to the production (P) and the consumption (C) processes the relative productivity of the water body can be evaluated from the magnitude of their variations.

This index gives correct indication of productivity in natural lakes which is applied in reservoirs, with fluctuating morphometric characters and the edaphic characters being more influenced by catchments this index does not always yield the accurate results. For example many shallow reservoir with high values of morphoedaphic indices are low producrtrive while many deep reservoirs are highly poroductive. Total alkalinity (a correlate of total dissolved solids) has been used for index calculation. Thus is more true in case of small reservoirs where depth is generally less with more dominant edaphic characters.

Hydrological characteristics

Open water bodies and closed water bodies (small reservoirs and beels) both vary widely in respect of their water quality parameters. Water with higher alkalinity, conductance, dissolved salts are more productive than those with lower values (Northcote & Larkin, 1956). Water with moderate alkaline pH, alkalinity above 50 mg/l, conductance above 200 mg. mhos/cm, hardness above 25 mg/l, organic carbon around 1 mg/l or above nitrate above 0.5 mg/l are considered to be productive. In beels generally the nutrients status in the water phase is poor despite the very high values in the soil phase. Since, most of the nutrients are used and locked by the infested macrophytes and are removed from circulation, as such water always shows nutrient deficiency.

Some of the physico-chemical parameters which are essential for determining productivity of open water bodies are as under.

Suspended matter, turbidity and transparency

The type and concentration of suspended matter controls the turbidity and transparency. Suspended matter consists of silt, clay fine particles and organic and inorganic matter, soluble organic compounds, plankton and other microscopic organisms. Heavy rainfall can also result in hourly variations in turbidity. Turbidity determines the primary productivity in the aquatic systems.

pH, Acidity and Alkalinity

It is an important variables in water quality assessment as it influences may biological and chemical processes within a water body and all processes associated with water supply and treatment are influenced with it. When measuring the effects of an effluent discharge, it can be usded to help determine the extent of the effluent plume in the water body.

The pH is a measure of the acid balance of a solution and is defined as the negatively of the logarithem to the base 10, of the hydrogen ion concentration. In unpolluted water, pH is principally controlled by the balance between the carbon dioxide, Carbonate, and Bicarbonate ions as well as other natural compounds such as humic acid, fulvic acids, Diel variations in pH can be caused by the photosynthesis and respirations cycles of algae in eutrophic water. The pH of the most water is between 6.0-8.5. Acidity and alkalinity are the base and acid neutralizing capacity of water.

Dissolved oxygen

Oxygen is essential to all forms of aquatic life including those organisms responsible for the self purification processes in natural waterways. The oxygen content in natural waters varies with temperature, salinity, turbulence, the photosynthetic activity of the algae and plants and atmospheric pressure. The solubility of the oxygen decreases as temperature and salinity increases. Determination of DO concentration is a fundamental part of a water quality assessment, since oxygen is involved in or influences nearly all chemical and biological processes within water bodies. Below 5 mg/l may adversely affect the functioning and survival of biological communities and below 2 mg/l may lead to death of most of the fish. The measurement of DO can be used to indicate the degree of pollution by organic matter, the destruction of organic substances and the level of self purification of the water. Its determination is also used in the measurement of biochemical oxygen demand (BOD).

Carbon-dioxide

It is highly soluble in water and atmospheric CO_2 is absorbed at the air water interface. In addition CO_2 is produced within water bodies by the respiration of aquatic biota, during aerobic and anaerobic metamorphic decomposition of suspended and sediment organic matter. Carbon dioxide is dissolved in natural water is part of an equilibrium involving bicarbonate and carbonatre ions.

Nitrogen

Nitrogen is essential for living organisms as an important constituent of proteins, including genetic material. Plants and microorganisms convert inorganic nitrogen to organic forms. In the environment inorganic nitrogen occurs in a range of oxidation states as (NO^{-3}) NO^{-2}, the NH_4^+ and molecular transformations in the environment as part of the nitrogen cycle. The major non-biological processes involve phase transformation such as volatization, sorption and sedimentation. The biological transformation consists (a) assimilation of inorganic forms (ammonia and nitrate) by plants & micro-organisms to form organic nitrogen e.g., amino acids, (b) reduction of nitrogen gas to ammonia and organic nitrogen by micro-organisms (c) Complex heterotrophic conversions from the one organisms to another (d) oxidation of ammonia to nitrate and nitrate (nitrification), (e) ammonification of organic nitrogen to produce ammonia during the decomposition of organic matter, (f) bacterial reduction of nitrate to nitrous oxide N_2)) and molecular nitrogen (N_2) under anoxic conditions (denitrification).

Ammonia

Ammonia occurs in water bodies arising from the breakdown of nitrogenous organic and inorganic matter in soil and water, excretion by biota, reduction of nitrogen gas in water by micro-organisms and from gas exchange with the atmosphere. It is also discharged into water bodies by some industrial processes (Pulp and paper industries) and also as a component of municiapl or community waste. At certain pH levels high concentrations of NH_3 are toxic to aquatic life and therefore, detrimental to the ecological balance of water bodies.

Nitrate and Nitrite

The nitrate ion (NO^{-3}) is the common form of combined nitrogen found in natural water. It may be bio-chemically reduced to nitrite (NO_2-) by denitrification processes usually under anaerobic conditions. the nitrite ion is rapidly oxidised to nitrate. Natural sources of nitrate to surface water include igneous rocks, land drainage, and plant and animal debris. Nitrate is an essential nutrient for aquatic plants and seasonal fluctuations can be caused by plant growth decay. Determination of nitrate plus nitrite in surface waters gives a general indication of the nutrient status and level of organic pollution.

Organic Nitrogen

It consists mainly of protein substances (e.g. amino acids, nucleic acids, and Urine) and the product of their biochemical transformation (e.g., humic acids and fulvic acids).

Phosphorous

Phosphorous is an essential nutrient for living organisms and exists in water bodies as both dissolved and particulate species. it is generally the limiting nutrient for algal growth and, therefore, controls the primary productivity of water bodies. Artificial increases in concentration due to human activities are the principal causes of eutrophication. In natural water and in waste-waters, phosphorous occurs mostly as dissolved orthophosphates and polyphosphate and organically bound phosphates. Changes between their forms occur contineously due to decomposition and synthesis of organically bound forms and oxidised inorganic forms. Natural sources of phosphorous are mainly weathering of phosphorous bearing rocks and the decomposition of organic matter. Phosphorous from 0.005 to 0.020 mg/l found in natural waters. High concentration of phosphates can indicate the presence of pollution and are responsible for eutrophic condition. Phosphorous concentrations are generally determined as orthophosphates, total inorganic phosphates or total phosphorous (organically) combined phosphorous.

COD

It is a measure of the oxygen equivalent of the organic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant, such as dichromate. The COD is widely used as a measure of the susceptibility to oxidation of organic and inorganic materials present in water bodies and in the effluents from sewage and industrial plants. the standard method for measurement of COD is oxidation of the sample with potassium dicharomate in a sulphuric acid solution followed by a titration.

BOD

The biochemical oxygen demand is an approximate measure of the amount of bio-chemically degradable organic matter present in water sample. It is defined by the amount of oxygen required for the aerobic micro-organisms present in the sample to oxidise the organic matter to a stable inorganic form. Un-polluted wastes typically have BOD values of 2 mg/l O_2 or less.

Calcium

It is present in all water as a Ca^+ and is readily dissolved from rocks rich in Calcium minerals, particularly as carbonates and sulphates, especially limestone and gypsum. Calcium compounds are stable in water when carbon-dioxide is present, but calcium concentration can fall when $CaCO_3$ precipitates due to increased water temperature, photosynthetic activity or loss of CO_2 due to increase in pressure. Calcium is an essential dominant nutrient for all organisms and is incorporated into the shells of many aquatic in-vertibrates, as well as the bones of vertibrates.

Quality of soil

The quality of basin soil and catchment area are important for determining fertility of a large water bodies. The soil quality relatively poor in water bodies not seen in water quality which appeared to be related more to soil conditions of the catchment area than to those of the basin alone. In case of beels rich nutrients status of soil is not reflected in water phase probably because of accumulation of large amount of nutrients by the macrophytes and effective removal from circulation.

Energy dynamics

Biotic communities in an aquatic ecosystem can be divided into various components on the basis of their trophic functions, such as primary producers, herbivores, detrivores, carnivores and decomposers. Energy enters the biological system by fixation of solar energy through photosynthesis and gets degraded as it passes from one trophic level to the other according to the laws of thermodynamics. For estimation of energy dynamics of water body from solar radiation to the end product (fish), three types of studied needed.

1. Transformation of solar energy into chemical energy by producers.
2. Pathways of energy transformation that lead to the end product i.e. flow of energy from producers to consumers.
3. Energy transformation efficiency at difference trophic levlels.

Energy transformation

Rate of conversion of solar energy to chemical energy gives a dependable parameter to assess the productivity potential of an aquatic system. The redox process of energy transformation is represented as under;

$$6CO_2+6H_2\text{-609 Cal of} \rightarrow CaH_{12}O6 + 6O_2 \text{ solar energy}$$

or

$$nCO_2 + n\text{ (H donar) - solar energy} \rightarrow (CH_2O)n + n\text{(Oxidised doner)}$$

This process is endergonic in nature and consequently plants can store large amounts of energy in the form of rich organic compound. The efficiency of energy transformation is known as photosynthetic efficiency.

$$\text{Photosynthetic efficiency} = \frac{\text{Energy fixed by producers X 100}}{\text{Solar Energy available in water surface}}$$

The energy required to liberatge one miligram of oxygen through photosynthesis is approximately 3.68. Calories and hence the amount of oxygen liberated gives a measure of solar energy trapped as chemical energy by producers. In reservoirs the energy transformation is mainly by phytoplankton while in beels aquatic macrophytes are the main primary producers.

Total energy available in the system = Energy import + Energy fixed by from all allochthonous source + Photosynthetic organisms.

Energy flow from producers to consumers
(Energy transformation)

The biotic communities in aquatic system are inter-linked with one another with energy chains. As such proper understanding of the trophic dynamics help in formulating policies for stock manipulation. There are two main routes through which the energy flows in an aquatic system.

1. Grazing of green organisms (Producers) by herbivores or plant feeders which are in turn taken by Predators (Energy from Producers level flows in various levels of consumers), Grazing Food Chain.

2. Flow of energy through dead organic matter of Detritus complex and path is known as Detritus Food Chain (all energy represented by producers is not utilised mostly by consumers directly and the un-utilised energy is deposited at the bottom after the death of the organisms. In beels infested with macrophytes, the primary energy fixed by macrophyte is not utilised by herbivores and unused is deposited at the bottom.

When decay occurs, these macrophytes contribute to rich organic detritus pool.

Energy at 1st Trophic level - (Herbivores-Preducors-Grazing food chain (Producer-Level)

Decay of organic matter-Detritus feeders-Predators-Detritus food chain (Organic detritus) Detritivores.

Due to selective feeding nature of the consumer organisms number of restricting conditions for the transfer of energy from the primary producers to secondary and tertiary consumers exists. All the energy represented by producer is not always utilised by consumers directly and the unused energy is utilised by consumers directly and the unused energy is utilised through detritus chain. In some aquatic systems Grazing path predominates while in others most of the energy flows through detritus chain. The distinction between Grazing and Detritus chain is of importance as there is a time lag between direct consumption of living plants and the ultimate utilisation of dead organic matter.

Nikolsky (1963) stated the manner the useful end product (Fish) stands to the first link in the food chain the higher the yield from the water mass as the loss of energy will be much higher, if the chain is longer. If the water body has the dominance of primary consumers (either herbivores or detrivores) the efficiency of conversion and the enrgy harvest will be higher. Mann (1969) and Odum (1975) used the energy flow apporach for fish productivity potential of aquatic ecosystem keeping in view that in passing from one trophic level to the next almost 90% of the energy is lost, Odum (1962) opined that large water bodies, which have wide range of fish population belonging to various trophic level, the productivity potential can be taken as 1% of gross or 0.5% of the energy fixed at producer level. The energy dynamics of an ecosystem do take into account the various trophic levels but it has disadvantage that many animals are omnivorous and thus can not be assigned to a particular level. The feeding habit of the animal do change with the availability of the food. It has been established by many workers that the most important single channel of energy flow leading to fish production is organic detritus complex.

Thus it is imperative to know the various mechanisms of nutrient cycle in evaluation of productivity in open waters. Many physico-chemical factors influence the productivity in a open water system. Until unless the relationship of nutrients and physical factors is known it is very different to determine productivity of a open water.

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STATUS AND SCOPE OF FISHERIES ENHANCEMENT FROM LARGE RESERVOIRS IN INDIA

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Introduction

In India a large number of river valley project have been commissioned since independence as a part of our developmental activities, resulting in a chain of artificial impoundments. India has more than 19,000 small reservoirs with a total water surface area of 1,485,557 ha and about 180 medium and 56 large reservoirs of 527,541 and 1,140,268 ha respectively. Indian reservoirs are classified into large medium and small based on their area and the total water spread under all categories. Reservoirs having total water spread area < 1000 ha fall under small category and in case of medium category, it is 1000-50000 ha, while large reservoirs are those which have water spread area > 5000 ha.

Reservoir management for fisheries is capable of generating additional national income of the order of 100 crores per year and providing employment to lakhs of rural poor through fishing, transport, marketing and ancillary industries. Large dams are increasingly becoming a characteristic component of river basins. The CIFRI's research over the last two decades has lẹd to sound technological approaches that can substantially augment production from Indian reservoirs. The productivity status of a large reservoir should be evaluated and accordingly appropriate fisheries enhancement strategies may be adopted to optimise the reservoir productivity.

The success of an organism and its productivity in reservoir ecosystem are determined in part by suitability of the environment. Amongst the most obvious aspects of the environment that affect animal production are termperature chemical factors and reservoir morphometry.

Temperature

Temperature influences the rates of activity from a molecular to an organismal scale. Many ecologists have found that rates of secondary production increased with temperature. However, production (P)/mean biomass (B) is believed to rise with increased temperature on a linear or curvilinear scale. The general positive effect of temperature on secondary production is a result of the reproductive biology of plankton and benthos. Many workers suggested that with increase in temperature growth rate and feeding rate increased, and the eggs development time decreased. These factors tend to increase productivity of biotic communities in reservoirs at high temperature. But the egg production by oligochaetes declines at high temperature. The temperature variation could have either a positive or negative effect on the productivity of biotic communities depending upon geographic location and basin morphometry of reservoir. The temperature regimes of reservoirs in north India are lower than that of the south. Variation of temperature from surface to bottom has been recorded only 3-4 ^{0}C for peninsular reservoir (Nagarjunasagar) whereas the same for north India has been registered as 10 ^{0}C. (Konar). this can be attributed to less-marked seasonal differences in temperarture as one progress towards lower latitudes.

Reservoirs in temperate region often develop thermocline with the formation of epilimnion, metalimnion and hypolimnion. But in tropical reservoirs no such thermal stratification occurs although some ill-defined thermal gradient, (Table 1) has been reported in few south Indian reservoirs and in a Waghyanala reservoir from central India.

Table 1. thermal features of some reservoirs

Thermal features	South India								Cent. India
	Pykara	Sandy-nulla	Amara-vathy	Krish-nagiri	Sathanur	Aliyar	Bhavani-sagar	Stanley	Waghya-nala
Surface 0^0C Max. Min.	 22.4 19.0	 22.6 16.4	 28.8 24.0	 31.4 23.5	 30.4 25.0	 32.8 26.0	 31.0 23.8	 32.0 24.2	 33.0 21.0
Bottom 0^0C Max. Min.	 20.2 18.0	 20.0 15.1	 27.0 21.5	 28.0 23.0	 28.5 24.0	 31.0 24.2	 30.2 22.2	 30.0 24.0	 31.0 20.0
Thermal stratification	Nil	Rare	Nil	Very rare (ill-defined)	Nil	Very rare (ill-defined)	Very rare (unstable)	Rare (un-stable)	Rare (un-stable)

(Modified from Sreenivasan, 1969)

Chemical factors influencing the productivity

Values of certain important chemical parameters of reservoir water and soil suggesting high biological productivity are depected in Table 2.

Table 2 : Chemical parameters of reservoir water and soil suggesting high biological productivity.

