MANAGEMENT OF FISHERIES IN SMALL RESERVOIRS

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

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National Training on *Management of Small Reservoirs*
organised at CIFRI during Feb.12 - 21, 2001

Reservoir - an important fishery resource of India and its utilisation for increasing fish production in the country

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Introduction

In India, inland open water fishery sector has been playing a major role in fulfilling protein requirement of the population and have been providing the needed support to improve socio-economic conditions of the operatives. Inspite of the phenomenal increase in country's fish production during the Seventh to Ninth Plan periods (2.94 million tons in 1986 - 87 to 5.96 million tons in 1998 - 99), the present per capita availability of fish is still only about 9.5 kg per annum against world average of 12.1 kg and WHO recommendation of providing a minimum of 11 kg of fish per capita annually. To fulfill this minimum nutritional requirement for the country's projected population, assuming 56% of population as fish eaters, the present annual fish requirement has been computed to be 8 million tonnes and double of that by 2010.

The potential harvestable yield from Indian EEZ has been estimated as 3.9 million tonnes. Of this, 2.86 million tonnes are estimated to have been harvested in 1996 - 97 with about 98.5% coming from inshore and off shore areas of the Indian seas. Population of mariculture is also beset with a number of problem (Dixitulu, 1996). As such, there is little scope of any substantial increase from marine resources until we go in for extensive deep-sea fishing, which is highly capital intensive.

The abovesaid scenario warrants a concerted effort to increase fish production from inland water where the resources are vast and diverse with estimated potential of 4.5 million tonnes (against production of 2.56 million tonnes (provisional) estimated to have been achieved during 1998 - 99). This potential is bound to further increase with additional resource (specially reservoirs) slated to be created in future. The last two decades have witnessed immense growth in fish production from freshwater pond culture, because of emphasis given for popularisation of scientific technology of fish seed production and composite fish culture and efforts made for its development through FFDAs. But with all emphasis laid during Seventh and Eight Plans only about 19% of the available resource could be brought under scientific pond culture. Scientific fish culture is cost intensive and its intensification is beset with problems of availability of required feed and possible impact on environment. Thus, total reliance on pond culture for meeting the targeted fish production can not be placed and it is essential to give due priority to development of reservoir fisheries, a resource vastly available in our country and tapped very little till now from fishery point of view.

One of the main focuses of developmental activities of post- independent India has been the harnessing the rivers for irrigation and hydro-electric power generation. Consequently, a vast number of small, medium and large reservoirs have come into existence, with the objective of storing the river water for irrigation, power generation and host of many other activities. It has also been recognised that these man-made lakes (reservoirs) constitute an important inland fishery resource of our country by virtue of their magnitude, and vast potential. Besides adding substantially to the production basket, this resource may also offer considerable employment opportunity through properly developed fishery activities, especially, for the rural population who are generally ousted during the process of creation of such bodies. However, till now this vital fishery resource is not contributing to the inland fish production of the country to the extent it can. The present fish yield from Indian reservoirs in general is frustaingly low, being at an average about 20 kg/ ha/yr. against 88 kg/ha/yr. in USSR and 100 kg/ha/yr. Sri Lanka. The present fish production from small reservoirs in our country fluctuates widely ranging from 3.9 kg/ha in Bihar to 188 kg/ha, in Andhra Pradesh with an average of about 50 kg/ha which is much lower than those of' Sri Lanka (300 kg) and Cuba (100 kg), The reason for this low yield may be attributed to the low priority laid on their fisheries development and unscientific management.

Reservoir resource

A number of anomalies persisted in earlier literature regarding nomenclature (reservoir, tanks, irrigation tanks etc.) of impounded water bodies, especially in case of small reservoirs. By a general consensus arrived at; during a National Consultation, held at CIFRI, Barrackpore in January, 1997, attended by all concerned authorities of fisheries of State and Central Governments; all man-made impoundment's created by obstructing the surface flow, by erecting a dam of any description, on a river, stream or any water course, have been classified as reservoirs. However, bodies less than 10 ha in area, being too small to be considered as lakes, are excluded. It was also agreed in the said consultation to uniformly classify the reservoirs of the country into small (< 1,000ha), medium (above 1,000 to 5,000 ha) and large (> 5,000 ha), based on their hectarage.

As per Sugunan (1995), India has 3,153,366 ha of reservoirs, spread in 15 states of the country (Table 1). It consists of 1,485, 557 ha of small reservoirs, 507, 298 ha of medium reservoirs and 1,160, 511 ha of large reservoirs.

Table 1 . State -wise area (in ha) of small, medium and large reservoirs in India (After Sugunan,1995)

States	Small	Medium	Large	Total
Tamilnadu	315,941	19,577	23,222	358,740
Karnataka	228,657	29,078	179,556	437,291
Madhya Pradesh	172,575	149,259	138,550	460,384
Andhra Pradesh	201,927	66,429	190,151	458,507
Maharastra	119,515	39,181	115,054	273,750
Gujarat	84,124	57,748	144,358	286,230
Bihar	12,461	12,523	71,711	96,695
Orissa	66,047	12,748	119,403	198,198
Kerala	7,975	15,500	6,160	29,623
Uttar Pradesh	218,651	44,993	71,196	334,840
Rajasthan	54,231	49,827	49,386	153,444
Himachal Pradesh	200	------	41,364	41,564
Harayana	282	--------	---------	282
West Bengal	732	4,600	10,400	15,732
Northeastern States	2,239	5,835	-----------	8,074
Total	**1,485,557**	**507,298**	**1,160,511**	**3,153,366**

Scientific appraisal of reservoirs

The biological potential of reservoirs in India was not evaluated to any reliable extent until 1970s. When yield from them stood at low level of 5 to 8 kg/ha/yr. The investigations conducted till then were isolated attempts to understand the ecology of individual reservoirs in some states. Organised large scale research on reservoir fisheries was initiated in the country only in the year 1971 with the launching of an "All India Co-ordinated Research Project on Ecology & Fisheries of Reservoirs" under the aegis of Central Inland Fisheries Research Institute (CIFRI). The project attempted to develop all determinants of reservoir productivity; including climatic, morphometric and edaphic variables; and the dynamics of biotic communities in the reservoir ecosystem, in different geo-climatic conditions of the country. Consequently, limnology has come to be used as a mold to cast location specific management strategy for reservoirs, which is known as ecosystem oriented management of reservoirs. Application of these norms has resulted in remarkable increase in fish yield of reservoirs of all categories (Tables 2 & 3). The average fish yield from reservoirs registered an increase upto 15 kg/ha by the mid 1980s and is presently estimated to be 20 kg/ha. The reservoir fisheries technology, developed by the Institute, is based on a three pronged strategy of stocking support, proper effort and appropriate mesh size of fishing gear.

Table 2. Increase in fish yield obtained in medium and large reservoirs as a result of scientific management techniques.

Reservoirs	State	Yield (kg/ha/yr.)	
		Before	After
Yeldari	Maharashtra	3	37
Girna	Maharashtra	15	45
Gandisagar	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

Table 3. High yield obtained in small reservoirs due to management based on stocking

(*modified after Sugunan,1995*)

Reservoirs	State	Area ha	Stocking rate no./ha	Yield kg/ha
Aliyar	TamilNadu	650	353	194
Meenkara	Kerala	259	1,226	107
Culliyar	Keraka	159	937	316
Gularia	Uttar Pradesh	300	517	150
Bachhra	UttarPradesh	140	763	140
Baghla	Uttar Pradesh	250	----	102
Bundhk Beratha	Rajasthan	----	164	94
Chapparwara	Rajasthan	200	300	79

Characteristics of the lacustrine ecosystem

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

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

Determinants of biological productivity

Biological productivity of an impoundment is influenced by a host of factors such as climatic, edaphic and morphometric. The geographic location affects the metabolism of reservoir through nutrition supply, shape of the basin and the efficiency with which the climatic factors are able to act in the dynamic exchange. They will have varying effect on final productivity.

The climatic factors have a profound effect on the utilisation of nutrients in the particular lake basin. The lower temperature retards the fish growth, which the higher accelerates. The edaphic factors affect the supply of dissolved nutrients in the reservoir water. Soil basin quality influences the reservoir productivity to a great extent. Area, mean depth and regularity of shoreline are the most important morphometric measurements having a significant bearing on the productivity of impoundment.