Parameters in mgl^{1} except pH	Water	Parameters	Soil
pH	> 6.5	pH	7.5
Alkalinity (bound CO_2 as carbonate)	> 50.0	Available Phosphorus ($mg100\ g^{-1}$)	> 6.0
Total Alkalinity	> 90.0	Available N ($mg100\ g^{-1}$)	> 75
Dissolved N	> 0.2	Organic carbon (%)	> 1.5
Dissolved P	> 0.1		
Calcium	> 25.0		
Total hardness	> 25.0		
Sp. Conductivity ($m.mhos\ cm^{-1}$)	> 200		

The *oxygen* curve is an important chemical parameter to indicate the biological productivity of a reservoir. Oxygen deficit at the bottom is a characteristic feature of productive reservoirs. Photosynthesis at the surface and tropholytic activity at the bottom cause *klinograde oxygen distribution* recorded for Bhavanisagar, Amaravathi, Nagarjunasagar and Govindsagar reservoirs in India. In unproductive reservoirs, the oxygen curves parallels the temperature curve since it is temperature-dependent. In Konar, Tilaya, Rihand and Tungbhadra reservoirs such *Orthograde Oxygen distribution* was observed along with low productivity.

In reservoirs with klinograde oxygen distribution, the carbon-di-oxide and carbonate concentration show a general inverse relationship to the oxygen i.e.concentration of carbon-di-oxide and bicarbonate increases slightly with depth. On the other hand, orthograde oxygen distribution is usually accompanied by only slight increase. if any, in carbon-di-oxide.

A number of South Indian Reservoirs recorded a range of 4.1-10 mgl^{-1} dissolved oxygen concentrations strikingly similar to central Indian reservoirs. The availability of oxygen is thought to be critical, specially to the benthos because they often live in areas that are oxygen-poor. Brylinsky(1980), however, has found that zooplankton production in a wide range of reservoirs is also influenced by oxygen concentration in the epilimnion. Sufficient oxygen is important to benthos production because food cannot be metabolised efficiently at low oxygen level. The egg production in freshwater oligochaetes is constant with decreasing oxygen concentration until some critical low level is reached.

Influence of miscellaneous environmental factors and reservoir morphometry

Many workers suggest that secondary production decreases with increasing water flow rate. A positive relationship with intensity of solar radiation has been established. Also it has been reported that high zooplankton and benthos production rates should be found in the most stable ecosystems.

Mean depth, defined as the volume of the reservoir divided by area, is considered the most important morphometric parameter. It is indicative of the extent of *euphoticlittoral* zone *i.e.,* the depth zone which permits the light penetration for growth of planktonic algae and also provides shallower shore areas for attachment of sessile algae and macrophytes. It is an inverse correlate of shore development, a direct correlate of area (Hayes, 1957) and an exact correlate of volume when area is held constant. Thus, mean depth portrays many morphometric features of a reservoir which contribute to the potential productivity of biotic communities in ecosystem. A distinct inflection in the mean depth curves at 18m (10 m in some Indian reservoirs) has been reported. This suggests that water mass below this depth serves as a *nutrient sink* as the nutrients from trophogenic zone in the form of settling seston and phytoplankton are shifted to tropholytic zone.

Shallower reservoir generally support higher rate of secondary production. Also it suggest that the surface area of reservoir might be important, since in large reservoirs the profundal zone was less enriched by the littoral zone or allochthonous materials to secondary production. Possibly due to high primary production in the littoral zone, it is generally believed that secondary production in near-shore areas and macrophyte beds is greater than all other areas.

Energy Sources and its transformation in Reservoir

Resrevoirs get energy from both autotrophic energy fixation and allochthonous sources. The energy fixed by the producers was in the range of 3,803 to 11,696 cal$m^{-2}day^{-1}$ in Rihand, Govindsagar, Bhavanisagar and Nagarjunasagar. As is depicted in table -3, the two tropical reservoirs, Bhavanisagar and Nagarjunasagar received almost similar amount of solar energy but the efficiency of energy transformation from primary fixed energy to fish or light to fish in Bhavanisagar was much more than in Nagarjunasagar (Table 3). Among the two subtropical reservoirs, Govindsagar has shown better conversion efficiency from photosynthetic energy to fish or light to fish than Rihand. Energy transformation through primary productivity of few Indian reservoirs is given in Table 4.

Table 3 : Photosynthetic energy fixation and energy conversion in four reservoirs.

	Bhavanisagar	Nagarjunasagar	Rihand	Govindsagar
1. Location	$11^0 5'$N	$16^0 34'$N	24^0N	$31^0 25'$N
2. (a) Total visible radiation K cal m^{-2} day^{-1}	2,130	2,050	1,884	1,720
(b) Total radiant energy cal m^{-2} yr^{-1} x 10^5	7,775	7,483	6,877	6,278
3. Photosynthetic production				
(a) gO_2 m^{-2} day^{-1}	2.380	1.620	1.003	3.178
(b) gO_2 m^{-2} yr^{-1}	870.89	590.93	377.04	1159.97
(c) Energy cal m^{-2} yr^{-1} x 10^6	3.205	2.175	1.387	4.269
4. Efficiency of energy transformation light to chemical (%)	0.412	0.290	0.202	0.682
5. Fish Production				
(a) kg ha^{-1} yr^{-1}	79.2	10.0	4.0	71.4
(b) g m^{-2} yr^{-1}	7.92	1.00	0.40	7.14
(c) Energy cal m^{-2} yr^{-1}	9.500	1.200	4.80	8.568
6. Conversion of energy				
(a) Fish/photosynthesis 5(c) - 3(c)	0.29	0.055	0.034	0.20
(b) Fish/light 5(c) - 2(b)	0.001	0.00016	0.00007	0.0013
7. Fish production 5(b) - 3(b)	0.90	0.17	0.105	0.61
8. (a) Photosynthesis (gC m^{-2} yr^{-1})	326.58	221.6	141.39	435.0
(b) Fish yield as (gC m^{-2} yr^{-1})	0.792	0.100	0.04	0.714
(c) % Conversion	0.24	0.045	0.028	0.164

(Jhingran, 1991)

Table 4 Energy Transformation through primary production in differnet reservoirs

Reservoir	Location	Incident visible/radiatient energy (Cal/m^2/day)	Energy fixed by producers (Cal/m^2/day)		Photosynthetic efficiency (%)		Net energy stored by producers (Cal/m^2/day)	Energy lost as respiration (Cal/m^2/day)
			Oxygen	Carbo-hydrate	Oxygen	Carbo-hydrate		
B. Sagar	11^0 5' N	21,30,900	8,781	9,168	0.412	0.430	4,610	4,172
N. Sagar	16^0 34' N	20,50,300	5,959	6,221	0.290	0.303	3,450	2,509
Ukai	21^0 15' N	19,55,000	6,175	6,671	0.320	0.340	4,910	1,227
Getalsud	23^0 27' N	19,25,000	2,721	3,100	0.148	0.161	1,368	1,353
Rihand	24^0 N	18,83,750	3,803	3,970	0.202	0.211	1,580	2,217
G. Sagar	31 25' N	17,19,900	11,696	12,210	0.682	0.710	7,626	4,071

(Jhingran, 1991)

Assessment of biotic productivity

The production process and productivity level of biotops of reservoirs are to be assessed through limnological studies. General holistic and comparative approaches, relying on statistical methods, are necessary. More accurate and comprehensive resource evaluation such as by remote sensing coupled with ground truth information is essential. When combined with limnological data and indices of fish production (such as fish catch and effort data), comparison between systems will allow important variables to be identified.

Role of biotic factors, yield status and strategies for management of reservoir

In the reservoirs nutrients are added to the system either through allochthonous source or mostly directly from benthic substrate with larger concenentration in the upper layers. It has been reported that the organic and nutrient input resulting from macrophytes production usually exceeds from other soruces put together. In large reservoirs, phytoplankton production may be more important than littoral production. However, secondary productivity in littoral zones is still significant. High zooplankton biomass but limited production, may be due to restricted access of fish to inshore areas of dense vegetation. The macrophyte-detritus cycle in littoral zones adds stability to the system. This is possible because of the physical stability of biotop as well as the nature of the mechanisms involved.

Amongst large reservoir in Rihand and Gandhisagar, fish yield reached its initial peaks in the fourth year of impoundment. However, this high production is not sustained for long. After a period ranging from one to several years, it declines to much lower level, partly due to diminution of bottom leaching as volume of impounded water increases and partly as nutrients are used up by aquatic vegetation when it becomes established in greater quantity. The productivity ultimately gets stabilised somewhere near half the magnitude of initial phase, getting adjusted to the basic productivity levels of the basin and allochthonous nutrients from the inflows and watershed runoff.

The fish yield from large reservoirs in India is low. At the present level of management, they yield, on an average about 11 kg/ha, whereas a production of 50 kg/ha can easily be augmented. The studies carried out by CIFRI after 1970 under All India Coordinated Research Project on Ecology and Fisheries of Reservoirs provided guidlines for managing the reservoir fisheries.

Depending upon the productivity potentials of reservoir ecosystem, its biotic potentials are to be aptly utilised for optimising fish yields. The management approach like enlargement of mesh size, increasing fishing efforts and stocking support for the purpose of establishing a breeding population of suitable fish species, is to be adopted for enhancement of fish yields from large reservoirs in India.

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ROLE OF CHEMICAL PARAMETERS AND COMMUNITY METABOLISM (ENERGY DYNAMICS) IN PRODUCTION PROCESS IN OPEN WATERS

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Introduction

The productivity of any aquatic system depends on various chemical and biological processes. The aboitic variables, dynamics of chemical parameters, circulation of nutrients and flow of energy from solar radiation to the desirable end product (fish) are some of the basic processes which have great bearing on the productivity of the aquatic system as a whole. The role of chemical parameters is to help in evaluating the productivity trends of various aquatic ecosystems while energy dynamics helps in understading the patterns of energy flow and the effective utilization of the available potential energy resource of the system. In order to stand the production process of open waterss it is essential to critically examine both the parameters for getting maximum output from such systems.

2. Factors affecting biological productivity

Various factors influencing biological productivity of any aquatic system can be put into three broad categories-climatic, edaphic and morphometric. The climatic factors like rain fall, wind velocity and air temperature, edaphic factors-soil and water quality provide essential source of energy and nutrients and thus they may be considered to be of first order importance while morphometric factors like water level, depth, shore development and volume development etc. Which serve as modifying factors that determine the heat and nutrients characteristics are second in order of importance. Several workers have shown the importance of these factors in evaluating the productivity trends of aquatic systems. Some workers have shown the importance of edaphic parameters and established their direct relationships with productivity. Wide seasonal fluctuation in air temperature with low values in winter and high values during summer have great bearing on the thermal features of impounded waters. Similarly neutral to slightly alkaline soils with more than 1% organic carbon, 3 to 6 mg/100 g or above available phosphorus and 25 to 75 mg/100 g or above available nitrogen are indicators of productivity. With respect to water quality slightly alkaline pH, alkalinity above 50 mgl^{-1}, conductance above 200 μmhos, dissolved solids above, 100 mgl-1, organic matter 1 mgl-1, nitrate above 0.5 mgl^{-1} are indicators of good productive waters. Several workers have shown the importance of morphometric factors, specially mean depth, and established inverse relation with productivity. The two ideas were combined in deriving morpho-edaphic index, a ratio of total dissolved solids and mean depth, and the index has been used in evaluating the productivity of large water bodies like lakes and reservoirs.

3. Dynamics of chemical constituents and their role in production process

From biological productivity point of view the water mass in an aquatic system is divided into two fundamentally different layers one above the other in which opposing processes are taking place. They are the regions of photosynthetic production (trophogenic zone) and the regions of breakdown at the bottom (tropholytic zone). The chemical reactions taking place in the two zones are:

i)	$6CO_2 + 6H_2O = C6H_{12}O_6 + 6O_2$	Trophogenic zone
ii)	$2HCO_3 = CO_3 + CO_2 + H_2O$	-do-
iii)	$C6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O$	Tropholytic zone
iv)	$CO_2 + CO_3 + H_2O = 2HCO_3$	-do-

The reactions during dark hours when there is no photosynthesis are same as that in the tropholytic zone. As a result of reactions in the trophogenic zone the water body will show increase of oxygen during light hours due to its production, decrease in bicarbonate as it breaks into carbonate and carbondioxide for maintaining the regular supply of CO_2 required for photosynthesis, increase in carbonate and pH. While the reactions in the tropholytic zone or during dark hours cause reduction in oxygen due to its consumption in oxidative processes or respiration, increase in bicarbonate due to recombination of carbonate and carbondioxide into bicarbonate decrease in carbonate and pH. If the reactions in two phases are fast the water body will show sharp variation in depth profile from surface to bottom during stagnation period (chemical stratification) or with the progress of day and night (diel cycle). In deep waters like lakes and reservoirs the two zones are separate and the increase in intensity of two opposing reaction results in the development of biogenic chemical stratification while in shallow waters like beels and small reservoirs, the variations in the chemical paramctrs reflects the intensity of reactions in both the zones. As the rates of these reactions are directly related to the production (P) and consumption (C) processes the relative productivity of the aquatic system can be evaluated from the magnitude of their variations.

High photosynthetic production of oxygen in the trophogenic zone and high rate of its consumption in decomposition in the bottom layers, cause clinograde oxygen distribution in large water bodies like lakes and reservoirs. As both the processes reflect the productive characters the oxygen curve in such waters gives important clue in determining the degree of productivity. The decomposition of organic matter in bottom layers and subsequent decline in oxygen is always accompanied by accumulation of carbondioxide. The increased carbondioxide results in increase of hydrogen ion concentration ($CO_2 + H_2O = H_2CO_3 \rightarrow H^+ + HCO_3^-$) and hence lowers the pH. Thus bottom accumulation of carbon dioxide, fall in pH, decline of oxygen, increase in bicarbonate etc. all reflect high productivity. In low productive waters these changes are less marked.

In shallower water bodies like beels, where the trophogenic and tropholytic layers are not marked, the light and dark chemical reactions responsible for diel variations reflect better productivity trends as the degree of variation is directly related to the production process. The depth-wise variation in chemical parameters of some reservoirs and diel cycle in some beels have been presented in Table 1 & 2.

4. Nutrient cycle

The effective functioning of any aquatic ecosystem depends on the circulation of nutrients which enter the cycle through autotrophic production process of plants and move to other higher trophic levels through consumption. At each trophic level the unused material reaches the bottom after the death of the organisms. Here the organic matter is broken up by oxidative processes and nutrients are again released to be used by the producers. In shallower waters the circulation of nutrients is not a problem but in stratified deep waters nutrients are locked in the tropholytic zone ('nutrient sink') and are removed from circulation. The aquatic systems which are permanently stratified the nutrient circulation is stopped and such waters become low productive with passes of time. However in reservoirs the stratification is broken by the influx of flood water and nutrient locking (if any) are for a very short period. In beel ecosystem the locking of nutrients is by the infested macrophytes for longer period and they are released only after the death and decomposition of those macrophytes.

5. Community metabolism (energy dynamics)

The biotic communities within an aquatic ecosystem are inter linked with one another by energy cahins. The primary energy fixed by producers is utilised by consumers at various trophic levels and the studieds of energy dynamics mainly concentrate on two points (i) quantitative assessment of synthesis of organic matter by producers that is transformation of solar energy into chemical energy (ii) the path ways of energy transformation that is flow if energy from producers to consumers at different trophic levels.

Energy transformation through primary production

Measurement of rate of conversion of solar energy into chemical energy by producers gives a dependable parameter to assess the productivity potential of an aquatic system. The redox process of energy transformation is represented by the basic equation:

$$6CO_2 + 6H_2O = C6H_{12}O_6 + 6O_2$$

or $$nCO_2 + n(H.doner) = (CH_2O)n + n(oxidised\ doner)$$

Through this endergonic process plants can store large amount of energy in the form of energy rich organic compounds. The efficiency of energy transformation known as photosynthetic efficiency is written as:

$$\frac{\text{Energy fixed by producers}}{\text{Solar energy available on the water surface}} \times 100$$

The energy required to liberate one mg of oxygen through algal photosynthesis is 3.68 cal. and thus the energy fixed by producers can be easily calculated from the amount of oxygen liberated during photosynthesis. Part of the energy fixed by the photosynthetic organisms is used for their own metabolic activities and lost as heat of respiration and the remaining is stored by them and thus:

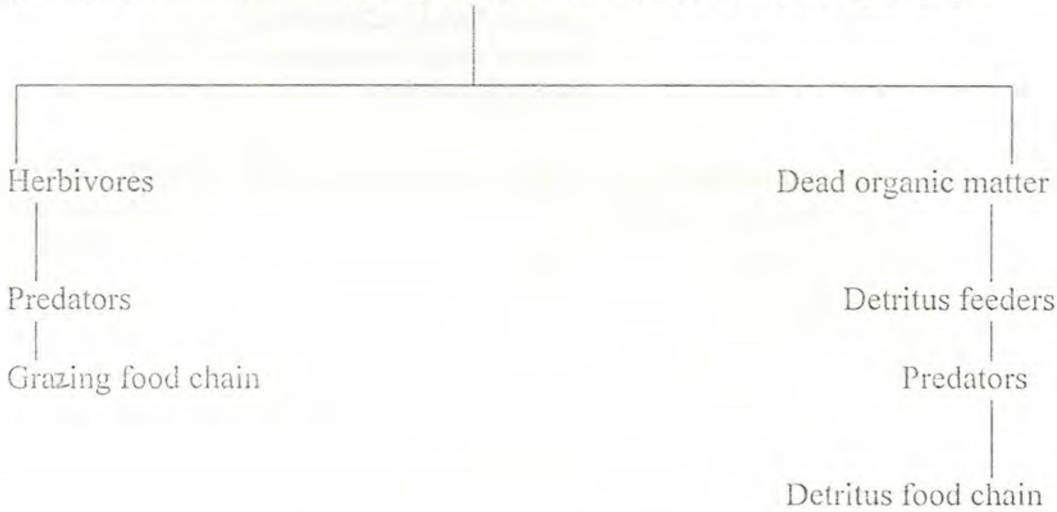
Gross energy fixed by = Net energy stored + Energy lost as respiration

In most of the water bodies the rate of energy transformation through primary production is mainly by phytoplankton while in beels and other shallower water bodies both phytoplankton and macrophytes are responsible for photosynthetic production the contribution of latter being maximum. In large water bodies likes lakes reservoirs and rivers the photosynthetic efficiency rarely exceeds 1%. Studies in several reservoirs have shown efficiency ranging between 0.126 to 0.682%. In beels, where macrophytes are the main producers, the efficiency is as high as 2 to 3%.

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

The energy fixed by producers flows to consumers at different trophic levels therefore proper understanding of the trophic dynamics of the aquatic ecosystems helps in formulating policies for stock manipulation. There are two main routes through which energy flows in the systems. The first one involves grazing of green organisms by herbivores or plant feeders which are inturn taken by predators and thus the energy from producer level flows to various levels of consumers. This is commonly known as grazing chain. All the energy represented by producers is not always utilized by cionsumers directly and the unutilized energy is deposited at the bottom after the death of the organisms. In beels, which are infested with macrophytes, the primary energy fixed by macrophytes is not utilized directly by herbivores and the unsed material gets deposited at the bottom after their depth. When decay occurs these macrophytes contribute to rich organic detritus pool These dead organic detritus deposites are consumed by organisms feeding on them (detritus feeders) which may be again taken up by predators. The second path of flow of energy through dead organic matter or detritus complex is known as detritus chazin. The two pathways are shown below

ENERGY AT FIRST TROPHIC LEVEL OR PRODUCER LEVEL



In some aquatic systems grazing path predominates while in many others most of the energy flows through dertritus chain. Functionally the distinction between grazing and detritus chain is important as there is a time lag between the direct utilization of energy by grazers and that through detritus chain. the patterns of energy utilization in some water bodies have been presented in Table 3.

It is apparent from the table that in large reservoirs Govindsagar, Nagarjunasagar and Rhand and Ganga river maximum energy flows through grazing chain while in small reservoirs Bhavanisagar, Aliyar and Bachhra the flow of energy is through detrtus chain. In beels which are generally in-fested wth macrophytes and the energy fixed by producers is not utilized by grazing the flow of energy is mainly through detritus chain. However in some large and deeper beels like Dhir beel in Assam observation have shown that the grazing chain is more stronger. It is well known that the nearer the useful end product (fish) stands to the first link in the food chain the higher the yield from the watemass as the loss of energy will be much higher if the chain is longer. Accordingly the water bodies dominated by primary consumers (either herbivores or detritivores) will show more yield than those which are dominated by secondary and tertiary consumers. The energy dynamics of an ecosystem do take into account the various trophic levels but this approach has disadvantage that many fishes are omnivorous and thus can not be assigned to a particular level. Moreover the feeding habits of the fishes changes with the availability of the food. Thus a catious approach is [illegible] in grouping the consumers at different trophic levels. It has been established that most important single channel of energy flow leading to fish production is through organic detritus complex;

Conclusion

The abiotic variables and dynamics of chemical parameters help in evaluating the productivity trends of various ecosystems while the enery dynamics opens the door for the management norms in order to get the maximum return and better utilization of the potential energy resource.

Table 1. Diel cycle of chemical parameters in beels

KULIA BEEL

Time of collection	D.O. (mg/l)	pH	Free CO_2 (mg/l)	Carbonate (mg/l)	Bicarbonate (mg/l)
06	2.0	7.5	0.66	0.0	170.0
10	5.7	7.7	0.00	2.7	164.5
14	15.5	8.4	0.00	14.0	140.9
18	11.0	8.2	0.00	13.8	149.2
22	8.6	8.1	0.00	7.4	153.5
02	6.5	7.7	0.00	4.4	164.0
Total fluctuation	13.5	0.9	0.66	14.00	29.1

DHIR BEEL

06	4.2	6.3	8.00	0.00	36.0
10	10.4	7.0	2.00	0.00	25.0
14	13.6	7.4	0.50	0.00	16.0
18	11.6	7.2	1.0	0.00	19.00
22	10.6	7.1	3.0	0.00	24.0
02	6.4	6.8	6.0	0.00	28.0
Total fluctuation	9.4	1.1	7.5	0.00	20.00

MUKTAPUR BEEL

06	2.5	7.8	4.0	0.0	110.0
10	8.5	8.1	0.00	6.0	103.0
14	11.8	8.5	0.00	20.0	100.0
18	9.8	8.5	0.00	14.0	100.0
22	7.6	8.2	0.00	5.0	104.0
02	5.8	8.0	1.00	0.0	108.0
Total fluctuation	8.8	0.7	4.0	20.0	10.0

Table 2. Dynamics of chemical constituent in Reservoir

Depth	dissolved oxygen (mg/l)	pH	Fre Carbon dioxide (mg/l)	Bicarbo-nate (mg/l)	Dissolved oxygen (mg/l)	pH	Free Carbonate dioxide (mg/l)	Bicarbonate (mg/l)
GOBINDSAGAR					NAGARJUNASAGAR			
0	8.3	8.2	-	62.0	5.98	8.6	-	125.0
3	8.3	8.2	-	63.0	5.98	8.6	-	125.0
6	6.9	8.0	-	65.0	5.98	8.6	-	127.0
9	6.0	7.85	2.0	65.0	5.6	8.6	-	127.0
12	5.7	7.85	2.0	70.0	5.6	8.6	-	130.0
15	5.7	7.85	2.0	72.0	5.6	8.5	-	130.0
18	5.0	7.85	6.0	78.0	2.9	8.2	5.04	141.0
21	5.0	7.85	6.0	80.0	2.9	8.2	5.04	143.0
24	4.5	7.85	6.0	80.0	2.9	8.2	5.04	143.0
27	4.5	7.85	6.0	80.0	2.9	8.2	5.04	150.0
30	4.5	7.85	6.0	80.0	2.9	8.2	4.04	150.0
33	4.5	7.65	8.0	82.0	2.6	8.2	5.07	150.0
36	4.2	7.65	8.0	82.0	2.6	8.2	5.04	150.0
39	4.2	7.65	8.0	82.0	2.6	8.2	5.04	152.0
42	2.8	7.65	8.0	82.0	2.5	8.2	5.04	152.0
60	2.0	7.5	11.0	84.0	-	-	-	-
BHAVANISAGAR					RIHAND			
0	7.9	8.35	-	34.0	8.2	8.0	8.0	44.0
3	7.5	8.35	-	34.0	8.2	8.0	8.0	44.0
6	5.0	7.30	4.5	44.0	8.0	8.0	10.0	44.0
9	3.5	6.90	6.0	48.0	7.0	7.9	10.0	40.0
12	2.0	6.80	9.0	51.0	7.0	7.9	10.0	40.0
15	1.0	6.80	11.0	56.0	6.5	7.9	10.0	38.0
18	-	-	-	-	6.5	7.9	12.0	38.0
21	-	-	-	-	6.5	7.9	12.0	36.0
24	-	-	-	-	6.5	7.8	13.0	36.0
42	-	-	-	-	6.3	7.7	13.0	34.0

Table 3. Patterns of energy utilization in different aquatic ecosystem

Ecosystems	Visible radiant energy K cal.h^{-1} yr^{-1} x 10^{6}	Energy fixed through primary production K cal.h^{-1} yr^{-1} x 10^{4}	Contribution of fishes at different trophic levels					Conversion of energy photo-synthesis to fish (%)
			Primary consumers Herbivores K cal.h^{-1} yr^{-1}	Primary consumers Detritivores K cal.h^{-1} yr^{-1}	Secondary consumers K cal.h^{-1} yr^{-1}	Tertiary consumers K cal.h^{-1} yr^{-1}	Total energy harvest as fish K cal.h^{-1} yr^{-1}	
Large reservoir								
Govindsagr	6278	4270	49080	9840	24840	170	85680	0.20
Nagarjunasagar	7480	2175	1545	645	4125	4725	12000	0.055
Rihand	6875	1390	4320	-	480	-	4800	0.033
Small reservoirs								
Bhavanisagar	7775	3204	24860	40200	6480	20640	95000	0.29
Aliyar	7847	4937	4344	48528	9912	2592	65376	0.132
Bachhra	6825	3485	29520	43560	13800	36960	123840	0.335
Beels								
Kulia	7154	22070	-	251589	46156	106824	404569	0.184
Media	7154	21780	140772	109488	-	30144	284400	0.131
Dhir	6770	19580	206736	78312	14381	96571	396000	0.202
R. Ganga at Patna	6807	1049	14786	1628	2738	17781	36933	0.35

STATUS AND SCOPE OF FISH PRODUCTION IN SMALL RESERVOIRS IN INDIA

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Introduction

Reservoir are being constructed in the country at a very rapid rate especially after independence to supply water to industries, irrigation, power generation and flood control measures. This area increases year after year with the addition of more and more impoundments. According to a recent estimate, there are 19000 small reservoirs with a total water surface area of 14,85,557 ha and about 180 medium and 56 large reservoirs of 527 541 and 1,140268 ha respectively. The reservoirs are generally classified as small (<1000 ha) medium (1000-5000 ha) and large (>5000 ha). Reservoir is a unique man made biome where fluviatile and lentic conditions co-exist alongwith certain unique characteristics of their own.

Fish yield from these reservoirs is frustatingly low, on an average beng 20 kg ha^{-1} in case of large and 50 kg ha^{-1} for small reservoirs against 88 kg ha^{-1} USSR and 100 kg ha^{-1} in Srilanka. The reason for low yield may be attributed to in adequate understanding of the reservoir ecosystem and their unscientific management. Studies conducted by CIFRI have furnished valuable information to develop basic hypothesis on the productive capacities of both large and small reservoirs (Gulariya, Bachhra Bghla, Aliyar etc.) leading to substantial increase in fish production (above 200 kg ha^{-1}). For scientific management of open water ecosystems understanding of abiotic determinants like oxidisable allochthonous and autochthonous materials, physico-chemical parameters of water and soil of the basin, spatio-temporal distribution of nutrients and biotic determinants *viz.* primary producers such as phytoplankton & macrophytes and ecological relationship among various consumers is *sine-qua-non.* Some of these aspects are discussed in the discussion that followed.

Aquaculture techniques in small reservoirs

The aquaculture, practiced in these impoundmnets, may be described as *'extensive'*, where cultured fingerlings are raised in water bodies with few or no modification of the habitat. This is in contrast to the intensive culture practised in ponds receways etc. where abiotic and biotic components are under control. The capture and culture fishery principles grade into each other in small reservoirs where the fishery depends on stockeded fingerlings while in large reservoirs stocking is adjusted against the loss in recruitment. The differences between large and small reservoirs are depicted in Table 1.

Past and present status of small reservoir fisheries

• Fish culture in the small reservoirs, hitherto being practised by the state Governments consists of supplementing the natural stocks of economic fishes with stocking on arbitrary basis without any definite levels or ratios based on the biogenic capacity of the ecosystem. Stocking rates wherever prescribed do not appear to have been followed strictly.

Despite the arbitrary stocking a few reservoirs, have been reported to show high fish production with repeated regular stocking. Keetham reservoir (250 ha) in U. P. for example, produced 530 kg/ha in 1959-60 although the yield declined drastically in the later years. This emphasises the need to focus attention towards fish culture in such ecosystems based on an understanding of the environmental and biological parameters, basic productivity levels and ecological relationships.

Stocking policy

Stocking of fish in small reservoirs has proved to be a useful tool for developing theire fisheries potential. Stocking of economically important, fast growing fishes from outside is aimed at colonizing all the diverse niches of the biotope for harvesting maximum sustainable crop from them.

This widespread management practise has been proved to be highly remunerative in such small water bodies where almost complete annual harvesting is possible. This has amply been demonstrated in Gularya, Bachhra and Baghla reservoirs (U.P.) and Aliyar reservoir in Tamil Nadu (Table 3). Stocking is not merely a simple matter of releasing of appropriate species into an ecosystem but needs evaluation of an array of factions *viz.*, biogenic capacity of the environment, the growth rate of the desired species and the population density as regulated by predatory and competitive pressure

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

Formulation of stocking policy

A number of methods are in vogue for assessing the potential fish yield from lakes and reservoirs. Most common approach towards formulation of stocking policy is to assess the potential of the reservoir by any one of the method (MEI, Gulland Model, Tropho-dynamic model) most suitable to the system and adjustment of stocking rate according to approach the potential yield. In the Indian context trophodynamic model found most suitable than MEI approach.

Stocking formula

The stocking rate can be calculated based on the average growth rate of the individual fish and the expected production.

$$\text{The stocking rate} = \frac{\text{Expected production (Kg)}}{\text{Av. individual growth rate (kg)}} + \begin{array}{l}\text{Loss due to mortality}\\ \text{and escapement (\%)}\end{array}$$

welcome has also given a formula for calculating stocking rate, the model assumes insignificant breeding by used stocked population and therefore applicable to total cropping situation. This model has not been used in India. How it will fit in Indian condition is at present only a gues work.

Case studies of some small reservoirs

To establish a baseline for evolving suitable management measures towards fishery development in small reservoirs, the Central Inland Fisheries Research Institute (CIFRI) initiated investigations on small reservoirs of M.P. *Viz.*, Loni, Kulgarhi, Govindsagarh and Naktara; Gulariya, Bachhra and Baghla in U.P., Aliyar Reservoir in Tamil Nadu and Kyrdemkulai in Meghalaya. Investigations on hydrology primary productivity, plankton, macrobenthos, macrovegetation, soil characteristics, experimental fishing and biology of commercial fishes have been conducted. Range of certain abiotic and biotic parameters in some small reservoirs of India are summerised in Table 2. The critical evaluation of the parameters indicates that they can support moderate to high fish production. Range of physico-chemical parameters indicative of productivity levels is shown in Table 4.

Biotic communities

Biological productivity of a impoundments is governed by a numbers of factors *viz.* climatic, edaphic and morphometric. The geographic location effects the metabolisms of reservoir through nutrition supply, snape of the basin and the efficiency with which the climatic factors are able to act in the dynamic exchange. They will have a varying effect on final productivity. Paiva has identified factors including abiotic and biotic which influence fish yield in Brazilian reservoirs (Table 5). He has given equal weights to these factors for evaluation of fishery potentials and each factor has arbitrarily assigned a value of 10 kg ha^{-1} in terms of its positive or negative influence. This approach has not been given a trial in Indian context. However, it should be used in some reservoirs to explore its suitability.