Options for management policies in large and medium reservoirs

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

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

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

Selection of suitable species for stocking

Primarily selection of fishes for stocking is based on the assessment of existing biotic communities and their efficiency in covering primary trophic resources to harvestable products. Fish farming in large/medium reservoir largely consists of selection of suitable species for stocking at the initial stage. Stocking in such reservoirs is mainly with the purpose of establishing a breeding population. It is imperative that the stocked fishes breed in such reservoir resulting in autostocking.

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

A rate of 250 fingerlings per hectare has been recommended for reservoirs without catfishes and 600 fingerlings (6" in length) with rich catfish population. But for new reservoirs the stocking rate should be at higher level (1,000 kg/ha.). Irritional stocking of fingerlings has a deleterious effect on reservoir fisheries. However, a rational approach for formulating stocking policy is required to be done through estimation of potential fish yield of the reservoir and adjustment of stocking rate in such a manner so that the yield comes close to the productivity potential. The above described scientific techniques/policies, wherever applied, have resulted in considerable increase in fish yield from large and medium reservoirs.

Fishing and mesh regulation

Reservoirs that could be converted into autostocking reservoirs offer lesser problem in their management. In such cases the management measures involve deployment of optimum fishing effort and selecting right type of gear. Raising the fishing effort to the optimum, coupled with monitoring of stock abundance by catch per unit of effort, is a recognized tool for improving stock productivity. Such type of management has paid rich dividends in Bhawani Sagar and Govind Sagar reservoirs. Finally, it may be concluded that for integrated development of reservoir supply of stocking material is a must. Construction of fish farm attached to reservoir under supervision of dedicated workers should be considered. In case of non-availability of suitable site near the reservoir, pen culture technology in bay areas of reservoirs may be made use of for rearing of seed to desired size.

Extensive aquaculture in small reservoirs

The aquaculture, practiced in these impoundments may be described as "*extensive*" where fingerlings are raised in water bodies with few or no modification of the habitat. The culture based capture fishery principle is recommended for small srervoirs as most of them either dry up or maintain very low water levels in summers.

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 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 ecosystem based on an understanding of the environmental and biological parameters, basic levels and ecological relationships.

Stocking policy

Stocking of fingerlings (4"-6" size) in small reservoirs has proved to be useful tool for developing their fisheries. Stocking of economically important, fast growing fishes from outside are aimed at colonizing all the diverse niches of the biotope for harvesting maximum sustainable crop from them.

This widespread management practise has proved to be highly remunerative in such small water bodies where almost complete annual harvesting is possible. 'I'his has amply been demonstrated in Gularia, 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 factors *viz.* biogenic capacity, of the environment, the growth rate of the desired species, the population density as regulated by predatory and competitive pressure and probable escapement through the irrigation canal and spillway.

During summer months, small reservoirs either dry up completely or else the water level in them gets so drastically reduced that through over fishing no brood stock is left over to contribute to the succeeding years fishery through natural recruitment. Consequently, the entire catch from these water bodies depend on the fishes stocked from outside to offset this loss. There is thus, a direct correlation between the stocking rate and catch per unit effort in such heavily fished waters (Jhingran *et al.*, 1981, Khan *et al.*,1990

Determination of stocking rate

The stocking rate can be calculated based on the average growth rate of the individuals fish and the expected production and using the formula (Huet, 1960) as under.:

$$\text{Stocking rate (nos./ha)} = \frac{\text{Expected production (kg)}}{\text{Av. Individual growth rate (kg)}} + \text{loss due to mortality and escapement (\%)}$$

Desirable species and their ratio need be decided based on ecological condition of the reservoir. Surface, column and bottom feeders ratio has to be as per food chain in the system.

Case studies of some small reservoirs

To establish a baseline for evolving suitable management measure development in small reservoirs, the Central Inland Capture Fisheries Research Institute (CIFRI) carried out investigations on small reservoirs of M. P *viz*,, Loni, Kulgarhi, Govindsagar and Naktara: Gulariya, Bachhra and Baghla in U. P., Aliyar and Tirumoorthy Reservoirs in Tamil Nadu and Kyrdemkulai in Meghalaya. Investigations on hydrology primary productivity, plankton, macrobenthos, macrovegetation, soil characteristics, experimental fishing and biology, commercial fishes have been conducted. A critical evaluation of these parameters indicates that they can support moderate to high fish production.

Option for 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-chemilcal aspects of the environment in terms of population and community dynamics.

General consideration for development of fisheries in small reservoirs

I. The breeding, of the major carps has repeatedly been observed to take their place above the spill-way resulting in heavy escapement of the brood fishes and this poses a serious problem for building up stocks of desirable fishes in such reservoirs. The situation is further worsened by heavy escapement of fingerlings and adult 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 Gularia reservoirs and have paid rich dividends in enhancing the fish yield from these reservoirs (Table. 3).

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

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

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

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

It may be stated that small reservoirs occupy a unique position in limnology analogous to field plots used in agricultural science *i.e.* means of assessing effects of environmental modifications on the ecosystem on it reduced scale. But they offer easiest way to obtain much enhanced fish production at minimum cost. They alone offer ample opportunity of employment to fishers (Table 4). This accompanied with hectarage available of this resource in the country calls for laying immediate priority for their fishery development.

Table 4. An assumptive model of employment potential of small reservoir fisheries

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I. INCOME

Fish yield	150kg/ha/yr
Annual Fishing days	250
Fisher per boat	2
Net per fisher	5 kg (150m)
Catch per day	3kg
Annual catch per fisher	750 kg
Sale price of fish at site	Rs. 25/-per kg
Gross income per fisher	**Rs. 18,750/-**

II. COST

A. Fixed Capital Cost

Boat cost (per piece)	Rs. 3,000/-
Annual depreciation on boat (life 10 years)	Rs. 300/-
Boat depreciation per fisher	Rs. 150/-#
Cost of 5 kg net	Rs. 1,500/-
Annual depreciation on nets (life 5 years)	Rs. 300/-#
Total fixed cost(#)	**Rs. 450/-**

B. Working Cost

Repair & maintenance of boat (per fisher)	Rs. 100/-
Repair & maintenance of net	Rs. 500/-
Imputed value of family labour(1/2 day X 250 day X Rs.50/-)	Rs. 6,250/-
Total working cost	**Rs. 6,850/-**
TOTAL COST (A +B)	**Rs. 7,300/-**

III. NET ANNUAL INCOME **Rs. 18,750 - Rs. 7,300 = Rs. 11,450/-**
NET MONTHLY INCOME PER FISHER **Rs. 954/-**

A net monthly income per fisher of Rs. 954/- (in addition to personal labour cost) is well above accepted subsistence level.

IV EMPLOYMENT POTENTIAL

Water area required for desired fish production per fisher 750/150 = 5ha
Employment potential for fishers 1485557/5 = 297112
In ancilliary activities (@ 0.5 of production activity) 148556

TOTAL EMPLOYMENT GENERATION POTENTIAL = 29,7112 + 14,8556
= 44,5668

Pollution in reservoirs

Reservoirs being the good source of water for industries, many industrial units are situated along their banks. Consequently, industrial effluents are often discharged into the reservoir causing deleterious impact on the fauna and flora at various trophic levels ultimately, leading to low fish out put. Adverse effects of effluents on spawning and direct fish kills are also frequent (Rihand reservoir, Panchet reservoir etc). It is, therefore, recommended that authorities should pay utmost attention to check the discharge of toxious effluents into the reservoir in order to maintain the ecosystem healthy and viable.

Socio-economic consideration

It has become necessary to impart certain measures of stability to fish production in reservoirs since wide fluctuations in yield rates result in consequent rise or fall in income of those who toil on their water. The fishery potential of the reservoir is largely under-utilized and it is well witnessed by prevalence of low productivity, low income, low savings and almost complete absence of inventory, building process. 'I'he 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 unskilled farm workers though risks and uncertainties in catch and incomes are much more in their case. Therefore, there is an urgent need to evolve a package approach comprising stocking. monitoring programme, equitable and just royalty arrangements, marketing intervention by Co-operatives and Corporations and quick distribution channels. Moreover, infrastructural support in term of post-harvest arrangement is very weak in respect of most of the reservoirs. The major impediments have been small marketable surplus that does not justify high investment. State Governments with financial help from loaning agencies should formulate a plan for establishing focal centres at a point where produce of several reservoirs in the radius of 100-200 km is transported. This lead centre should have facilities like transport vans, ice plans etc. Unlike the Co-operatives in Gujarat involvement of Co-operative sector so far, has been of marginal significance in reservoirs. At best, they act as input suppliers without market intervention. Till today, it is difficult, if not impossible, to displace the contractors in fish trade.