Plankton:- Plankton population ranged from 58 unit/l to a high of 40,000 unit/l in Baghla reservoir. The high population was observed due to *Melosira*. The low plankton population was observed in monsoon due to high inorganic turbidity and high in post monsoon followed by summer months. Dominance of Myxophyceae was observed in these reservoirs followed by Bacillariophyceae and Chlorophyceae. Myxophyceae was chiefly represented by *Microcystis aeruginosa;* Bacillariphyceae by *Synedra ulna Fragilaria* spp., *Melosira granulota* and *Chlorophyceae* consisted of *Pediastrum duplex, Spirogyra* sp. *Oedogonium* sp., *Pandorina* sp. as dominant forms.

Copepods and rotifers were the main constitutents of zooplankton, mainly represented by *Diaptomus, Cyclops Brachionus, Keratella, Filinia* and *Polyarthra*. Maximum abundance was observed in summer and minimum in monsoon.

Macrobenthos communities:- Bottom fauna was generally rich which ranged from 95 unit/m^2 (Gulariya reservoir) to a high of 4620 (Bachhra reservoir). In these water bodies, insects dominated. The fauna was represented by chironomids, phylopotamus (insecta), *Pisidium, Corbicula, Lymnaea (Mollusca)* and *Brahchiura* sowerbyii (Annelida).

Fish fauna:- Fish fauna was observed well diversified belonging mainly to carps, cat fishes, featherbacks, murrels and clupeids, only in Kyrdemkulai reservoir mahseers like *Tor putitora, Tor tor* and *Acrossocheilus hexagonolepis* were observed besides small hill-stream fishes. Recommendations for development of Kyrdemulai and Nongmahir reservoirs have been submitted to the Northeastern Council for implementation by the State of Meghalaya.

Planning criteria

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

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

In tune with the need for rapid assessment of the country's small reservoirs resources, the following planning criteria are suggested for the resource assessment.

1. Preparation of an inventory of such small ecosystems alongwith their estimated potential yields. This can be further divided into:-

a) Reservoirs which are best developed as capture fisheries
b) Reservoirs mostly of local interest having significant potential for fish culture
c) Reservoirs intermediate in size and potential yield.

General consideration

i) Since the breeding of the major carps has been repeatedly observed to take place above the spill way, resulting in heavy escapement of the brood, this poses a serious problem for building up stocks of desirable fishers in such reserovirs. The situation is further worsened by heavy escapement of fingerlings and adults through irrigation canals. Development of fisheries in such water bodies, therefore requires suitable screening of the spillway and the canal mouth. Such protective measures have already been installed in Loni, Bachhra, Baghla and Gulariya reservoirs and have paid rich dividends in enhancing the fish yield from these reserovirs (Table 3). In some of the reservoirs fishes have also been observed to move up the spillways into the reservoir whereas in others the spillways provide an insurmountable barrier to fish moving up the dam. To minimize losses by way of escapement of fish through spillway and canal, it would be an economic proposition to have an annual cropping policy so that the reserovir is stocked in August-September and harvested by June end.

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

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

iv) Aquaculture in small reserovirs can also play an impaortant role in integrated rural development since it can be profitably combined with duckery and piggery.

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

Socio-economic consideration

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

Table 1. The distinguishing features of small and large reseroviirss may be summerised as under:

(After Jhingran, 1965)

Small reservoirs	Large reservoirs
Single-purpose reservoirs mostly for minor irrigation	Multipurpose reservoirs for flood-control, hydroelectric generation, large-scale irrigation, etc.
Dams neither elaborate nor very expensive. Built of earth, stone, masonary work on small seasonal streams.	Dams elaborate, built with precise engineering skill on perennial or long seasonal rivers. Built of cement, concrete or stone.
Shallower, biologically more productive per unit area. Water-weeds commonly observed in perennial reservoirs but absent or scanty in seasonal ones.	Deep, biologically less productive per unit area. Usually free of aquatic weeds. Subjected to heavy drawdowns.
May dry up completely in summer. Notable changes in the water regiment	Do not dry up completely. Changes in water regimen not so pronounced. Maintaining a conservation-pool level.
Sheltered areas absent.	Sheltered areas by way of embayments, coves, etc. present.
Shore line not very irregular. Littoral areas mostly gradually sloping.	Shore line more irregular. Littoral areas mostly steep.
Oxygen mostly derived from photosynthesis in sthese shallow, non-stratified reservoirs lacking significant wave action	Although photosynthesis is a source of D.O. the process is confined to a certain region delimited by vertical range of transmission of light (euphotic zone). O_2 also derived from significant wave action.
Provided with concrete or stone spillway, the type and size of its structure depending on the runoff water handled.	Provided with much more complex engineering devices.
Breeding of major carps invariably observed in the reservoir abaove the spill way.	Breeding mostly observed in the head waters or in other suitable areas of the reservoir.
Can be subjected to experiemental manipulations for testing various ecosystem responses to environmental modifications	Cannot be subjected to experimental manipulations.
Trophic depression phase can be avoided through chemical treatment and draining and cycle of fish production can be repeated as often as the reservoir is drained.	Trophic depression phase sets in.
The annual flooding of such reservoirs during rainy season may be compared to overflowing flood-plains. Inundation of dry land results in a release of more nutrients into the reserovir when it fills up, resulting in high production of fish food through decomposition of organic matter, predominantly of plant origin leading to higher growth and survival.	Loss of nutrients occurs which get locked up in bottom sediment. Reduction in benthos also occurs due to rapid sedimentation.
Through complete fishing or overfishing in such seasonal reservoirs, no brood stock is left over to contribute to succeeding year's fishery through natural recruitment. The fish population has to be built up solely through regular stocking. There is thus established a direct relationship between stocking rate and catch per unit of effort.	In contrast, prominent annual fluctuations in recruitment occur and balancing of stock number against natural mortality requires excessive number of fingerlings in such large reservoirs. Their capture requires effective exploitation techniaques.

Table 2. Range of certain physico-chemical and biotic parameters of small reservoirs.

Parameters	Reservoirs					
	Gulariya	Bachhra	Baghla	Aliyar	Chapparwara	Kyrdemkulai
Transparency (cm)	11-80.0	17-145	9-204	108-182	-	2.20-2.84
D. O. mgl^{-1}	4.9-9.0	2.5-8.60	2.40-12.80	4.2-11.6	6.10-10.0	6.70-7.10
pH	7.2-8.4	6.96-8.30	7.32-8.84	6.6-6.8	8.0-8.40	6.8-7.0
Free CO2 mgl^{-1}	Nil-4.0	Nil-7.20	Nil-3.0	Nil-10.0	Nil	2.0-2.60
Alkalinity mgl^{-1}	38-80	95-190	42-106	16-72	76-100	22-32
Hardness mgl^{-1}	13-34	21-80	-	-	-	18.56-27.84
Nitrate mgl^{-1}	0.08-0.20	0.085-0.180	0.28-0.33	-	0.40-1.10	0.02-3.61
Phosphate mgl^{-1}	0.05-0.13	0.06-0.250	0.28-0.36	Trace-0.4	0.11-0.16	Trace-0.02
Silicate mgl^{-1}	5.0-14.0	6.80-14	2.4-4.9	Trace-0.2	1.92-8.0	1.0-10.0
Plankton u/l	245-4060	70-8432	58-40000	-	3100-20100	8420*
Macrobenthos u/m^2	95-4169	342-4620	976-2132	-	110-947	134*
Macrovegetation u/m^2	Absent	Absent	250-2200	Absent	470-1350	Absent

(* indicates average value)

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

Reservoirs	State	Area ha.	Stocking rate no ha^{-1}	Yield Kg ha^{-1}
Aliyar	Tamil Nadu	650	353	194
Meenkara	Kerala	259	1226	107
Chulliyar	Kerala	159	937	316
Gularya	Uttar Pradesh	300	517	150
Bachhra	Uttar Pradesh	140	763	140
Baghla	Uttar Pradesh	250	-	102
Bundhk Beratha	Rajasthan	-	164	94
Chapparwara	Rajasthan	200	300	79

Table 4. Range of physicochemical features in reservoir ecosystems

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

(after Jhingran, 1991)

Table 5. Showing positive and negative factors determining productivity of the reservoir

Augmentative factors	Reductive Factors
1 Extent of shoreline development (coves, bays, etc.)	1) Erosion in the reservoir watershed areas
2. Existence and extent of marginal vegetation	2) Reduction of the quanitity of water flowing into reservoirs.
3. Tree and brush clearing	3) Large seasonal water-level fluctuation
4. Average depth of less than 18 m	4) Fish population-unbalanced condition-to favour predatory species
5. Conditions which permit the passage of migratory fishes	5) Pollution in the reservoir watershed areas
6. Introduction of species well adapted to lentic environment	
7. Existence of permanent fisheries	
8. Utilization of modern fishing gears	
9. Enforcement of fishery regulations	
10. Management and financial assistance to fisheries	

After Bhukaswan (1980)

CLASSIFICATION, MANAGEMENT AND STATUS OF FISH PRODUCTION IN BEELS

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Introduction

Beels represent the transitional phase between the terrestrial and aquatic systems with water table at or near the surface or the land is covered with shallow depth of water. The delineation of their use depends upon the pattern of ecological succession which operates in the system based on the level of wetness. The wetland ecosystems including the beels have attracted the attention of ecologists and planners in recent years, being highly fragile in nature. The beels or floodplain lakes with substrate of pre-dominantly undrained hydric soils, due to permanent coverage of water, are generally shallow but highly significant biologically. The beel/maun/jheel/tal/pat are known for their rich biological diversity including fish fauna. Fisheries remain an important activity in such water bodies, practiced since time immemorial, but such waters have still larger spectrum of utilities such as I) *re-charge & de-charge of ground water, ii) accumulation of flood waters, iii) shore-line stabilisation, iv) trapping of toxic substances, v) trapping of nutrients, vi) repository of biodiversity as abode for large variety of plant & animal species, vii) sources for entertainments, viii) protection & development of aquatic food chains, ix) breeding, grazing & nursery grounds for riverine fish stock, x) regulator of local climate and so on.*

The floodplain of Ganga and Brahamputra basins of India have extensive distribution of beels of varied shape, size and origins. The people living in the vicinity of such ecosystems have high stake on these lakes for various economic activities be it agriculture, horticulture, fisheries or cottage industries. The utility of beels, thus, can be summarised into three major aspects such as *economic*, *aesthetic* and *cultural*. In recent years, however, these ecosystems have been subjected to undue stress in the face of increasing demographic pressure followed by changed land use patterns. Changing face of river valleys on account of man induced modifications due to conflicting demands by various user groups have further compounded the situation. The net result is habitat degradation at an accelerated pace. The beels are, in fact, reeling under the threat of extreme stress pointing to their total extinction, if not managed rationally. Utter neglect in the past and over exploitation in the present have made these ecosystems highly vulnerable in respect of biodiversity and accordingly the production functions. Presently, the beel ecosystem appears to pass through a critical phase of ecological succession and are in advanced stage of eutrophication leading to swampification at a very faster pace. It is time that all-out efforts are being made to conserve the beel ecosystem so as to protect the legitimate demands of various user group besides conserving the aquatic biodiversity for sustainable production and its safe transfer to the next generation.

Definition of wetlands

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

Floodplain wetlands

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

Origin of beels

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

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

- *The origin of tectonic lakes locally known as chaurs, pats, dhars, beels etc. is a function of geo-morphological changes brought about on the earth crust, leaving behind a trail of depressed land scape where monsoon run-off and flood waters accumulate and assume the states of lakes of varied shape, dimension and depths. The tectonic lakes are generally shallow and saucer shaped in extension. They may either be perennial or seasonal depending upon the depth of the depression. The North-Eastern portion of North Bihar and Assam have plenty of such lake area. These water bodies are known for their rich biodiversity reserves and beautiful refuge for migratory and resident avian fauna. The Kusheshwar sthan, Kabartal, Simri-Baktiarpur and Goga beel of North Bihar are the famous lake area (chaurs) of such type and are known to play very significant role in the over all ecological climate of the area besides performing a host of economic activities(Jha & Chandra, 1997).* The difference between a ox-bow lake and a beel has in described in Table 1.

Classification of floodplain lakes or beels

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

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

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

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

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

B. Physically the **tectonic lakes** of Ganga and Brahamputra river systems can be classified in various ways (Sinha & Jha, 1997 a) such as:

a) based on duration of water retention or **seasonality**

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

b) based on major **bio-production**

i) chaurs with makhana (*Ferox eurryale*), singhara (*Trapa spinosa*), lotus cultivation as major economic activities.
ii) chaurs where fish and fisheries remain the major activity.

Besides the aforesaid artificial or arbitrary classification more pragmatic approach for their classification can also be adopted such as trophocity or boidiversity for better and effective management biological resources thriving therein.

Ecological status of floodplain lakes in India

(*Jha, 1989, 95, 97, Jha and Chandra 1997, Sinha and Jha1997 b, Sugunan, 1995b, Yadava,1989)*

- Dissolved organic matter generally very high in the soil phase indicating constant in-put of vegetative matter.

- Wide fluctuations in dissolved oxygen values, as low as almost nil to as high as 12 mg/l or even more, indicating stressed aquatic regime due to external disposal of wastes on one hand and supper-saturated condition owing to massive weed infestation on the other.

- Water phase generally poor in nutrients as locked in the macrophytic chain.

- Moderate to very high values of conductance depending on effluent load in the system. Systems receiving sewage or other effluens indicate higher values as compared to lakes free from such ingress.

- Phytoplankton primary production poor to moderate indicating impaired abundance of phytoplankton.A typical characteristics of weed infested water bodies.

- The nannoplanktonic assemblage has been found to be much larger as compared to net plankton and dominated by high incidence of bacterioplankton. The phenomenon is a reflection of stressed aquatic regime, manifested by thick stand of macrophytes in such systems besides an indication of broken grazing chain required for healthy propagation of carp fishery.

- The floodplain wetlands of Ganga and Brahamputra river systems are passing through a phase of advanced eutrophication as evidenced from high density of macrophytes, to the tune of more than 30 kg/m^2 at times. Macrophytes of all kinds viz. *Submerged*, *emergent*, *free-floating* and *marginal* have been reported dominating the beels.

- The benthic niche appeared to be worst affected as the solid-liquid interface is either blanketed by the over growth of submerged vegetation or covered under vegetational canopy of floting macrophytes creating a under water desert which in turn inhibit the growth of desired benthic organisms on one hand, while the oxidative- microzones responsible for the release of nutrients in the ambient water are being shielded on the other.

Transfer of energy and productivity potential

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

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

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

The normal grazing chain of floodplain wetlands has been impaired in the face of fast changing aquatic regime of such water bodies. Over colonisation of macrophytes is one factor which may be identified as the destabilizer of the production functions of such systems and making it topsy-torvy. The focus has now been shifted to the huge reserve of detrital load at the bottom and remains largely unutilized in absence of efficient grazers. The present fish yield from the lakes is only a fraction of the total energy fixed at primary or producers level. The floodplain lakes being weed choked in characteristics exhibit very high detrital load, even to the tune of 400-500 gm^2 . The primary production and energy conversion of some such lakes have been presented in Table 2, whereas the values pertaining to mode of transfer of energy is given in Table 3.. The phtosynthetic efficiency of these lakes has been found to be governed by two factors viz. the level of management and the influx of waste materials in the system. It has been observed that the photosynthetic efficiency in case of floodplain lakes of Bihar ranged between 3.26 %(stressed lakes) and 4.86 %(partially managed nonstressed lakes).Based on the the level of primary production, the productivity potential of floodplain lakes in the States of Assam, West Bengal & Bihar has been worked-out in the range of 1000 to 2000 kg ha^1 yr^1. Against this potential, however, the present level of yield ranges between 30 to 300 kg ha^1 yr^1 only leaving behind enough scopes for enhancement of fish yield.

Table 1. Difference between ox-bows and tectonic floodplain lakes

Ox-bow lakes	**Chaurs(tectonic**
1. The outer boundary of the lakes are generally fixed.	The boundary of the lakes are never fixed rather changes with the quantity of water ingress. Large scale swelling during monsoon and considersble srinkage in lean months are the hall-mark of such lakes.
2.Ox-bow lakes are the obstructed bends of rivers as such generally serpentine in physical extension.	Chaurs are not the part of any river and they have no definite physical structure.The physical extention depends on the shape of the depression. However, most of them are generally saucer shaped.
3.The shore-line of ox-bows are invariably straight, being the cut-off portion of rivers.	The tectonic lakes generally represent very irregular and zig-zag shoreline.
4.Ox-bows are relatively deeper than chaurs.	Chaurs are always shallow in characteristics
5. The ingress of riverine water may or may not take place.If connecting channels exists and are functional river water would entre otherwise not.	The topographical distribution of chaurs in floodplains, where occurrence of flood is a regular phenomenon, are such that ingress of flood water is almost certain.
6. Less fluctuation in water spread area coupled with meagre or no intensity in the incoming water provide relatively stable niche for the higher colonisation of aquatic vegetation.	Characteristically the chaurs exhibit very high fluctuation in water extention and the flood water enters in such lakes with greater force and up-root the vegetation to a large extent therby less infested by aquatic vegetation as compatred to ox-bows.