Conclusion

It is evident from above that presently obtained production from reservoirs in the country, a major existing resource simply because of its magnitude, is much below its potential. Sugunan, (1995) has compiled the present level of fish production potential of different categories of reservoir in the country (Table 5). It is evident therefrom that presently existing reservoir fishery resource in the country has the potential to yield about 3.2 lakh tons of fish, with modest targets of average production, if managed on scientific lines. Moreover, it holds maximum promise in view of the fact that this is the least tapped resource a it present and that this is the only fishery resource whose hectarage is bound to go up with the increase in population and resultant development activities.

Table 5. Present yield and potential of production from different categories of reservoirs in India.

Category	Total available area (ha)	Present	Production	Potential	Production
		Averag Production (kg.ha)	Fish production (t)	Average Production (kg/ha)	Fish production (t)
Small	14,85557	49.90	74129	150	222833
Medium	5,27541	12.30	6488	75	39565
Large	11,40268	11.43	13033	50	57013
Total	31,53366	29.70	93650	101.29	319411

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

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National Training on *Management of Small Reservoirs*
organised at CIFRI during Feb.12 - 21, 2001

Guidelines for fisheries management of small reservoirs in India

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Introduction

In India, the small reservoirs, which spread over nearly 1.5 million ha, form one of the mos important inland fisheries resources on account of the large resource size and the huge untappe production potential. They have the advantage of enabling quick enhancement of yield due t their small size and easy maneuverability of fish stocks. Available technologies offer possibilitie for achieving fish yields of 100-200 kg/ha, though the present national yield is about 50 kg/ha By virtue of their unmistakable role in promoting fisheries development through mas participation of local communities, the small reservoirs assume special significance. India ha 19,134 small reservoirs (including irrigation tanks) with a total water surface area of 1,485,557 h (Table l). The State of Tamil Nadu accounts for maximum number (8,895) and area (315,941 ha) o small reservoirs, followed by Karnataka (4.651 units and 228,657 ha) and Andhra Pradesh (2,89 units and 201,927 ha).

Some broad guidelines for distinguishing small reservoirs from the medium and large ones ar given in Table 2. In addition to physical aspects, impoundments are defined by factors includin species diversity, fertility, and structural complexity of the aquatic habitat. The goal of fisher management is to control these factors to produce a harvestable surplus while maintainin dynamic equilibrium with the system.

Table 1. Distribution of small reservoirs and irrigation tanks in India

States	Small reservoirs		Irrigation tanks		Total	
	Number	Area (ha)	Number	Area(ha)	Number	Area (ha)
Tamil Nadu	58	15,663	8,837	300,278	8,895	315,941
Karnataka	46	15,253	4,605	213,404	4,651	228,657
Andhra Pradesh	98	24,178	2,800	177,749	2,898	201,927
Gujarat	115	40,099	561	44,025	676	84,124
Uttar Pradesh	40	20,845	-	197,806	40	218,651
Madhya	*6	172,57	-	-	*6	172,575

Pradesh		5				
Maharashtra	-	-	-	-	-	119,515
Bihar	112	12,461	-	-	112	12,461
Orissa	1 433	66,047	-	-	1,433	66,047
Kerala	21	7,975	-	-	21	7,975
Rajasthan	389	54,231	-	-	389	54,231
Himachal Pradesh	1	200	-	-	1	200
West Bengal	4	732	-	-	4	732
Haryana	4	282	-	-	4	282
Northeast	4	1,639	-	600	4	2,239
Total	2 ,331	551,69 5	16,803	933,862	19 134	1,485,55 7

Table 2. The broad distinguishing features of small and large reservoirs

Small reservoirs	Large and medium reservoir
Single purpose reservoirs mostly for minor irrigation	Multi-purpose reservoirs for flood control, hydro-electric generation, large-scale irrigation, *etc.*
Dams neither elaborate nor very expensive. Built of earth, stone and masonry work on small seasonal streams.	Dams elaborate, built with precise engineering skill on perennial or long seasonal rivers. Built of cement, concrete or stone.
Shallow, biologically more productive per unit area. Aquatic plants common in perennial reservoirs, but scanty in seasonal ones.	Deep, biologically less productive per unit area. Usually free of aquatic plants. Subject to heavy drawdowns.
May dry up completely in summer. Notable changes in the water regime.	Do not dry up completely. Changes in water regime slow. Maintain a conservation-pool level (= dead storage).
Sheltered areas absent.	Sheltered areas by way of embayments., coves, *etc.* present.
Shoreline not very irregular . Littoral areas with a gentle slope	Shoreline more irregular. Littoral areas mostly steep.
Oxygen mostly derived from photosynthesis in the shallow, stratified reservoirs, lacking significant wave action.	Although photosynthesis is a source of dissolved oxygen, the process is non-confined to a certain region delimited by vertical range of transmission of light (euphotic zone) . Oxygen also derived from significant

	wave action.
Provided with concrete or stone spillway, the type and size of the structure depending on the size of the runoff.	Provided with more complex engineering devices.
Breeding of major carps not commonly observed.	Breeding mostly observed in the headwaters or in other suitable areas of the reservoir.
Can be subjected to experimental manipulations for testing various ecosystem responses to environmental modifications	Cannot be subjected to experimental manipulations.
Trophic depression phase can be avoided through chemical treatment and draining. Cycle of fish production can be repeated as often as the reservoir is drained.	Trophic depression phase sets in .
The annual flooding during rainy season may be compared to overflowing of floodplains. Inundation of dry land results in release of nutrients into the reservoirs when it fills up, resulting in high production of fish food through decomposition of organic matter, predominantly of plant origin, leading of higher fish growth and survival.	Loss of nutrients occurs as they are locked up in bottom sediments. Rapid sedimentation will reduce benthos production.
No brood stock is left due to complete fishing or over-fishing of seasonal reservoirs. Fish stock has to be rebuilt through stocking. There is thus established a direct relationship between stocking rate and catch per unit of effort.	Prominent annual fluctuations in recruitment occur and balancing of stock number against natural mortality requires high density stocking of fingerlings. Their capture requires efficient capture methods.

The chemical properties of water in reservoirs are a reflection of the properties of bottom soil When oxygen supply falls short in mud layers that are not well aerated, the decomposition o organic matter becomes slow. This, along with the presence of partially oxidized compounds an short chain fatty acids, make the soil strongly acidic. The bacterial action is reduced an productivity lowered. pH also influences transformation of soluble phosphates and controls th absorption and release of essential nutrients at soil water interface. A slightly alkaline soil (pH 7.5 has been considered optimal for fish production. Productive soils range mostly between slightl alkaline to slightly acidic (7.5 - 6.5) in reaction.

From a large number of observations, it has been found that soils with available phosphoru value (mg/100 g of soil) less than 3 are poor, 3-6 average and above 6 are highly productive Available N below 25 (mg N/100 g of soil) gives poor production, the same in the range 25-6 indicates average to high production. Organic carbon less than 0.5% is considered too low, 0.5 1.5% average and 1.5-2.5% optimal. Range of physico-chemical parameters and their significanc in productivity are shown in Table 3.

Table 3. Physico-chemical features of Indian reservoirs (range of values)

Parameters	**Overall range**	**Productivity**		
		Low	Medium	High
A. Water				
pH	6.5-9.2	<6.0	6.0-8.5	>8.5
Alkalinity (mg/l)	40-240	<40.0	40-90	>90.0
Nitrates (mg/l)	tr.-0.93	Negligible	up to 0.2	0.2-0.5
Phosphates (mg/l)	Tr.-0.36	Negligible	up to 0.1	0.1-0.2
Conductivity (μ mhos)	76-474		up to 200	>200
Temperature (°C)	12.0-31.0	18	18.22	>22
B. Soil				
pH	6.0-8.8	<6.5	6.5-7.5	>7.5
Available P (mg/100 g)	0.47-6.2	<3.0	3.0-6.0	>6.0
Available N (mg/100 g)	13.0-65.0	<25.0	25-60	>60.0
Organic carbon (%)	0.6-3.2	<0.5	0.5-1.5	1.5-2.5

(After Jhingran and Sugunan, 1990)

Organic matter in reservoir ecosystem comes from both within (autochthonous) and outsid (allochthonous) sources. Primary production by the photosynthetic phytoplankton, the base o food chain, is the major autochthonous source of organic production. The allochthonou nutrients that come along with runoff from the watershed and inflow are more significant bot qualitatively and quantitatively.