Table 2. Primary production and available bottom energy in certain floodplain lakes of Bihar (Jha & Chandra, 1997)

Lakes	Primary production (mg C m^3 hr^1)	Fixation of Energy (Cal m^3d^1)	Available bottom energy (Cal m^2)
Larail	98.07-154.11	26136	38.66x10^4
Mahisath	75.08-110.0	19988	39.13x10^4
Dabhadih	95.20-103.05	21411	46.29x10^4
Kamaldaha	41.09-190.06	24975	51.26x10^4

Table 3. Transfer of energy in certain floodplain lakes of Bihar (Sinha & Jha,1997b)

Lakes	Status	Primary production to fish (%)	Solar energy to fish (%)
Muktapur	Almost free from external stress & partially managed for fishery	0.1622-0.2408	0.00335-0.01037
Kanti	Highly stressed due to ingress of thermal ash slury. No fishery management	0.1209-0.1873	0.00241-0.009633
Manika	No major external stress. Partially managed for fishery develpment	0.1831-0.3015	0.00463-0.018431
Motijheel	Highly stressed due to sugar factory effluent and city sewage. Partially managed	0.1462-0.2517	0.00251-0.010324
Tarkulia	External stress factor absent. Well managed	0.1843-0.3047	0.00546-0.01

Fishery Management of Beels

The beels are higly productive ecosystem besides the repository of rich biodiversity. The essence of biological productivity is to promot the human welfare both in terms of quality and quantity of food. The floodplain lakes such as beels are known for lucarative fishery since their origin besides such water bodies have many other usage. In recent years, however, impairment in production functions has been affected with the increased man induced interferences. Presently, the floodplain natural lakes have developed chronic symptoms of aberrations and are reeling under the threats of swampification. The lakes have not only been brutally assaulted at the hands of various user groups but these have been reclaimed for arable lands. Over growth of macrophytes and other producers has further compounded the already over exploited systems to the extent that the processes of eutrophication has set-in firmly. The lakes are generally dominated by small fish and minnows with multiple breeding annually resulting which the prized carp population has gone down to a alarming level. The fishery management of lakes needs urgent attention whrein stringent regulatory norms can be applied. The management of fishery should aim at sustainable production from these systems at the same time care must be taken not to disturbing the existing biodiversity. The following steps may be required to rehabilitate the depleted fishery of these ecosystems.

- Clustering of lake types for effective management.
- Upgradation of fishing gears and elimination of destructive ones to protect the biodiversity in general and fish germplasm in particular.
- Effective management of macrophytes so as to provide conducive environment for fish growth and development.
- Proper stocking of the lakes with suitable fish species besides making efforts to rejuvenate the processes of auto-stocking fro riverine source.
- Proper utilization of existing food chain and the available benthic energy.
- Introduction of fish husbandry like pen culture

Recommendations

The management of beels for getting sustainable fish production and to conserve the existing biodiversity need a holistic approach of resorce management such as :

- exploitation of biotic resources must be rational.
- to understand & halt the processes of habitat degradation identification of causative factors is a must
- the level of peoples participation in the conservation of the resources must be increased by making them aware of the importance of beel ecosystem.

- introduction of scientific and technical know-how in the mangement of beels.
- proper synthesis of endemic fish germ plasm and stocking material is a must for sustainable fishery development.
- effective propogation of fish husbandry like pen and cage culture in large scale.
- making the cooperative societies more responsive and responsible in tune with the environmental facets and conservation norms.
- strengthening of credit and subsidy schemes to make the fishery activities sustainable and economically viable.
- strengthening the mechanism of technology transfer for holistic fishery development.
- stringent regulation prohibiting destructive fishing practices.
- strict adherence to environmental laws with regards to point & nonpoint sources of pollution.
- extention of Insurance scheme in fisheries sector also to instil confidence amongst fisher community with regards to investment.
- prioritisation & rationalisation of water use for varios activities for sustainable economic gain.

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CAGE/PEN CULTURE PROSPECTS IN RESERVOIRS AND BEELS-SUCCESS AND CONSTRAINTS

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Introduction

India is one of the richest countries in the world in terms of reservoir and lake resources of water. With more than 3 million hectares of reservoirs, 2 lakh ha of floodplain lakes and 42,000 ha of estuarine wetlands (bheries) there is ample scope for developing culture-based fisheries and various forms of enhancements (Table 1). The current utilization of culturable water bodies is just 22%. Even after a 50% level of utilization, the contribution from aquaculture will not exceed 1.24 mt by the turn of the century. In freshwater sector, which includes both fisheries and aquaculture, the country has set a target of 4.5 million t fish for 2000 A. D.. The country has to depend mainly on inland fisheries resources for fish yield optimisation. The fish production from inland waters increased from 0.22 million tonnes in 1951-52 to 1.70 million t in 1991-92. But still the per capita availability of fish in the country remains at 3.2 kg against a world average of 12.1 kg. Average production from reservoirs is c.15 kg/ha/yr while the production potential is 50-300 kg/ha yr. Likewise the present yield of oxbow lakes and bheries are 160-200 and 770-1360 kg/ha/yr respectively while their yield potential is about 1000 and 2000 kg/ha/yr respectively. In reservoirs, priorities of water use are given to power generation, irrigation and other types of water abstraction. In wetlands, extensive flood control measures and irrigation works have reduced fish production levels through siltation, habitat destruction and heavy weed infestation. While eutrophication, heavy weed infestation and accumulation of bottom muck continue to be the major problems, indiscriminate killing of brood fish during recruitment phase also is a threat to fishery in these water bodies. Under such conditions, mitigation measures should be taken for the optimal development of fisheries. Pen culture and cage culture get importance under such situations.

Pen and Cage Culture

Pen and cage culture are adopted as a part of the management measures for enhancement of production of table fish as well as seeds for stocking. The main aim in developing reservoir/wetland fisheries is to (i) increase animal protein supply and (ii) employment or income of the rural population. Through regular stocking only species as well as production enhancement are achieved. This is in other words explained as culture based capture fisheries.

Role of pen and cage culture in reservoir fisheries

Fry or fingerlings for stocking reservoirs were usually purchased from state cooperative farms or from private agencies. Certain reservoirs have their own hatcheries and rearing ponds. Shortage of available land for ponds in the immediate vicinity of a reservoir can be overcome by rearing seeds in net cages in the main water body relying on natural food production. The mortality of seeds during transportation also can be avoided if the stocking materials are reared in the main waterbody itself. Floating net cages would be more useful and suitable for deeper reservoirs and lakes where water level fluctuation [illegible] are dominated by [illegible] cage or pen culture might be the only alternative practice in raising [illegible] yields (Bhukaswan, 1980). The raising of stocking materials as well as table [illegible] net cages. They recommend 0.7 to 1.5 cm mesh size for raising fingerlings, the size of cage was from 20-40 m^2 and the stocking density was 200-500 fry/m^2 depending on the availability of natural food. For low nutrient reservoirs the stocking density was 150 fry/m^2 (Lu, 1986). The common candidates for cage culture were grass carp (*Ctenopharyngodon idella),* common carp (*Cyprinus carpio)* and tilapia *(Oreochromis niloticus* and *O. mossambicus)* with either supplementary feeding or complete feeding. The carnivorous fish *Simperea chuatsi* had been cultured as table fish in cages completely on artificial diet (Huang, 1988). This practice had become a very popular means for increasing fish production and income. The culture of tilapia in cages yielded 28,546 kg of fish averaging 95.2 kg/m^2 (Lu, 1992). In another instance, the total output of grass carp, Chinese bream and tilapia in net cages was 12,520 kg accounting for 19.7% of total yield of cultured fish in the reservoir.

In Nepal warm water carp production has been very successful with cage culture of silver carp and big head carp in lakes of the Pokhara Valley now being pursued by 200 out of 300 low income families (Anon, 1988). In Southern Africa, cage culture is not so popular. But in Mazvikadei dam some cages were tried. Because of crocodile problems the cages were made of wire mesh. *Oreochromis niloticus* was stocked with 50 g fingerlings at a density of 235/m^3 and harvested after 180 days with a weight of 250 g each (Marshall and Maes, 1995).

In India cage culture of fishes had been successfully carried out in Veeranam lake and in Poondi reservoir of Tamil Nadu (Sreenivasan, 1986). However, pen farming is more popular in India. Pen is always a fixed structure with the bottom is opened, facilitating the stocked animals to utilize the food available at the bottom. At Poongar fish farms in Bhavanisagar, pen rearing of early fry to fingerlings had been practised very successfully (Sreenivasan., 1986).

Role of pen and cage culture in floodplain wetlands (beels)

Pen culture was adopted by China as early as in 1950s for rearing carps in freshwater lakes. Between 1968-70 it was spread to the Philippines for the rearing of milk fish (*Chanos chanos)* in the Laguna Lake. Pen culture is practised in commercial basis in the Philippines, Indonesia and China. The principal species being cultured in these countries according to Beveridge (1984) are milk fish, and carps like grass carp (*Ctenopharyngodon idella),* bighead carp *(Aristichthys nobilis)* and silver carp (*Hypophthalmichthys molitrix).* Some experimental pen culture of carps have been conducted in ox bow lakes in Hungary also.

In India, there are c 2 lakh hectares of beels (Table 2). Almost 50% of the beel area is in the State of Assam followed by West Bengal and Bihar. As a part of management measures for this resource pen culture is fast growing popularity. As early as in 1981 pen culture experiments were conducted by CIFRI in Assam and later in Bihar. A production of 32 kg/20sqm was achieved at Rs. 3.84/kg production cost in Assam. In the ox-bow lake of Gandak Basin (North Bihar) a production of 300 kg/ 6 months with species ratio of catla 7: rohu 12: mrigal 6 was achieved through pen farming in the year 1985-86. In the beels of West Bengal also the experiments were carried out and successfully demonstrated in Akaipur beel with giant freshwater prawn. The freshwater prawn *Macrobrachium rosenbergii* was successfully cultured in pens erected in Akaipur beel. The prawn grew from 4 g to 90 g (av.) during a culture period of 87 days. At present this technology is getting momentum as a part of enhancement of production in beels. Pen culture for brackishwater species especially for prawns *Penaeus monodon* and *P. indicus* was initiated in Kille backwaters of southern India by Tamil Nadu Fisheries and FAO, Bay of Bengal Programme. It was proved that three crops could be raised in a year (Sreenivasan, 1986).

Advantages of pen and cage farming

Although the initial costs of cage and pen culture may be considerable, their operational costs are relatively low. The advantages of pen and cage culture as described by Balarin and Haller (1982) are listed below:-

1. Put no pressure on the land
2. Better utilization of water area
3. Fish production is intensified
4. Optimum utilization of artificial feed for growth
5. Competitors and predators are easily controlled
6. Daily observation promotes better management and early detection of disease or other problems.
7. Fish handling and mortality is reduced
8. Harvesting is easy and flexible.

In Malaysia and Singapore, the culture and harvesting of planktivorous species is said to clean up eutrophic waters (Beveridge, 1984).

Disadvantages of pen and cage farming

There may be some detrimental environmental effects of enclosure cultures. Intensive culture of fishes in cages with feed and fertilization leads to eutrophication of the water body. When large number of cages and pens are constructed without taking care of the carrying capacity of the water body dissolved oxygen level may be decreased which causes mortality of the animals. According to Balarin and Haller (1982) the disadvantages of cage or pen farming are:-

1. Affect by rough weather
2. Adequate water exchange through cages is not there
3. Rapid fouling necessitates frequent cleaning
4. Absolute dependence on artificial feeding and the food is easily lost through the cage/pen walls.
5. Small fish from outside can enter and compete for food or can introduce diseases.
6. Poaching is easy
7. Labour costs are relatively high
8. Blockading the spawning areas of wild fishes.

There is a general feeling that the pen or cage constructions will interfere with free navigation through the water body. In south Asian countries reservoirs are not generally used for navigation. While doing site selection for cage/pen construction, this point can be taken care in case of wetlands. Loyacano and Burch (1976) have shown that cage culture of fish had no impact on water quality. In Udawalawe reservoir in Sri Lanka, Sreenivasan (1986) also observed that the culture of *O. nilotius* had no adverse effect on water quality of that reservoir. However, deterioration in water quality during enclosure culture is reported by Beveridge (1984).

Conclusion

Keeping all the advantages and disadvantages, a cautious approach in pen and cage farming can give very positive results. Major constraints are the poor understanding of the limnological and biological situation of each water body and the lack of technical knowhow of enclosure cultures. Blind adoption of a successful technology can be a problem than profit.

Table 1. Inland water resources of India

River length (km)	29,000
Irrigation canals (km)	120,000
Floodplain lakes (ha)	202,213
Upland lakes (ha)	72,000
Reservoirs (ha)	3,000,000
Estuaries, mangroves, backwaters, and brackishwater lagoons (ha)	6,000,000
Estuarine wetlands (ha)	50,000
Brackishwater aquaculture areas (ha)	12,00,000
Freshwater ponds (ha)	22,54,000

Table 2. Oxbow lake resources of India

States	Area (ha)
Arunachal Pradesh	2,500
Assam	1,00,000
Bihar	40,000
Manipur	16,500
Meghalaya	213
Tripura	500
West Bengal	42,000
Total	2,01,713
Present level of yield	160-200 kg/ha/yr
Production potential	1,000 kg/ha/yr

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STATUS OF RIVERINE FISHERIES IN INDIA

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Introduction

Rivers have played an important role in the development of human civilization by providing water food transport and recreational activities. But at the same time human race irrationally exploited riverine resources together with their floodplains and had drastically altered them to save the urban areas and production systems. On account of this cultural eutrophication only a few large rivers system of the world retain their original functional integrity and many have probably lost much of their capacity to adjust and recover from severe perturbation. Rivers degradation is one of the most striking manifestation of the human failure to utilize renewable resources without deterioration of their natural basis. When we examine the status of Indian rivers in the above context, it repeats the story of misery of mismanagement. Most of the Indian cities which are situated on the river's bank discharge their wastes into rivers, thus polluting the aquatic ecosystem by degrading water quality and exerting stress over its inhabitants. On account of this, the most of the rivers have lost natural purity of water as well as its biodiversity. Even, fish production is continuously declining along with alteration of plankton, benthos and fish population in favour of pollution resistant species followed by gradual increase in bacterial load. These are the well established symptoms of deterioration of water quality of the rivers.

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 river system of the country has a total length of 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 (Table 4). Perusal of the Table 4 reveals that a general decline in fish production is perceptible from 1958 to 1989-1995 on all the centres for which data is available. 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 centres is depicted in Table 2.

Decline in Hilsa Fishery : The commissioning of Farakka barrage in 1972 caused an adverse effect on hilsa fishery, being migratory in nature. In pre-Farakka period (1958-74), 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 [illegible] dwindling of their population.

[illegible] Allahabad was 21.33 during [illegible] during 1980-86 and 15.19 Kg ha^{-1} during 1989-93. But only 13.29-15.74% 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 (Table3). Thus, in general the fish yield potential is unadequately utilized in all the sectors leaving scope for further improvement. The potential fish yield of some of the important rivers based on physiographic characteristics is depicted in Table 1.

Brahamaputra River System : The Brahamputra [illegible] originates from a glacier (Kubiangiri) in Tibet and had a combined length [illegible] including its tributaries. The geological nascent state of Himalaya [illegible] this river originates has substantially contributed to the high silt in [illegible]. 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 teritory 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 CICFRI, 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 cat fishes 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 exploitatin of brooders (ujaimara activity) and as well as of juveniles. Domination of miscellaneous fishes over quality fish indicates symptoms of Pauly's ecosystem over fishing syndrome similar to Ganga river.

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: brown trout (*Salmo trutta fario*), rainbow trout (*S. gairdneri*), mahseers (*Tor tor, T. putitora*), snow trouts (*Schizothorax* spp.) certain cyprinids (*Labeo dero, Gara gotyla*); loaches (*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 : *Shizothorax* spp., *Labeo dero, L. dyocheilus, Crossocheilus latius, Puntius conchonius, Cyprinus carpio (C. communis and C. specularis)* loaches and *Glyptothorax* spp.

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

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 headwaters harbour 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 consist 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 existant 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 these rivers which has altered the ecology of these rivers. 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, whcih is rocky and unaccessible. According to a report (1963) about 91 to 136 kg of fish was caught in the river at Vijaywada. No informaiton 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. silondia*. 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 tonneswas 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) obliteratiing 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 dependance 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 regulartory 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.

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				
Godavari	1465	0.31	5936	6364
Krishna	1401	0.26	5434	5365
Cauvery	800	0.09	1791	1917
Mahanadi	880	0.14	2088	2943
West coast rivers				
Narmada	1312	0.10	4844	2124
Tapti	720	0.06	1454	1294
Mahi	533	0.02	802	446

(After Khan and Tyagi, 1996)

Table 2. Estimated mean annual landings (metric tonnes at different centres

Centres	1958-59 to 61-62	62-63 to 65-66	73-74 to 76-77	77-78 to 80-81	81-82 to 85-86	1989-93
Allahabad	183.73	230.60	111.48	147.78	163.5	72.66
Buxar	91.53	40.10	12.74	14.43	25.65	-
Bhagalpur	77.01	86.85	73.37	97.63	97.45	-
Patna	-	108.86	-	-	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 transfor-mation $calm^{-2}$ day^{-1}	Photosynthetic efficiency %	Fish production potential $kgha^{-1}$ yr^{-1}	Actual harvest kgh^{-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
	1987-88	730.5	5906	0.316	208.70	28.69	13.74
Varanasi	1987-88	589.1	3243	0.173	112.20	-	-
Patna	1987-88	293.0	3534	0.190	122.40	30.84	25.19
Bhagalpur	1972	-	3586	0.186	120.68	31.64	26.30
	1987-88	420.0	4124	0.220	142.80	36.75	25.73

(After Jhingran & Pathak, 1988)

Table 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

STATUS OF ESTUARINE FISHERIES IN INDIA.

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The geographical area of India is about 329 million hactares and its coast line stretches to nearly 7,000 km. The climate ranges from temperate to arctic in the Himalays, to tropical and subtropical in its Indo-Gangetic plains and the peninsular region. The vegetative cover is rich and of a varied type, consisting of all kinds of forests and a vast expanse of grasslands, each with its teeming millions of fauna characteristic of these habitats. Though the area of the country is only about 2% of world`s total landmass, India harbors as much as 5% of all known species of animals and plants and is endowed with a vast expanse of open inland waters in the form of rivers , canals, estuaries, natural and manmade lakes, backwaters, brackishwater impoundments and mangrove wetlands. Most of the major cities and harbours in the world are located on estuaries, and for many people estuaries represent their nearest available biological habitat.

FISHERIES RESOURCE POTENTIAL

The major estuarine systems on the east coast of India are constituted by the river Ganga in West Bengal (the Hooghly-Matlah estuary), the Mahanadi in Orissa, the Godavari and Krishna in Andhra Pradesh and the Cauvery in Tamil Nadu. The other important estuarine fishery resources on the east coast are the Chilka lake in Orissa and the Pulicat lake in Tamil Nadu. Besides, the coast line of India runs to an estimated 6,900 km. of which about 50% lies on the east coast supporting a fishery in shallow coastal waters and in the continental shelf.

COASTAL FISHERIES

Annual marine fish production from the East coast during 1978-79 was estimated to be about 3,54,516 t, during 1981-82 and 1985-86, it accounted for 3,95,063 and 4,22,791 t respectively indicating thereby an increase by 7 to 11% over the production during 1978-79.

Among the maritime states on the East coast, Tamil Nadu alone contributred about 2,17,394 to 2,21,296 t forming about 55% of the east coast fish catch. The State of Andhra Pradesh has its share of 1,16,013 t to 1,16,143 t, about 30% of the total catch, and the rest, 15% came from the States of West Bengal, Orissa, Pondichery and the Andaman and Nicobar Islands.

The coastal fisheries of the State of Tamil Nadu(including Pondichery) ranked third in the country. The major fisheries of this region are of Leiognathus spp. Gazza sp., sardines, elasmobranchs, ribbon fishes and carangids. The other important groups contributing to the fisheries are Sciaenids, perches, catfishes and prawns. Since midseventies mechanised crafts have maintained a steady rate of yield. Fisheries of nonpenaeid crustaceans, crabs and that of molluscs are equally important in the coastal waters of Tamil Nadu and Pondichery.

Andhra Pradesh ranks fifth in marine fish landings. Sardins account for about 17% of the catches, followed by elsmobranchs, prawns, Leiognathus sp., catfishes, other clupeids and sciaenids. Mechanised fishing is done in a limited scale in Andhra Pradesh and account for only about 10% of the State`s marine fish landings.

West Bengal and Orissa, though have large coastal belt and shelf area, contribute comparatively less in the east coast fish yield, largely due to lack of good fishing grounds, low mechanisation and distances of fishing grounds from the shore bases. The abundance of fish stocks is also believed to be poor and even these pertain to low priced species. This coastal zone of Bay of Bengal has phenomenal Hilsa ilisha fisheries which alone contributes about 8-11% of the total fish landings. Catfishes,elasmobranchs, sciaenids, saurids and sauras, pomfrets, non-penaeid prawns and miscellaneous fishes also showed higher catches in recent years after the introduction of mechanised botats and improved nets.

A multispecies fishery mainly dominated by perches, caranx, anchovies, mullets, seer fish and elasmobranches exists in the coastal area of Andaman and Nicobar islands. The mechanisation of crafts and introduction of improvised nets have boosted up the landings in recent years, and the total yield of 28-39 t recorded during 1974 to 1976 has gone upto 1,802 to 1,803 t in 1981 and 1982 respectively.

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 hydrological conditions unconducable for breeding migration of the species to the freshwater zones of these estuarine systems. Monsoon catch of H. ilisha alone contributes 70-80% of the total annual landings of the species in Hooghly as well as Mahanadi estuaries. The landings of H. 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 in Cauvery, 53 t/y in Hooghly and 1.5 to 4.2 t/y in Adyar estuary respectively. The dominant species are M. cephalus, L. parsia, L. cunnesius, M. speigleri, M. dossumeri, L. troshelii and L. oligolepis. Other than mullet and H. ilisha the commercially important species of fishes in the east coast estuaries are Setipinna spp., P. pama, Trichiurus spp., Coilia spp., T. jella, Ilisha spp., Sillago spp., Leiognathus spp., Lutianus spp., H. nehereus, Poluynemous spp., Lates calcarifer, pomfrets etc. These species of fishes are unevenly distributed in this estuaries. About 150-168 species of fin fishes are available in the estuaries of the east coast region.

Prawns comprising mainly M.monoceros, P.indicus, P.monodon, M. dobsonii, M. affinis, and M. brevicornis, L. styliferus and P. sculptilis are also equally important in the estuarine annual landings. Godavari is favoured with maximum prawn catch, about 5,000 t/yr. followed by Hooghly (85.7 to 1799 t/yr). Cauvery (90 to 98 t/yr.) and Mahanadi (16 to 30 t/yr.), and Adyar estuary yields minimum prawn (2.1 to 3.8 t/y) from the system.

FISHERIES OF HOOGHLY ESTUARY

The estuarine system pertaining to Ganga river in West Bengal (Hooghly-Matlah estuaries) has unique faunestic characteristics. Pantulu and Bhimachar (1964) classified the Hooghly Matlah estuarine fauna into residents and transients or migrants. Generally, speaking 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, Polynemous paradiseus, Sillaginopsis panijus and Pama pama.

2 Freshwater species which spawn in saline area viz. Pangasius pangasius and the prawn Macrobrachium rosenbergii and

3 Marine forms coming to saline zone of the estuary for breeding like Arius jella, Osteogneiosus militaries, Polynemus indicus and P. tetradactylus.

The three salinity zones demarcated on the basis of chloride concentration as Zone I (Freshwater zone), Zone II (low saline), Zone III (High saline zone) yield significantly different fish catches so far the quality as well as quantity is concerned. The upper freshwater (Zone I), and middle 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 loike H. nehereus, Arius jella, Osteogeneiosus militaries, Polynemus indicus, P. tetradactylus, Coilia spp., Plotosus canius, Sciaena miles, 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 Polynemous 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 comprises 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 P. monodon, M. brevicornis, M. monoceros, P. indicus and L. styliferus.

On special importance in the Hooghly-Matlah estuarine system is the practice of so called migrating fishing activities during the winter 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 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 of effort obtaining in the upper and lower reaches during the whole year. Uniquely, bag net landings alone contribute to 42 to 80% of the whole estuarine 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.

THE MAHANADI ESTUARINE FISHERIES

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, the mullets, thread fins, perches, sciaenids, and cat fishes 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.

FISHERIES IN OTHER ESTUARINE SYSTEMS

The estuaries in south east coast of India are characterised by very low tidal ingress restricting to 30-40 km upstream. The species varients are also not much in these estuarine systems. As already have been told the marine and neritic species of fishes are the main contributors in the landings. Among these groups of estuaries, Godavari has an unique feature for its fisheries where prawns viz. M. monoceros (42.9%), P. indicus (24.5%), P. monodon (10.9%), M. dobsoni (3.9%), M. affinis(3.6%), M. brevicornis (2.0%) contribute 5000 t per year.

PRODUCTIVE POTENTIALITIES OF EAST COAST ESTUARINE SYSTEM

The average rate of production from the estuarine systems mixing Bay of Bengal in east coast range between 25.5-114.1 kg/ha (avg. 58.7 kg/ha) with minimum in Adyar estuary in Tamil Nadu and Maximum in Godavari estuarine system in the State of Andhra Pradesh. However, the production rate in Hooghly Matlah estuarine system though stands slightly below the average level (46.0 kg) because of its huge water spread area the maximum estuarine landing comes from this system alone (80%).

CHILKA LAKE FISHERIES

Chilka lake has a rich faunestic population comprising 152 species of fin fish (Annandale and Kemp and others 1915-24 ; Chaudhuri, 1916, 1917 & 1923 ; Hora, 1923 ; Koumans, 1941 and Roy and Sahoo, 1957) and 21 species of prawns (Kemp, 1915).

The rising trend in the annual yield from the lake continued from late forties till early fiftees and thereafter a gradual decline in the catch was observed with minimum landings during early sixties. This decline in Chilka fisheries was investigated by the then CIFRI and the suggestive measures were recommended along with the possible reasons behind the short fall in annual turn over from the lake (Jhringran and Natarajan, 1969).

Fisheries of the lake mainly comprise mullets, (*Mugil cephalus*, *M. macrolepics*, *L. parsia*), Cat fish (*Mystus gulio*), thread fins (*Polynemus tetradactylus*), Perches (*Lates calcarifer*), hilsā (*Hilsa ilisha*), *Nematolosā nasus*, *Gerres setifer*, *Pseudosciaena coibor* and prawns (*Penaeus monodon*, *P. indicus* etc.). Percentage composition of the species in annual yields during 1957 and 1965 indicates mullets to be the most important group of fishes followed by catfishes, threadfins, perches and so on. Contribution of different species of prawns to the lake fisheries is also significant.

Fisheries of the Chilka lake are exploited by means of (i) net fishing, (ii) large impoundments constructed by split bamboos in shallower region, locally known as "Janos" and (iii) traps. Net fishing contributes 50-66% of the annual catch of the lake. As good as 112 janos are constructed every year in the lake and between 13% and 22% of the lakes fish yield is accounted by them. It is interesting to note that 80% of the `jano` catch is contributed by mullets like *M. cephalus* and *M. macrolepis*. Traps are mainly used for catching prawns and these fishing tools alone account for 19 to 32% of the total fish production of the lake.

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Methods of project appraisal of aquatic production systems in Indian scenario

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A sound and effective plan for national development depends upon a number of appropriate investment projects, which are viable to contribute to national economy. A poorly identified and prepared project often slows down the developmental process. All the countries have various types of resources, which have alternate uses in different sectors and sub-sectors of an economy. To keep the ball of growth and development of a country rolling at its fastest pace, it is emergent to clearly define the developmental priorities and accordingly allocate the limited resources among projects belonging to different sectors. The aquatic resources of India are abounding. Since independence, much has been achieved towards increase in production and productivity of these aquatic production systems. But, lot is yet to be done. With financial stringency and broadening horizon of fisheries research, the process of selection of worthy projects becomes increasingly important. It should be in concurrence with national fisheries development objectives and policies. The appraisal of the projects forms a crucial and integral part of this selection procedure. The sequence of fisheries project planning and implementation involve many steps, which collectively form the fishery project cycle. Before going into depth of project appraisal, it is necessary to understand the basic concepts and steps involved in this project cycle. These include concept, definition, identification, preparation, appraisal, negotiations and supervision of the project. Although, the main emphasis of present chapter is on methods of project appraisal, but to have more clarity other concepts of project cycle are also touched upon in very brief. These concepts can be applied to projects belonging to different enterprises including fisheries and aquaculture.

Project concept

Most crucial part of project cycle is the very concept of project. Project ideas are generated at this stage. The project concept should essentially be aimed to express the country's fisheries development objective. It means that the project ideas should be based on thorough understanding of country's fishery development objective, its resource base, and an assessment of options encountered by the fisheries sector of our country.

Definition

Several research workers defined the term project in different way depending on their situation. But few of the most accepted definitions are mentioned below.

Gittinger defined agricultural project as an investment from which we can expect to realize benefits over an extended period of time.

FAO defined the production project as a proposal for investment with the definite aim of producing a flow of output over a specified period of time.

These definitions tie investment activities to benefits suggesting almost a passive relationship. In contrast we see a project in a much dynamic context. So, in the present scenario it may be defined as an instrument of change:

Project is a coordinated series of actions resulting from a policy decision to change resource combinations and levels, so as to contribute to the realisation of the country's development objectives.

This definition first forces the fisheries project planner to set the project's objectives with in the framework of country's fisheries developmental priorities and second, to ask probing questions about what is to be changed, the reasons for change, and the strategy for implementing change in fisheries sector.

Project identification

The thrust of project identification is to delineate main outlines of the project and to establish overall viability of project proposal. The overall viability implies ability of the project to meet the standards put forth by the government or lending institution. The project's output must be technically, financially and economically viable.

The major steps in identification process are:

- evaluation of present scenario for fisheries in India;
- identifying relevant fishery policy issues;
- establishing the fishery project's rationale;
- developing design and concept of fisheries project;
- setting the scale of fisheries project;
- preparing cost estimates and benefits of fisheries project;
- proposing the organisation and management structure of fisheries project; and
- spelling out the further work requirements.

Project preparation

The process of project identification should establish sufficient justification to proceed to next stage of project preparation. This can be a costly and time-consuming process, particularly, for more complex projects involving number of fisheries sub-sectors. The end result of preparation is a feasibility study which forms the basis for financing institution to decide about going ahead to appraise the project. The nature and content of such a feasibility study will vary according to type of fisheries project.

Project appraisal

The funding agency of the project generally conducts the project appraisal, as an independent check. It generally implies an activity undertaken by an external agency, but local or domestic may also undertake their own appraisal depending upon the available expertise. In practice, appraisal does cover much of the same ground as that of identification and preparation, but there are specific areas, mainly involving project financing, that receive special emphasis. Appraisal tries to establish that the major assumptions in project formulations are, in fact, correct and realistic. Technical assumptions relating to yields, project cost estimates and assumptions relating to economic and financial viability of the project would be checked. The administrative feasibility is checked through reviewing the proposals for organisation and management. Appraisal must establish that project has satisfactory economic rate of returns. This part is dealt in detail particularly for economic feasibility.

Project negotiations

The negotiations permit the representatives of both the financing agency and project submitting agency to defend their respective positions regarding various policy issues that are related to execution of fishery project. The end result of loan negotiations is drawing up of a set of loan documents.