Assessment of yield potential

Several methods are in vogue to assess the fishery potential of small reservoirs by derivin equations based on area, depth, catchment area and the chemical parameters of soil and water Later, morpho-edaphic index (MEI) has evolved in an attempt to combine the morphometric a well as chemical parameters. Relationships between MEI and catch are based on the assume characteristics for some sets of reservoirs possessing a certain number of limnologica conditions, *i.e.* (i) that the ionic composition is dominated by the carbonate-bicarbonate system (ii) that the water body is not dystrophic, (iii) that the volume does not fluctuate noticeably an (iii) that the temperature regime is similar. A morpho-edaphic index as :

$$MEI = \frac{\text{Specific conductivity } (\mu \text{ mhos/cm})}{\text{Mean depth (m)}}$$

has been set for African lakes (Henderson and Welcomme, 1974). Fish yield potential i calculated from the MEI as :

$$C = 14.3136 \, MEI^{0.4681}$$

Asian reservoirs are known to have a lower yield potential than their African counterparts However, till an Indian formula is derived, this formula can be applied to obtain a roug indication of the productivity of any reservoir within the limits of between one half and twice th estimate. Such equations are sufficiently precise to give an idea of the scale of investment whether in research or developmental infrastructure, appropriate to any water body. Mor precision can be achieved after separate equations have been derived for different classes o reservoirs.

Enhancement

Majority of the small reservoirs and other community water bodies in India are essentiall amenable to culture-based fisheries and there is a general consensus that any significan improvement in yield from them can be achieved only through some sort of enhancemen activities. Fisheries enhancement can be achieved through human interventions in the aquati ecosystems with a view to increasing their productivity. The nature and extent of th enhancement will determine the overall sustainability and environment-friendliness of th fishery.

The common modes of enhancement which are relevant to inland water bodies in Indi are *stock enhancement* (increasing the stock), *species enhancement* (inducting new species t broaden the catch structure), and *environmental enhancement* (enriching the water qualit through artificial eutrophication).

Stock enhancement

Augmenting the stock of fish has been the most common management measure that is followe in the reservoirs in most countries of the world. Stocking of reservoirs with fingerlings o economically important fast-growing species to colonize all the diverse niches of the biotope i one of the necessary prerequisites in reservoir fishery management. This has proved to be useful tool for developing fisheries potential of such small aquatic systems. However, stocking i not merely a simple matter of putting appropriate number of fish into an ecosystem but need evaluation of an array of factors *viz.* the biogenic capacity of the environment, the growth rate o the desired species and the population density as regulated by predatory and competitiv pressures.

During summer months, small reservoirs either dry up completely or else the water level in the gets so drastically reduced that through over-fishing no brood stock is left over to contribute t the succeeding years' fishery through natural recruitment. Consequently, the entire catch fro these water bodies depends on the fishes planted from outside to compensate this loss. There i thus established a direct correlation between the stocking rate and catch per unit of effort in suc heavily fishes waters. Stocking is, therefore, a useful tool for the management of small reservoir where stock can even be maintained at levels higher than the natural carrying capacity of th environment through supplemental fertilization. The number of fish to be stocked per unit are has to be based on the natural productivity of the system, growth rate of fishes, natural mortalit rate and escapement through the irrigation canal and spillway.

Fish yield of small reservoirs, where the management is on the basis or culture-based fisheries i dependent on a number of parameters, such as growth rate, natural mortality and fishin mortality. Therefore, stocking density, size at stocking, size at harvesting, rate of fishin mortality, and harvesting schedule hold the key for obtaining the optimum yield. A clos scrutiny of the fishery management followed in the small water bodies indicates that these vita aspects of management have not received adequate attention.

The primary aim of good management is to ensure utilization of the food reserves in th reservoir by large-scale stocking with suitable species to obtain higher productivity. Lack of suc measures would lead to poor utilization of the biological productivity of such water bodies.

Selection of species for stocking

The basic principles that should be followed in selecting a species to be stocked are :

1. The planted species should find the environment suitable for maintenance, growt and reproduction.

2. It should be a quick growing form from which highest efficiency of food utilizatio is obtained.

3. A fishery based on high production of herbivorous fishes with shorter food chain i more productive and hence energy -effective.

4. The number of them to be planted should be such that the food resources of th ecosystem are fully utilized and densest population maintained consistent wit normal growth.

5. Size of the stock should be chosen with the expectation of getting the desire results.

6. Stock should be readily available without major shift in the cost involved in it transportation

7. Cost of stocking and managing the species must be less than the benefits derive from stocking and management.

Stocking rate

Stocking rate: A large country like India, with too many water bodies to be stocked, ha inadequate state machinery to meet the stocking requirements of all its reservoirs. This ha resulted in under-stocking of the reservoirs. Stocking densities need to be fixed for individua water bodies or a group of them sharing common characteristics such as size, presence of natura fish populations, predation pressure, fishing effort, minimum marketable size, amenability t fertilizing and multiplicity of water use. The main considerations in determining the stockin rate are growth rate of individual species stocked, the mortality rate, size at stocking and th growing time. Recently, based on the National Consultation on Reservoir Fisheries (Sugunan 1997), the Government of India has adapted the following formula (Welcomme, 1976) to calculat the stocking rate for small reservoirs:

$$S = \frac{q.P}{W} e^{-z(tc-to)}$$

S Number of fish to be stocked (in number/ha)
P- Natural annual potential yield of the water body
q The proportion of the yield that can come from the species in question
W Mean weight at capture
t_c Age at capture
t_o Age at stocking
-z Total mortality rate

P can be estimated through MEI method (mentioned above) and the range of mortality rates ca be found out from the estimated survival rate. Table 4 illustrates calculation of stocking rate using the formula given above, when P = 200 kg/ha, q = 1, W = 0.5 kg and t_c-t_0 is 1. The mode assumes insignificant breeding by stocked population and therefore applies mainly to tota cropping situations *i.e.,* those in which fish are caught below their minimum size for maturity those whose natural reproduction does not take place and those where water body is no permanent. It shows that stocking density, which depends on the natural conditions o productivity, growth and mortality, are very sensitive to Z. Because of the very large numbers o fry needed, this formula may have very limited utility in large reservoirs.

Table 4. Calculated stocking density at different levels of mortality
(adopted from Welcomme, 1976)

Approx. annual survival (%)	-z	Estimated number of fish to be stocked (number/ha)
50	0.7	805
37	1.0	1,087
22	1.5	1,792
13	2.0	2,955

Successful stocking has also been reported from a number of small reservoirs in India. I Markonahalli, Karnataka, on account of stocking, the percentage of major carps has increased t 61% and the yield increased to 63 kg/ha. Yields in Meenkara and Chulliar reservoirs in Keral have increased from 9.96 to 107.7 kg/ha and 32.3 to 316 kg/ha respectively through sustaine stocking. In Uttar Pradesh, Bachhra, Baghla, and Gulariya reservoirs registered steep increase i yield through improved management with the main accent of stocking. An importan consideration in Gulariya has been to allow maximum grow out period between the date o stocking and the final harvesting *i.e.*, before the levels go below the critical mark. The possibl loss due to the low size at harvest was made good by the number. Bundh Beratha in Rajasthan stocked with 100,000 fingerlings a year (164/ha), gave a fish yield of 94 kg/ha, 80% of whic constituting catla, rohu and mrigal (Table 5).