Project supervision

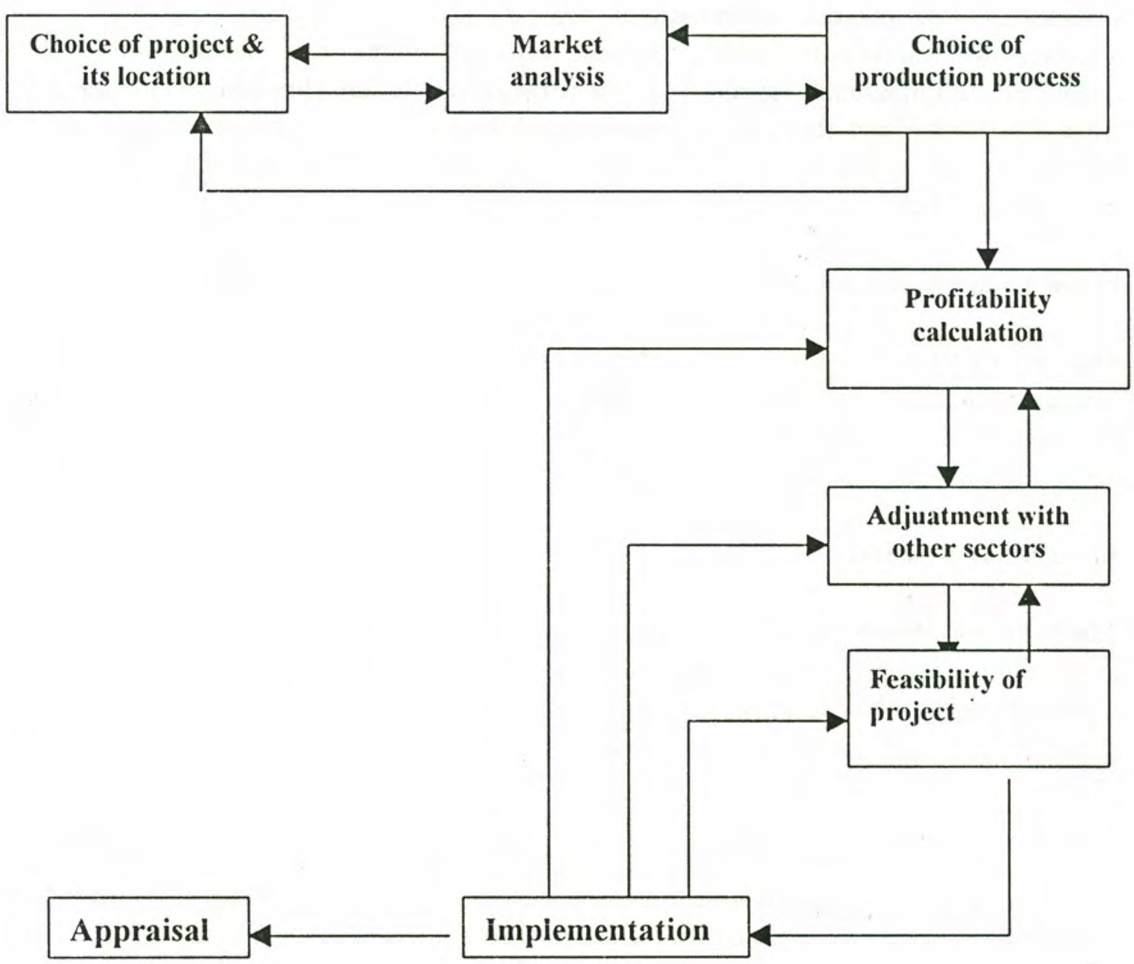
The purpose of supervision is to ensure that the project implementation is carried out to acceptable standards, and project targets are being realised. This entails a review of progress reports. An important spin off of the supervision is that at sometimes it generates repeater projects, which are really follow up phases of previously financed projects.

The general steps involved in project cycle are also depicted in figure 1. It indicates that in project cycle the steps may be repeated again and again during formulation to have a better preparation and justification of the project.

Methods of project appraisal

The exercise of project appraisal largely depends on environment of the project in which it is to be implemented. It includes the national priorities and targets; and sector and enterprise to which it belongs, i.e. private or public and industry, agriculture, fisheries, etc. Accordingly, based on the priorities and objectives, appropriate weights would be assigned to respective projects. This forms the pre-requisite for the economic appraisal. There is no one best technique for estimating project worth. These measures are only tools of

Figure 1. Steps in project cycle



decision making. There are many non-quantitative and non-economic criteria for making project decisions. The usefulness of these analytical techniques is to improve decision-making process and not to substitute for judgement. In economic terms the process of project appraisal mainly concentrates on economic feasibility analysis, when it is used for private sector it is referred as financial analysis. There are several measures to appraise and compare the economic feasibility of investment in projects. These may be classified into

A) Non-discounting measures
B) Discounting measures

A) Non-discounting measures

These measures generally do not consider time factor. So, the cash flow for expenses and returns is not analysed over time. These measures include

1. Urgency

According to this criterion projects of greater urgency, get priority over other less urgent projects. It can be used for socio-economic and the projects with less investment. But, it is not possible to rank the project, which are production based and involve larger investments.

2. Ranking by inspection

By appraisal of costs to be incurred in a fishery project and returns anticipated as the output, the projects can be ranked. In this method net incremental productivity (NIP) or net returns are calculated as follows

NIP or net returns = value of incremental production - (operating cost + maintenance cost + production cost).

The projects can be ranked according to value of NIP. But, it is distributed over more years. Some projects may have higher NIP but take longer period, which is a disadvantage. The projects with maximum net returns in earlier years may be preferred. It is because higher risks are involved in case of longer period projects.

3. Pay back period

This measure provides a rudimentary measurement for appraising an investment. It simply estimates the time required to recover the initial investment out of the expected earnings from the investment before any allowances for depreciation. It may be estimated as

$$T = \frac{C}{E}$$

where T = payback period (years)
C = initial investment cost
E = average annual profits expected from the investment before depreciation.

The major limitations of this measure are

i) it does not account for profits realised after the capital recovery period; and
ii) it fails to consider the timing of expenditures and incomes.

This is generally used in high-risk conditions.

4. Average rate of returns

The average annual return of an investment is computed by following formula

$$R = \frac{E}{C}$$

R = average annual rate of returns
E = average annual profits expected after depreciation
C = initial investment

Like pay back period, this measure also fails to consider the crucial time factor of earnings and expenditures. So, this method should be considered as a preliminary indicator of returns on investment or for comparing projects, whose time profiles of expenditures and earnings are same.

B) Discounted measures

Whether we are concerned with the financial appraisal of a project or with its wider economic and social implications, it is useful to have a single value, which reflects all of the costs and benefits of the project. It is generally accepted that the most appropriate measures of the kind known are discounted cash flows (DCF). The costs and benefits of a project are normally spread over a number of years. In order to obtain a single measure, which indicates the profitability of the project, a method is needed for putting costs and benefits, which occur at different points of time on a comparable basis. It is possible through discounting measures.

Discounting

Before going to the discounting measures it is pertinent to be familiar with the term discounting. Suppose one is offered the choice of receiving Rs100 today and receiving the same sum in a year time. It will be rationale to receive the money today for several reasons. To begin with, one may expect the inflation to reduce the real value of Rs100 in a year time. Even when there is no inflationary effect (say, where offer is made in real terms), it would still be preferable to take the money today and invest it at some rate of interest, say r, hence receiving a total sum 100 (1+r) at the end of the year. Even if no investment opportunities are available, such as might be true on a desert Island, one might justify his preference for today on the ground that there is a finite risk of not being around to collect the money next year. Moreover, it is sometimes argued that even while inflation, investment opportunities, risks are ignored, there is some thing called 'pure time preference' which would lead one to prefer immediate. Otherwise we need to find the present worth of a future value. This process is called discounting. It is reverse of compounding, where the future worth of a present value is determined. The interest rate assumed for discounting is the discount rate.

Mathematically compounding is expressed as

$$A_t = A_0 (1+r)^t$$

where, r = interest rate,
A_0 = present value, and
A_t = value after t years.

By reversing the process, we get

$$A_0 = (1+r)^{-t} A_t$$

which is the discounting formula. The factor $(1+r)^{-t}$ is called the discounting factor.
Here we have used a single discount rate assuming the time value falls at a constant rate. It can be done at a variable discount rate as well. Three features of present value should be borne in mind:

i) present value is always less than the nominal value that occurs in future;
ii) longer the delay in realising some nominal value, the less is its present value; and
iii) higher the discount (interest) rate, the lower the present value.

The general formula for the present value of a series which is spread over n year is:

$$\sum_{t=1}^{n} \frac{A_t}{(1+r)^t}$$

Four discounted measures are most frequently used to appraise fisheries and agricultural projects. These are net present worth (NPW), internal rate of return (IRR), benefit-cost ratio (BCR) and net benefit investment ratio (NKR). The arithmetic of these discounted measures is exactly the same whether we are using them for financial analysis or for economic or social analysis and for any of the aquatic production systems, i.e. capture or culture fisheries.

1. Net present worth (NPW)

The most straightforward discounted cash flow measure of the project worth is NPW. This is simply the present value of the incremental net benefit or incremental cash flow stream. Consider an aquaculture project, earning a gross benefit stream. After deduction of capital investment and operating costs of machinery, fertilizers, fish seed, fish feed, hired labour, management, consultants, etc. from this gross benefit stream the residual is the net benefit stream. Deducting the without project net benefit gives the incremental net benefit stream. These streams are commonly called cash flows.

The calculation of net present worth requires the determination of an appropriate discount rate. For financial analysis, it is usually the interest rate at which the entrepreneur is able to borrow money from banks. For economic analysis, it is the opportunity cost of the capital. For social analysis, it is accounting rate of interest or consumption rate of interest, which is usually lower than the discount rates used in financial and economic analysis.

Mathematically,

$$NPW = \sum_{t=1}^{n} \frac{(B_t - C_t)}{(1 + r)^t}$$

where B_t represents benefit and C_t cost in year t and r is the discount rate.

Obviously, the same result can be obtained by discounting each cost and benefit streams separately and then adding together present value of each series treating costs as -ve benefits.

The criteria for net present value measurement is that

If $NPW > 0$, the project has +ve incremental net benefit stream, it is profitable

$NPW < 0$, the project has -ve incremental net benefit stream, it is not profitable

$NPW = 0$, the project has no incremental net benefit stream, it is at a break even situation

2. Benefit cost ratio (BCR)

A second discounted measure of project worth is benefit cost ratio. This ratio is obtained when the present worth of the benefit stream is divided by the present worth of the cost stream and represented by formula:

$$BCR = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+r)^t}}$$

The benefit cost ratio was first of the discounted measures of project worth that became well known. The formal selection criterion for BCR of project worth is to accept project with ratio 1 or greater, where costs and benefit streams have been discounted at opportunity cost of the capital. Among the alternative projects, the project with highest BCR ratio would be preferred. One convenience of the benefit cost ratio is that it can be used directly to note how much costs could rise without making the project economically unattractive.

3. Internal Rate of Return (IRR)

In case of NPW and BCR one may encounter the problem of choosing appropriate rate of discount. A method that can avoid this problem is IRR. It is the discount rate that makes NPW of the project equal to zero. This discount rate is called the internal rate of return. It is the maximum interest that the project could pay for the resources used if the project is to recover its investment and operating costs and still break even.

Mathematically it is discount rate r such that

$$\sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t} = 0$$

The internal rate of return is a very useful measure of project worth and tells us the earning rate of the money invested in the project. It is a measure World Bank and many other international financing agencies use for financial and economic analysis of projects funded by them.

4. Net benefit investment ratio (NKR)

All the three discounted measures described above cannot be relied upon to rank projects. The formal selection rule of each is to accept all projects that meet the criterion - a net present worth of zero or greater at opportunity cost of capital, an internal rate of return opportunity cost of capital, an internal rate of return equal to or greater than opportunity cost of capital, or a benefit-cost-ratio of 1 or greater at opportunity cost of capital. Yet, in many instances, it is convenient to have a reliable measure to rank projects to determine order in which projects should be undertaken especially, so, when the capital budget is not sufficient to implement all objects.

A suitable and convenient criterion for ranking independent projects is the net benefit investment ratio (NKR). This is simply the present worth of net benefits divided by present worth of investment. It is a kind of benefit cost ratio.

Mathematically,

$$NKR = \frac{\sum_{t=1}^{n} \frac{N_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{K_t}{(1+r)^t}}$$

Where N_t is the incremental net benefit in year t after stream has turned positive and K_t is the incremental net benefit in initial year when the stream is -ve.

The formal selection criterion is to accept all projects with NKR of 1 or greater discounted at opportunity cost - in order, beginning with the largest ratio value.

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COMMON FISH DISEASES OF OPEN WATER SYSTEMS AND THEIR REMEDIAL MEASURES

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Introduction

Floodplain lakes and small reservoirs in the country are increasingly used for enhancing fish production during the last few years. New methods of fish culture *viz.*, cage culture or pen culture are also being widely used to increase fish yield with the use of fertilizers, both inorganic and organic, on a limited scale. All these practices influence the environmental and parasitological factors in these culture areas and consequently various fish disease epizootics are encountered.

Fish diseases encountered in lakes

The common fish diseases recorded in the lakes where enhancement practices like stocking and fertilization are undertaken are discussed below:

1. Ulcerative dropsy

Fish species affected: *Catla catla*, *Labeo rohita* and *Cirrhina mrigala*

Symptoms: There is accumulation of water in the body cavity and scale pockets along with subcutaneous haemorrhages.

Causative agents: Pathogenic bacteria *viz. Aeromonas hydrophila* and *Pseudomonas* sp. A myxozoan parasite, *Neothelohanellus catlae* is also found infecting the kidney of affected *C. catla.* Affected fishes are normally found stressed due to certain environmental factors associated with the disease such as, low dissolved oxygen and large number of aquatic vegetation.

Treatment:

a) Lime (CaO) application @ 50-100 kg/ha
b) Bleaching powder application @ 1 mg/l after one weeek.

2. Columnaris disease

Fish species affected: *C. catla*, *L. rohita* and *C. mrigala*

Symptoms: Initial stages exhibit greyish patches over the head and dorsal sides of the body.

Causative agent: Pathogenic bacteria, *Flexibacter columnaris.* The disease is often associated with high organic load and increased temperature.

Treatment: Same as for ulcerative dropsy disease

3. Trichodiniasis

Fish species affected: *C. catla, L. rohita* and *C. mrigala*

Symptoms: Fishes with heavy infestations have pale coloured gills with creamish coating. Surfacing of fish occurs.

Causative agent:- Urceolariid ciliates *viz., Trichodina nigra, T. reticulata, Tripartiella bulbosa, T. copiosa* and *T. obtusa.*

Treatment:- No viable treatment methods for open waters.

4. White gill spot

Fish species affected: *C. catla* and *C. mrigala*

Symptoms: The gills of affected fishes are covered with whitish spots of different size. Excessive mucus secretion occurs and fishes surface for gulping air.

Causative agent: Myxozoan *viz. Thelohanellus catlae* and *Myxobolus bengalensis.*

Treatment: No feasible method of treatment for open water bodies.

5. Dactylogyrosis

Fish species affected: *C. catla, L. rohita* and *C. mrigala*

Symptoms: Excessive secretion of mucus occurs in the infected gills which are affected, often with localized haemorrhage.

Causative agent : Monogenetic trematodes of the genus *Dactylogyrus* sp.

Treatment: Application of lime @ 100 kg/ha

6. Argulosis

Fish species affected: *L. rohita, C. mrigala* and *C.catla*

Symptoms: Infestation is accompanied by excessive mucus secretion, irritability, erratic swimming behaviour and retarded growth. Heavy infestation often leads to circular depression with haemorrhage and ulceration.

Causative agent: Branchiuran species of the genus, *Argulus*

Treatment:

i) Gammaxene treatment @ 1 ppm
ii) The eggs of *Argulus* can be mechanically removed after collecting them on the hanging bamboo mats in water.

7. Epizootic ulcerative syndrome

Fish species affected: *Channa sp., Mastacembelus sp., Puntius sp., Nandus sp., C. catla, L. rohita C. mrigala, C. carpio* and *G. chapra.*

Symptoms: The fishes become lethargic and float on the surface of the water, sometimes with the head projected out of water. Initially, the disease appears as red coloured lesions, haemorrhagic in nature. These red lesions spread and enlarge gradually becoming deeper and assuming the form of ulcers. With further advancement, scales fall off, ulcers become deep necrotizing ulcerative lesions. Histopathologically, it is characterized in having mycotic granuloma in epidermis.