Table 5. High yields obtained in small reservoirs due to management based on stocking

Reservoir	State	Stocking rate (number /ha)	Yield (kg/ha)
Aliyar	Tamil Nadu	35	194
Tirumoorthy	-do-	435	182
Meenkara	Kerala	1226	107
Chulliar	-do-	937	316
Markonahalli	Karnataka	922	63
Gulariya	Uttar Pradesh	517	150
Bachhra	-do-	763	140
Baghla	-do-	-	102
Bundh Beratha	Rajasthan	164	94

Stock protection

Indian major carps are observed to congregate above the spillways breeding, which result in heavy escapement of the brood. This poses a serious problem for building up stocks of desirable fishes in such reservoirs. The situation is further worsened by heavy escapement of fingerlings and adults through irrigation canals. Development of fisheries in such water bodies, therefore, requires suitable screening of the spillway and the canal mouth. Such protective measures have been installed in some of the reservoirs paying rich dividends in enhancing the fish yield. However, caution is to be exercised to see that the screens erected across spillways do not get clogged during flood season to the detriment of dam. In some reservoirs, fishes have also been observed to ascend upstream through spillways, 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 spillways and canals, it would be an economic proposition to have an annual cropping policy so that the reservoir is stocked in September-October and harvested by June end. However, this depends on the growth of fish and general productivity of the water body.

Species enhancement

Decline of indigenous fish stocks due to habitat loss, especially caused by dam construction, is a universal phenomenon. The extent of such fish species loss is not assessed to any reliable degree in many countries. In India, all the major river basins have been affected. Planting of economically important, fast-growing fish from outside with a view to colonizing all the diverse niches of the biotope for harvesting maximum sustainable crop from them is *species enhancement*. It can be just stocking of a new species or *introduction*. Introduction means one time or repeated stocking of a species with the objective of establishing its naturalized populations. This widespread management practice has more relevance to larger water bodies were stocking and recapture on a sustainable basis is not feasible.

Environmental enhancement

Improvement of the nutrient status of water by the selective input of fertilizers is a very common management option adopted in intensive aquaculture. However, scientific knowledge to guide the safe application of this type of enhancement and the methods to reverse the environmental degradation, if any, is still inadequate. On account of all these, this is not a very common management tool. Fertilization of reservoirs as a means to increase water productivity through abetting plankton growth has not received mush attention in India. Multiple use of the water body and the resultant conflict of interest among the various water users are the main factors that prevent the use of this management option.

Modelling approach in culture-based fisheries

Recent studies based on modeling approach have opened up new avenues for the culture-based fisheries of small reservoirs. Notwithstanding the fact that studies on the population dynamics based on modeling approach demand higher levels of inputs in the form of money and trained manpower, an insight into the modeling approach will help the manager in understanding the ecosystem approach. Many of the small water bodies seem to be overstocked. In a culture-based fishery, an undue increase in stocking density can lead to severe loss of production. It is well known that at higher stocking densities, the fish grow at a slower rate with attendant higher rate of natural mortality. A moderate overstocking results in sub-optimal production due to this slow growth and high mortality, but fishery can still operate. On further increase in stocking density, the asymptotic length of the population falls below the gear selection length (if the mesh is selective) and the fishery fails to remove biomass from the population. If stocking continues, the water body is literally choked with stunted populations without any production.

Available models have clearly confirmed that production is a function of fishing mortality and stocking density. If some standard variables on population parameters, such as the *density-dependent growth, size dependent mortality* and *weight-length relationship* are known, the optimum stocking density and the fishing mortality can be arrived at. It has also been pointed out that the highest production is achieved if fish are produced at the minimum marketable size. Thus, it becomes very important to determine the minimum size at which the fish are preferred for domestic consumption or can be marketed. The mesh size regulations and the gear selection have to be guided by this parameter. The fishing pressure assessed on the basis of size groups in the population is a useful guide in determining the quantum of fishing effort. This tool has been effectively used in many countries to make necessary adjustments in fishing effort. In reservoirs, the populations of some species consist of more than one age group and the older individuals dominate the populations in terms of biomass, clearly indicating low fishing pressure. This situation calls for an increase in fishing effort.

Similar models to suit Indian conditions need to be derived from field data. Adoption of such rational stocking rates, guided by models will go a long way in improving the fish yield from the small reservoirs.

Small reservoirs offer immense scope and potential for generating additional national income of the order of Rs.100 crore per year and providing additional employment to lakhs of fishermen and others through fishing, handling, transport, marketing and ancillary industries. A systematic and integrated approach towards scientific studies and planning criteria for undertaking fish culture in small reservoirs should be so directed as to have an understanding of various factors such as reservoir morphometry, water residence time, the physico-chemical characteristics of water & soil, biotic communities and growth rate of commercially important fish species.

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DOs and DON'Ts in small reservoir fishery management

Dos	DON'Ts
Get scientific advice in determining the production potential, stocking density and fishing effort.	Do not stock without a plan
In the absence other criteria, use the recommended formula to determine stocking density.	Do not overstock the reservoir. (Remember, production loss due to over-stocking is higher than that of under-stocking)
Follow staggered stocking and harvesting schedules, whenever feasible	Do not fish immediately after stocking
Stock fish in shallow areas away from the spillways and other outlets.	Do not stock in deep areas and near to spillways and other outlets.
Approximately estimate the possible production loss through inlet and outlet channels and account for this while putting the value of mortality in the formula for stocking density.	Do not plan transporting fingerlings from far away places for stocking (Raise them near the reservoirs).
Get engineering help to explore possibilities for providing wire mesh to guard for inlet and outlet channels in order to prevent escape of fish.	Do not try to provide wire mesh structures without consulting the dam authorities (It may cause undue increase in water pressure leading to

	collapse of the hydraulic structure).
Fix the minimum size at capture and restrict the use of mesh size accordingly (Remember that theoretically, stocking fish at smaller size in large numbers and catching them at the smallest marketable size will give more yield, compared to larger size. However, survival is size-dependent).	Do not catch fish at too small or too large size. Do not grow fish to higher size than marketable/acceptable size.
Fix the size at stocking high where the predator population is very high. Work out an optimum fishing effort and limit the number of fishing units	Do not stock higher sized fingerlings if there is no predator pressure
Explore possibilities of stocking locally available indigenous species	Do not stock exotic species without obtaining clearance from the authorities
Select fish species for stocking carefully, taking into account the available fish food resources and the catchability.	Do not stock/overstock fish species only because their seed are available
Explore possibilities of integrating animal husbandry practices to make the fisheries more profitable.	Do not practice animal husbandry in reservoirs used for drinking water purposes
Participatory management often works better than punitive measures and deterrents to motivate the community to follow mesh size and fishing effort regulations. Therefore, ensure community participation in management	Do not fertilize the reservoirs with organic and inorganic manures, unless it is very essential and does not conflict with other water uses.

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Abiotic factors and their significance in the fisheries management of small reservoirs

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Introduction

India is graced by its tropical small reservoir resources with immense production potentiality. Size of this resource (>1.5 million ha) is so enormous that even a modest increase in yield rate could bring forth substantial hike in the availability of fish in inland fishery sector. Apart from serving the basic purposes of irrigation and soil conservation they offer ample scope of enhancing higher fish productivity and other income generation involving community development process. However, the quantum of fish yield realised from these water bodies till date remains unimpressive due to inadequate knowledge of the intrinsic production dynamics of these ecotopes with poor adoption of scientific management strategies. Thus, the present national yield (approximating 50 kg/ha) can be increased three to four folds by suitably manoeuvring fish stocks through available technologies.

Small reservoirs are basically meant for minor scale irrigation being made across seasonal streams with simple earthen dams mostly. These are shallow in nature, non-irregular shoreline, littoral areas with gentle slope, getting dried up more or less completely during summer resulting in phenomenal change in water regime. Perennial reservoirs are infested with aquatic macrophytes. Both culture and capture fisheries can be fruitfully augmented in these ecotopes as these are having the congregation of pond as well as reservoir ecosystems being situated in the secluded areas of human inhabitants with lesser environmental impact showing more biological productivity. Trophic depression is of shorter duration and can be overcome also with suitable reclamation programmes as and when required. Nutritional loading is much higher than large reservoirs during full monsoon when inundation of fertile croplands takes place with the release of substantial amount of organic matters as well as readily available nutrients rendering higher fish growth.

Located at different geo-climatic regions of the country with varying degrees in their morphometry, nature of watershed and catchment ecology and anthropogenic activities in the catchment make these water bodies vulnerable to be studied individually. This basic research on limnology would provide clues to the production potential of such ecosystems and would help in setting targets of fish production from such water bodies.