Causative agents: Role of suspected causative agents namely, virus, bacteria and fungus could not be established conclusively. In India, so far 20 species of pathogenic bacteria have been isolated from affected fishes of which *A. hydrophila* has been consistently found along with fungus *Saprolegnia.* The latest investigations point out the prime causative agent to be a fungus called *Aphanomyces sp.*

Treatments: can be tried only in lakes below 40 ha.

Prophylactic: During post-monsoon period, the desease prone water areas can be treated with lime, CaO @ 50 kg/ha followed by application of bleaching powder @ 0.5 ppm after one week.

Therapeutic: At the initial stage of lesion formation, lime (CaO) is applied @ 100 kg/ha followed by application of bleaching powder @ 1 ppm after one week.

Fish diseases encountered in reservoirs

The parasite fauna of a reservoir is derived mainly from its parent stream, but some may be added along with the stocked fishes. Later, rheophilous parasites tend to disappear and the typical lake, pond and sluggish river species tend to become more numerous. The potentially dangerous parasites and diseases existing in the Indian reserovirs are:

1. Ligulosis

Fish species affected: *C. catla*

Symptoms: Abnormal swelling of the abdomen, dark colouration, erratic swimming behaviour and emaciation.

Causative agent: Plerocercoid larval stage of the cestode *Ligula intestinalis*

Treatment: Since *L. intestinalis* is an endoparasite and the infections are more common in large water areas, chemical control is not feasible. The permanent hosts of the parasite are the fish eating birds which can be removed by scaring away or destroyed by shooting. The method has been successful in Tilaiya reservoir.

2. Black spot disease

Fish species affected: *C. catla* and *Oxygaster bacaila*

Symptoms: Affected fishes have black ovoid patches overlying cysts of metacercaria larvae. Growth retardation occur.

Causative agent: Metacercarial larval forms of the digenetic trematode *Diplostomum* sp.

Treatment: Removal of the resident molluscan population is one method of control.

3. Isoparorchiosis

Fish species affected: Murrels, catfishes and carps

Symptoms: Affected fishes are weak, emaceated with soft and flabby muscles. Infection is characterised by presence of black nodules in body cavity of fish.

Causative agent: Metacercarial larval stage of the digenetic trematode *Isoparorchis hypselobagri*.

Treatment: Remedial measures are limited to reducing the population of affected fishes.

4. Ergasilosis

Fish species affected: Mostly carps

Symptoms: Infestation occur in the gills, buccal cavity, operculum and fins. Heavy infestation leads to anaemia, respiratory distress and frequent surfacing.

Treatment: Gammaxene treatment @ 1 ppm

Quarantine and fish health certification

Stressing the importance of preventing fish diseases, it must be emphasized that the introduction and movement of fishes should be subjected to strict quarantine procedures. In recents years, stocking of phytophagous carps *viz. C. idella, H. molitrix* and *T. mossambica* has become common in India, either intentionally or accidentally in lakes and reservoirs. There is every possibility of dangerous parasites getting established on fish species. There are reports that some parasites from exotic fishes *viz. Trichodina reticulata*, *Tripartiella bulbosa, T. copiosa, T. obtusa* and *Neoergasilus japonicus* got established in the cultured native fishes. To prevent such diseases in future the following steps should be taken.

i) Transfer of eggs rather than fish for stocking
ii) Chemotherapy of fish if transferred
iii) Careful supervision of any introduced fish
iv) Enactment of fish control legislation

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ROLE OF PLANKTON AND MACRO-BENTHOS COMMUNITIES IN FISH PRODUCTION IN OPEN WATERS

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Introduction

Plankton is defined as more or less passively floating or drifting animals and plants. Plankton occurs in all natural water bodies as well as in artificial impoundments. They are mostly very small in size and occur mainly near the surface. All true plankters have been often arbitrarily classified as (a) macroplankton consisting of forms larger than 3 mm in size; (b) microplankton comprising forms less than 3 mm in size and (c) nannoplankton consisting of forms which have a diameter less than 60 μ. In general, plankton is divided into two main division, the phytoplankton and the zooplankton. To the phytoplankton belong most of the diatoms, dinoflagellates and other unicellular plants or animal like plants that are capable of synthesizing food. Zooplankton are mainly protozoans, rotifers and large number of the small crustaceans such as copepods, ostracods, amphipods etc.

The community of organisms living on the bottom of a water body is called benthos. The benthos comprises (1) sessile animals such as the spongs, barnacles, mussels, oysters, corals, crinoids, hydroids, bryozoa, all the sea-weeds and eel grasses and diatoms (2) Creeping forms, such as crabs, lobsters, certain copepods, amphipods, and many other crustacean, many protozoa, snails and some bivalves and fishes, (3) burrowing forms including most of the clams and worms, some crustacea and echinoderms. Benthos may be devided into phytobenthos and zoobenthos. Benthic organisms are often classified into non-taxonomic functional categories especially based on size such as.

a) Macrobenthic consisting of organisms larger than 500 μ or 0.5 mm. eg most molluscs, many polychaets, decapods, crustacean etc.

b) Meiobenthic organisms are smaller than macrobenthic forms but larger than 44 μ m or .044 mm eg. nematodes, harpoacticoid copepods and several minor phyla.

c) Microbenthic organisms comprising smaller than meiobenthic forms. The macro-zoobenthos includes especially molluscs, polychaets and crustaceans. All species are dependent on oxygen at least temporarily, for their metabolism.

Aquatic ecosystem can be divided into two main aspects, the abiotic features dealing with physico-chemical parameters and the biotic features dealing with various biotic communities. Plankton and benthic organisms occupy a major portion of biotic communities particularly in 1st and 2nd trophic levels of any aquatic ecosystem.

Importance of plankton and benthos

The importance of plankton cannot be overemphasized. It comprises the bulk of all aquatic living matter. Particularly, phytoplankton are the chief producers of the primary food of all aquatic ecosystem and zooplankton are the primary consumers. Directly or indirectly all high seas animal life including fish is depended on phytoplankton productivity in the upper layer illuminated by sunlight. In more turbid coastal waters photosynthesis may be limited to depths of fifty feet or less, but in the clear open ocean, sunlight at three hundred feet or more is sufficient for conversion of the carbon dioxide into organic matter. Benthic animals are directly or indirectly involved in most physical and chemical processes that occur in aquatic ecosystem. Benthic algae (autotrophs) act as primary producers and all benthic heterotrophs regenerate nutrients that can stimulate primary production and nearly all serve as food for the large members of demersal nekton. The macro-zoobenthic organisms, as consumers of phyto and zooplankton and as food organisms for higher animals including fish are an integral part of aquatic environment and play a vital role in fisheries.

Thus, phytoplankton and benthic algae are the most ubiquitous group of autotrophic organisms occuring in almost all aquatic system and contributing substantially to overall primary production. While many abiotic factors such as, temperature, light intensity, transparancy, available nutrients (phosphate, nitrate, silicate, carbon etc.), dissolved oxygen, carbon dioxide, alkalinity, dissolved oxygen, carbon dioxide, alkalinity, water current are responsible for primary production of an aquatic ecosystem which in turn, contribute directly or indirectly to the fish yield.

Trophic level and food chain in aquatic ecosystem

The transfer of food energy from the source in through a series organisms eating one another is referred to as a food chains interconnect with one another. The word trophic is used interchangably with food, and trophic dynamics refers to the pattern of food consumption as it occurs and change over time.

The primary producers (autorophs) that is, phytoplankton, phytobenthos (benthic algae) and green rooted plants manufacture their food through photosynthetic activity utilizing abiotic elements (CO_2, NH_4^+, NO_2^- NO_3^-, PO_4^- etc.) water. The primary producers occupy the lowest level of food chain pyramid. Other organisms in the aquatic ecosystem, largely animals are consumers which utilize the producers as their food and these organisms are heterotrophs either micro or macro consumers.

Another category of heterotrophs is of those organisms (bacteria and fungi) which are decomposers (saprophytes) of dead organic matter. This decomposing material is called organic detritus and the food web it supports is called detrital food web. Organic detritus is an important food in estuaries. Whereas, the food web begins with consumption of like plants is called a grazing food web. There is a progressive decrease in number in the communities placed at next higher trophic level in the food chain. Thus, the higher the trophic level of an organism in the food chain, smaller the number in its community as the food conversion rate is always less than one.

Food and feeding habits of fish and position of fish in the food chain

On the basis of the nature of food, fish may be broadly classified as (1) plankton feeder (planktivores) – feeding on plankton, (2) herbivores – feeding on plant materials (3) omnivores – feeding on both plant, animals and organic detritus, (4) Carnivores – feeding mainly on animals, (5) piscivores – feeding on fish (6) detritivores – feeding on organic detritus (7) cannibalistic – feeding on their own. But there is not a single fish in nature which is exclusively planktivorous or carnivorous or herbivorous. All fish are strictly omnivorous and it is only on the basis of the percentage of animal and plant in their food they are categorised into one group or the other. Thus, fish populations may be classified into several trophic levels depending upon their food habits. Several food chain are given in Table 1 and 2. It is revealed from Table 1 that fish population are found in 2^{nd}, 3^{rd} and 4^{th} trophic levels. Certain fish species particularly phytoplankton feeders are very close to the primary production in the food chain. It also reveals from the Table 1 and 2 that a part of the primary production enters the food chain and the total fish biomass is produced through two food chains *viz.*, (i) the grazing food chain and (ii) the detritus food chain. A small fraction of energy source through energy cycle of the food chain is being consumed or transferred into the next higher trophic level. As a result a part of primary productivity is used for fish growth and production. It is assumed that one trophic level in a food chain has a production about 10% of the production of the previous trophic level and ultimately fish production comes to about 0.1% of the primary production. Thus, primary productivity of an aquatic ecosystem gives a gross idea of fish production (total weight) of that particular system. On the whole, the purpose of estimating primary and secondary production is to finally determine the annual potential yield (tertiary production) of exploitable living resources that can be harvested. The tertiary production may be calculated as 0.1% of primary production or 10% of secondary production. The tertiary production can be estimated by using a factor of 0.1% to convert primary production into carbon than multiply by a factor of 10 to convert into live weight.

Relationships between plankton production and fish yield as well as benthos production and fish yield

Casual relationships between plankton production and fish landings as well as macro-zoobenthic production and fish landing at Allahabad, Bhagalpur centres of Ganga river system and in Hooghly estuary indicate (Table-3) a positive effect of plankton and macro-zoobenthos on total fish yield.

It is also reported that North sea landings of demersal fish rose after 1963 to more than one million tonnes from a rather constant level of about 4000,000 tonnes since 1909. The enhanced demersal landings mainly caused due to structural change in productivity as well as increased densities of food organisms (phyto and zooplankton) for fish larvae and adult fish of the North sea.

Plankton as an indicator

The occurrence of some specific planktonic food organisms which form the main food of the fish. For example, the abundance of oil sardines. Sardinella longiceps, may be related to the blooming of a particular diatom, *Fragilaria oceanica* which forms the choice food organisms of oil sardine.

Some planktonic molluscs such as, the species of *Janthina, Limacina* and *clione* particularly drift in vast swarms into the North sea from the Atlantic ocean due to water currents and winds. As a result, they serve as useful indicators of movements of water masses and associated fishery resources in these area.

Table 1. Trophic levels of fish in food chain

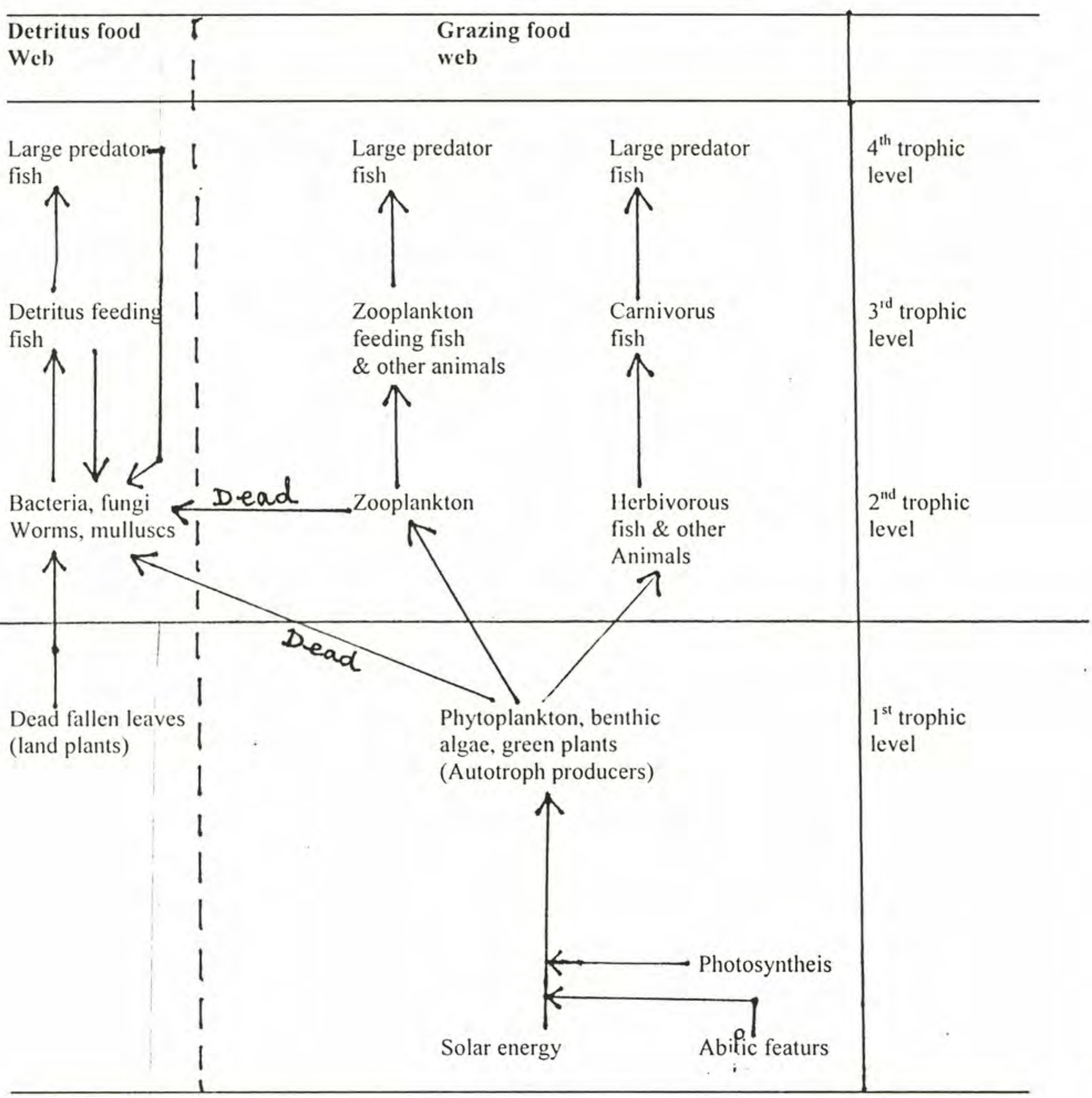

Table 2. Several food chains for fish communities

1st trophic level	2nd trophic level	3rd trophic level	4th trophic level
1) Phytoplankton	Fish		
2) Rooted plants (Sea weeds, grasses etc.)	Fish		
3) Phytoplankton	Zooplankton	Fish	
4) Phytoplankton	Zooplankton	Fish	Fish
5) Phytoplankton	Benthos & other	Fish	Fish
6) Phytoplankton	Fish	Fish	
7) Phytoplankton	Benthos	Fish	
8) Phytoplankton	Benthos	Crustaceans	Fish
9) Plants, animals & organic matters	Detritus	Fish	
10) Phytoplankton	Detritus	Fish	Fish
11) Phytoplankton	Detritus	Zooplankton & other invertebrates	Fish

Table 3. Relationships between plankton production and fish yield as well as benthic production and fish yield in different aquatic ecosystems.

	ALLAHABAD **1960**	**1995-97**
Max. plankton density (u/l)	45,13	2,400
Max. macro-zoobenthos density (u/m^2)	3,436	418
Av. Yearly fish production (t)	205.43	59.3
	BHAGALPUR **1960**	**1995-96**
Max. plankton density (u/l)	1,444	675
Av. Yearly fish production (t)	90.95	35.70
	HOOGHLY ESTUARY **1956-63**	**1995-97**
Max. plankton density (u/l)	60-335	414-1,267
Max. macro-zoobenthos density	-	681-2,612
Av. Yearly fish production (t)	3,204.0	42,703.2

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