Morphometric and hydrographic features

Salient morphometric and hydrographic characteristics of some selected small reservoirs are depicted in Table 1. Climatic and edaphic factors contributing essential source of energy and nutrients in reservoir are considered to be of first order importance. Morphometric factors primarily area, mean depth, irregularity of shoreline regulating heat and nutrients are of second order type. Aliyar reservoir over Aliyar river in Bharathapuzha basin in Tamil Nadu having mean depth 18.2 m, Kyrdemkulai reservoir over river Umiam in Meghalaya having mean depth 4.63 m and Nelligudda reservoir near Bangalore with mean depth 3.0 m are some of the small reservoirs with highest and lowest mean depth. The shallowest small reservoirs are more productive due to extended euphotic zone facilitating greater mixing of nutrients and circulation of heat. In contrast, deep reservoirs serve as a nutrient sink at the bottom, accumulating organic matters with non-availability of nutrients at euphotic zone thus branding them as 'biological deserts'.

Catchment ecology plays a significant role in determining reservoir productivity. Nature of soil, precipitation in the catchement and land use pattern are the prime domain of catchment ecology. The catchment of Aliyar and Thirumoorthy is located in the rain shadow region of Western Ghats with annual rainfall fluctuated between 509.1 & 1059.2 mm and 413.3 & 913.8 mm respectively. The total annual inflow in Aliyar ranged from 3158.45 to 3960.67 cumecs against the total outflow of 3235.27 to 4904.84 cumecs while in Thirumoorthy the inflow ranged between 5000.50 and 8287.07 cumecs in 1992-96 with outflow between 4277.80 & 6712.35 cumecs. In Karnataka, Manchanbele (329 ha, 9.5m m.d.) and Nelligudda (80 ha, 3m m.d.) regions are characterised by low rainfall (annual ranging from 679-789 mm) categorising as a dry zone with the reception of both Southwest and Northeast showers with more than 50% being received between August and October having two distinct peaks in rainfall pattern (May and September/October). The catchment of Sarni in M.P. (1012 ha, 9.29m m.d.) is neither denuded nor that much fertile (in the Satpura range of hills with annual rainfall 1524 mm) to supply substantial amount of allochthonous inputs into the reservoir.

In Indian reservoirs, it has been noticed that the catchment determines the quality of water to a large extent than the basin soils (Natarajan, 1976) which is mostly true in case of medium (1000-5000 ha) and large (>5000 ha) reservoirs. In small reservoirs, which are basically shallow in nature and where maximum fluctuation of water level taking place (viz. Gulariya 300 ha at FRL & 6.7 ha during summer, Bachhra 140 ha at FRL and 4 ha in summer, Baghla 250 ha at FRL and 4 ha in summer) the basin soil has a definite role in supplying available nutrients to the water phase. So, basin soil is as equally important as the catchment in case of small reservoirs so far as nutrient supply is concerned. Thus, it can be predicted that higher the catchment to reservoir area, higher is the productivity of the reservoir provided the catchment is fertile. The catchment (C) to reservoir area (A, at FRL) i.e. C/A, an index of allochthonous inputs, varied widely amongst the reservoirs studied viz., Manchanbele (435), Aliyar (73), Thirumoorthy (21), Nelligudda (93), Sarni (35), Govindgarh lake (8) and Kyrdemkulai (2).

Shore development index ($S/2\sqrt{A}$, where S = shoreline length, A= area) indicates the degree of irregularity of shore line as indicated by the high values of this index is indicative of higher productivity as in Kyrdemkulai (11.65) with 10 major and minor bays due to its elongated shape. In general, shore development index is of low values in small reservoirs like Manchanbele (2.9), Sarni (4.0) and Nelligudda (2.3) with less number of sheltered bays and coves.

Volume development index (3 x mean depth / max. depth) denotes the depth of basin in relation to the nature of basin wall. If the value is above one, the basin is cup shaped like Manchanbele (1.3) and Aliyar (1.2) and if it is less than one, the basin wall is convex towards water as observed in Sarni (0.96).

Sudden and drastic hydrographic changes in small reservoirs have a direct bearing on productivity. Fluctuations in water level which is maximum in such water bodies, inflow and outflow have direct effect on biotic communities. Plankton, benthos and periphyton pulses always coincide with the period of least water level fluctuation.

Degree of formation of littoral areas is more in small reservoirs, which is also an indicator of productivity.

Sediment characteristics

A sound knowledge of nature and properties of basin soil wherein a series of physico-chemical, biochemical and microbial reactions are constantly taking place rendering release of nutrients is of utmost importance in determining the productivity of these ecotopes. The major physical and chemical characteristics of sediment are particle size distribution. types of clay colloids, cation and anion exchange capacity, soil-reaction, electrical conductivity and nutrient dynamics.

A distinct colloidal, loosely stratified organic layer followed by a clayee mineral layer of varying composition is optimum for maintaining productivity. The basin soil of Aliyar comprising 24.1% sand, 29% silt and 46.99% clay represents a moderate to high productive nature of soil. Whereas in Manchanbele, sandy-clay nature of soil having 70-77% sand, 9-12% silt and 14-20% clay has been observed like many of the other small reservoirs studied. Mechanically, the bottom soil should not be so adsorptive as to eliminate most of the nutrients from water phase and at the same time it must not be so porous to allow excess loss of nutrients. Small reservoirs with sandy basin can be reclaimed with the application of farm yard manure (FYM) @ 10t/ha to reduce the porosity of the bottom soil and facilitating in forming a thick organic layer followed by a thick loam to clay loam layer for economic utilization of the nutrients.

Several chemical reactions responsible for availability of nutrients in optimum quantities to the fish food organisms and in providing a congenial healthy environment for the growth and survival of biotic communities are governed by soil reaction (pH). The pH of sediment of Aliyar, Thirumoorthy, Manchanbele, Sarni and Kyrdemkulai are in the range 6.42, 6.5-7.9, 4.6-5.0, 5.9-6.9 and 5.9-7.6 respectively. In some reservoirs, it is in the moderately acidic range and in others it is near neutral to alkaline range. In general, soil pH is not being reflected as such to the above lying water phase due to strong buffering capacity of water rendered by CO_2 - HCO_3 - CO_3 system which is associated intrinsically with photosynthetic activities during day time (except in extreme condition like acid sulphate soil). Release of phosphorus is primarily dependent on soil pH. Bottom sediment containing high organic matter with slower decomposition rate (like Manchanbele having 1.78% organic carbon) develops acidity due to humic and short chain fatty acids leading to less productivity.

Specific conductivity representing total soluble salts in the bottom sediment does not necessarily attain high values so as to affect fish productivity. Electrical conductivity (mS/cm) of Thirumoorthy, Manchanbele, Sarni and Kyrdemkulai is of the range 0.17-4.0, 0.9-1.34, 0.25-0.41 and 0.087-0.12 respectively. As the changes in electrical conductivity are associated with the release or depletion of soluble ions in the soil-water system, it definitely might have an indirect role to play in reservoir productivity.

Availability of different nutrients ascertains the growth of various fish food organisms in aquatic system. The dynamics and the availability of these nutrients are governed by the prevailing conditions in bottom sediment so far as small reservoirs are concerned. Available nitrogen (mg/100g) is more found in newly impounded Nalkari reservoir (991.52 ha at FRL) in Chotanagpur hill Division of Bihar, dammed across Nalkari river, a tributary to Damodar to the tune of 47-150 as compared to other reservoirs like Thirumoorthy (44-48), Aliyar (29.2), Sarni (40-43), Manchanbele (50-90) and Kyrdemkulai (7.7-32.33).

Nitrogen is basically present in soil in organic form, gradually getting mineralised to ammonium and nitrate forms thus making its acceptability to fish food organisms. Out of the NH_4^+ ions some are i) adsorbed by soil colloidal complex ii) released to water phase being utilized by plankters as NH_4^+ or as NO_3^- forms and iii) lost through volatilization when associated with high pH and temperature mostly in the post-monsoon period in tropical small reservoirs. The nitrate ion, being the readily available form of nitrogen to phytoplankters is highly soluble in water as well as diffusive in nature. Thus, a considerable amount of it may be leached downward into the reduced layer of the bottom mud from where it is either lost through leaching by further downward movement or gets denitrified in the soil-water interfacial aerobic zone and escapes into the atmosphere. However, these low supply of soil -N to water phase could be considerably compensated by ultimate supply of nitrogen through fixation by azotabacter, blue-green algae (BGA), atmospheric electrical discharge, photochemical fixation etc. A water body having medium to high productive potential requires 25-75 mg available -N per 100g of soil.

Phosphorus, the assimilator of nitrogen into cellular matter, has been singled out as the most critical factor in maintaining productivity of aquatic ecosystem. Its importance is very much felt due to its lesser availability in Indian reservoirs. Inorganic-P is very reactive, forming sparingly soluble iron and aluminium compounds in acid soil and insoluble calcium phosphate in alkaline soil, thus restricting its release from soil to water phase under both extreme pH conditions. However, fixation of phosphorus into insoluble form especially under small reservoir ecosystem is not of permanent nature and in turn, the anaerobic condition at the bottom sediment develops congenial environment as to increase the solubility of phosphorus through several mechanisms (Mondal, 1984). Soil available phosphorus (mg/100g of soil) should be in the range of 4.7 to 6.2 for moderate to high productivity but is of low order in some small reservoirs studied in the range 0.22- 0.40 in Thirumoorthy, 3.30 in Aliyar, Tr - 2.2 in Sarni, 0.73 - 0.98 in Manchanbele, 0.59 - 1.12 in Kyrdemkulai barring Nalkari reservoir with high values of it (10-16) probably due to its new impounding condition.

Potassium, the third major nutrient in maintaining aquatic productivity has not been emphasised so far due to its easy and optimal availability in soil as well as in water under Indian context. Bottom sediment in productive reservoir having moderate pH and base saturation helps in maintaining a high level of potassium in the exchangeable phase and thereby in water-soluble forms. Liming, which can be done fruitfully in small reservoirs of around 100 ha water spread enhances potassium availability in soil through cation exchange. In tropical reservoirs, release of potassium takes place under dry summer signifying the increasing potassium status during subsequent monsoon months.

Very limited attention has been given so far to micronutrients, which are of great significance in improving aquatic productivity inspite of their requirement in very small amounts. They influence on availability and uptake of other nutrients in aquatic system. Bottom sediment of fine texture with rich organic matter content can retain larger amount of micro nutrient cations in the exchange phase.

Soil organic matter plays a dominant role in maintaining biological productivity and functions as a food source of benthic feeding fishes and invertebrates, a substrate for bacterial growth including other micro organism and the dissolved organic matter acts as exogenous growth substances, vitamins and chelating agents. It not only influences various physico- chemical properties of bottom sediment rendering release of nutrients into available form in aquatic environment but also controls the oxidation reaction - an important property of reservoir ecosystem. Sediment of small reservoirs contains more or less same amount of organic matter as that of their surrounding upland fields due to its quicker accumulation through autochthonous as well allochthonous sources. The organic carbon (%) content in some small reservoirs is to the tune of 0.28 - 3.7 (Thirumoorthy), 0.82 in Aliyar, 1.05-1.51 (Sarni), 1.76-1.81 (Manchanbele), 0.29-1.63 (Kyrdemkulai) and 0.26-0.67 in Nalkari reservoir. The rate of decomposition of organic matter is much more faster (three to four folds) in smaller reservoirs with heavy fluctuations in water level than deep medium or large reservoirs having lesser water level fluctuation rendering more release of bound nutrients into water phase. Organic matter is of low nutritive value but is often fortified with the colonizing bacteria and fungi thus making it more nutritious. A fish productive bottom sediment should have 1.5-2.5% organic carbon.

Nitrogen mineralization or immobilization is solely restricted by the C/N ratio - the higher the C/N ratio (>20) the more is the immobilization of inorganic - N as compared to the narrower C/N ratio (<10) resulting in mineralization of organic-N in soil into readily available form rendering its increased supply into water phase. Obviously, their highly favourable range of C/N ratio as noticed in Thirumooorthy (4-20), Aliyar (13.9), Sarni (6-13) and Manchanbele (6-15) adorns small reservoirs.

Physical features of water

Prevailing water temperature influences the rates of activity from a molecular to an organismal scale which in turn depends on climate, sunlight, depth and transparency of water. In tropical Indian reservoirs temperature is not a limiting factor and diurnal variation of water temperature ranging from 2-4°C and 10-12°C during post-monsoon and pre-monsoon seasons respectively exerts influence on plankton dynamics and availability of nutrients from soil to water phase. Increase in secondary production has been noticed by many ecologist and 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. Increase in temperature leads to accentuating growth and feeding rate with the decrease in egg development period in biotic communities rendering their increase productivity. Its effect on small reservoirs is more pronounced due to extended euphotic zone with more penetration of sunlight nearly to bottom of these ecosystems.

A stable thermal stratification with distinctly stratified hypolimnion in sub-tropical and some of the tropical small shallow reservoirs in India is responsible for more productivity as compared to homothermal reservoirs. Tropical small reservoirs with more heat budget have greater fish yield potential than temperate ones.

Productive water should be a little bid turbid. Transparency of water becomes low during monsoon due to inflow being loaded with suspended organic and inorganic particles, which gets stabilised subsequently in post-monsoon months. Turbidity is considered to be a limiting factor, which is more phenomenal in small reservoirs in plankton productivity (Benson and Cowell, 1976). Transparency showed clear seasonality in almost all the small reservoirs studied, in Nelligudda, Secchi depth is 27 cm in rainy season (inorganic turbidity) and the maximum of 118 cm in winter; in Manchanbele except during July-mid Sept. euphotic zone extended more than 4 m year round due to gravely red soil of catchment. In Sarni, the Secchi depth ranged from 15 cm in monsoon to 220 cm in subsequent pre-monsoon. Small reservoirs in northern India remains turbid for a longer period than peninsular one due to soil characters.

Turbidity due to colloidal micelles (organic and inorganic) is of paramount importance as these micelle by virtue of their extensive surface area coupled with electrical charge keep nutrient ions adsorbed/absorbed on their surface rendering equilibrium concentration of these ions in water phase. So, clear water is as much undesirable as highly turbid water.

Chemical characteristics of water

Dissolved oxygen (DO) is the prime important critical factor in natural waters both as regulator of metabolic processes of plant and animal community and an indicator of water health. A series of oxygen determination along with a knowledge of turbidity and colour of water could provide more information about the nature of water than any other chemical features. DO is more during pre- and post-monsoon seasons than monsoon in Indian reservoirs due to downpour. It is not at all a limiting factor even so far as small reservoirs are concerned. The range of DO in surface waters of Sarni, Manchanbele, Nalkari, Kyrdemkulai, Aliyar, Thirumoorthy and Nelligudda is 6.9-7.5, 6.8-8.8, 6.8-7.6, 6.7-7.1, 4.2-11.6, 6.5-7.5 and 4.0-8.2 mg/l respectively. Good productive water should have DO concentration more than 5 mg/l. However, very high concentration of DO leading to super saturation may become lethal to fish fry.

Substantial concentration of free CO_2 both in surface and sub-surface waters has a great bearing on productivity. It is highly soluble in natural waters but is a minor constituent of the atmosphere and remains present in equilibrium concentration by giving an acidic reaction in water. In small reservoirs with shallow depth its presence is noticed in monsoon due to rain and generally present year round at the bottom with high content especially in summer during the active phase of degradation of organic loads. Its presence is noticed at the bottom mostly year round to the tune of (mg/l) Manchanbele (3-9), Nelligudda (2-5), Nalkari (2-9), Thirumoorthy (1-3), Aliyar (3-10) and Kyrdemkulai (3.6-11.2). But in the surface water, it is predominantly present during monsoon to the range 1.0-3.0 mg/l and in summer (in some of the small reservoirs) to the tune of 1.5-2.5 mg/l. Its presence is essential for photosynthesis either in the form of CO_2, HCO_3

or CO_3 and its degree of concentration at the bottom is an important determinant of biogenic productivity, which is more phenomenal in tropical small reservoirs.

Water reaction, though not a limiting factor under tropical Indian reservoirs is a sole important factor influencing aquatic productivity as larger fish crops are usually produced in water just in the alkaline region (pH 7.0-8.0) and above pH 10.8 or below 4.8 have a detrimental effect. Reproduction and growth of fishes will diminish at pH < 6.45 or pH > 9.5 (Swingle, 1961; Mount, 1973). Due to strong buffering capacity offered by CO_2- HCO_3 - CO_3 system, Indian reservoirs seldom show acidic reaction. In general, water pH is low during monsoon due to dilution of alkaline substances or dissolution of atmospheric CO_2 with the resultant increase in subsequent post-monsoon and pre-monsoon periods. The small reservoirs studied have water pH in the range Thirumoorthy (7.0-7.6), Aliyar (6.6-8.8), Manchanbele (7.2-8.63), Nelligudda (7.2-9.2), Nalkari (7.8-8.3), Sarni (6.8-7.7), Kyrdemkulai (6.7-7.0).

Measurement of dissolved solids, an index of specific conductivity indicating the total concentration of soluble ions has wide bearing on productivity. It also gives an indication of state of mineralization in any aquatic system. Its value in fresh water ranges from 25-500 μS/cm and the optimum limit for high productivity is around 200 μS/cm or more. Its value is in the range (μS/cm) Manchanbele (300-400), Nelligudda (196-453), Sarni (133-350), Aliyar (39-110) and Thirumoorthy (25-35). Conductivity also provides a useful estimate of salinity/ chlorinity in freshwater. In normal freshwater, chloride content lies within 10 to 30 mg/l and if the value is somewhat more than this indicating local pollution.

In Natural fresh water, alkalinity is caused by carbonates and bicarbonates of calcium and magnesium. Along with these, dissolved CO_2 in water forms an equilibrium system, which is of prime importance in determining productivity of reservoir. Fresh water showing 40 mg/l total alkalinity (TA) or more are more productive (Moyle, 1945). TA values (mg/l) of some small reservoirs are Aliyar (16-58), Thirumoorthy (14-21), Manchanbele (96-180), Nelligudda (70-160), Sarni (62-94), Nalkari (48-55) and Kyrdemkulai (22-32).

Total hardness (TH) refers to the concentration of divalent metal ions in water expressed as equivalent of $CaCO_3$ which is usually related to TA as the anions of alkalinity and cations of hardness are normally derived from the solution of carbonate minerals. Ecosystems having moderately hard (61-120 mg/l TH) to hard (120-180 mg/l TH) water are more productive as the total hardness reflects the trends of Ca and Mg in water bodies. The TH values (mg/l) as observed in some small reservoirs are Manchanbele (68-86), Nelligudda (60-100), Aliyar (36-78), Sarni (52-53), Amaravathy (18-50) and Kyrdemkulai (19-28). In reservoir ecosystem where TA falls below 15 mg/l, the water develops low buffering capacity. Again, very high alkalinity 200-250 mg/l coupled with low

TH (<20 mg/l) results in the rise in pH during afternoon beyond 11.0 and causes death to fish.

For productive waters, a small amount of Ca and Mg is required and the necessary quantities are mostly present if TH is above 20 mg/l. Ca is an integral part of plant tissue, it increases the availability of other ions and reduces toxic effects of NO_2-N especially in small reservoirs where denitrification of NO_3-N to NO_2-N is a common phenomenon occurring in many occasions. Mg is a component of chlorophyll and at times it acts as a carrier of phosphate and stimulates bacterial reduction of organic matters. Ca and Mg are present in the range (mg/l) (14-21 & 5.8-10.1) in Manchanbele, (2.8-24.0 & 1.2-6.2) in Aliyar, (9.3-14.8 & 3.7-13.9) in Kyrdemkulai and (16-20 & 0.7-2.9) in Sarni respectively.

Nutrient dynamics in water

The effective functioning of any aquatic ecosystem depends on the circulation of nutrients, which takes place in most of the occasions at a faster rate in shallow small tropical Indian reservoirs as compared to their large/medium deep counter parts. Nutrients enter into the aquatic system through allochthonous inputs basically in addition to their autochthonous resources. Among nutrients, the role of nitrogen and phosphorus in aquatic productivity have been recognised and widely studied. Nitrogen, a major constituent of protein occupies a predominant place in aquatic system. Dissolved inorganic nitrogen in the range 200-500 μg/l may be considered favourable to fish productivity. Free NH_3 and NO_2 forms are toxic to fish if concentrates exceed 25 μg/l and 1000 μg/l respectively. In Indian reservoirs, available - N in water is very low in most part of the year except in monsoon and summer. In some small reservoirs it ranges (μg/l) from (1-54) in Manchanbele, (Tr-240) in Nelligudda, (Tr-40) in Aliyar, (10-272) in Sarni, (Tr-70) in Nalkari and (20-3610) in Kyrdemkulai. Owing to its quicker utilization by plankters, higher solubility, leaching loss and denitrification, NO_3-N is a limiting factor in Indian reservoirs. An inverse correlation between nitrate and phosphate is observed in Manchanbele, Nelligudda, Kyrdemkulai and Aliyar reservoirs.

Though, a relatively minor constituent, phosphorus is often considered to be the most critical single element in maintaining aquatic productivity. It helps in assimilation of nitrogen into cellular mater. The extremely reactive nature of phosphate ion (PO_4^{-3}) has made it the centre of interest to the researchers. The role of phosphorus as a limiting factor in the production of algae in natural lakes is diverse and complicated (Welch, 1952). Reynold (1998) found a significant correlation of total-P with biotic communities out of 40 limno-chemical factors studied. The range of available phosphate (μg/l) in some of the small reservoirs is Manchanbele (1-280), Nelligudda (10-110), Aliyar (Tr-20), Amaravathy (Tr-10), Sarni (10-70), Nalkari (Tr-60) and Kyrdemkulai (Tr-20). Thus, in most of the Indian reservoirs except for a shorter period during monsoon, availability of phosphate is of very low order and rarely exceeds 100 μg/l. Lack of these nutrients in water does not seem to be indicative of low productivity because of their rapid turn over and quick recycling.

In natural waters, silicon remains in silicate form which is reactable. Normally, 1-30 mg/l silicate-silicon or more remains present in natural fresh waters. At high temperature and pH, the solubility of silicate has been greatly increased. As silica has been an integral structural constituent of diatoms and many sponges it is able to regulate their growth. The assimilation of silica and subsequent precipitation by diatoms has been forming the greatest sink of silica in water. It ranges (mg/l) from 1.4-38.5 in Amaravathy, 2.8-24.0 in Aliyar, and 2.0-22.8 in Manchanbele, 3.0-12.0 in Nelligudda, 7.0-9.0 in Nalkari, 2.5-6.3 in Sarni and 1.0-3.0 in Kyrdemkulai reservoir.

Stratification

Physical stratification precedes chemical stratification. In tropical Indian reservoirs, thermal stratification may not be stable and prolonged as well as degree of thermoclinity is also lesser as compared to temperate ones but definitely it has tremendous influence on productivity. North Indian reservoirs like Getalsud, Konar, Rihand and Govindsagar under medium and large categories and Nalkari and Kyrdemkulai in smaller category have shown stable thermal stratification. Even though seasonal fluctuations in temperature is less pronounced in peninsular India due to lower latitude, small reservoirs like Manchanbele and Nelligudda in Karnataka have shown stable thermoclinity for a shorter period. The maximum thermal difference between surface and bottom in some small reservoirs is Manchanbele (5.5°C, 15 m), Nelligudda (4°C, 4m), Nalkari (9°C, 14m) and Kyrdemkuklai (6°C, 11m). In Harangi (1909 ha), a medium reservoir in Southern Karnataka, stable thermocline is noted in summer between 4 and 9m depth with a clear demarcation of epi- and hypolimnion. Thermal stratification with a fall in metalimnion temperature of less than 1°C has been observed in many tropical lakes (Lewis, 1973).

Locking up of nutrients at the bottom due to formation of epi- and hypolimnion is not commonly occurred in small reservoirs. Even high bottom temperature prevailing in deep tropical reservoirs facilitates rapid decomposition of organic loads accelerating the process of nutrient release.

Thermal stratification results in chemical stratification even also in small reservoirs in India mostly occurs in pre- and post-monsoon months. In Manchanbele, prolonged anoxic condition after 6m depth sets in i) March to June ii) September & October in 1999-2000. The difference in oxygen content (mg/l) between surface and bottom in some small reservoirs is Nelligudda (4.8 at 3m), Kyrdemkulai (6.7 at 11m), Nalkari (6.7 at 14m) and Aliyar (4.2 at 16m). Alkalinity shows an increasing trend with clinograde distribution in pre-monsoon as is well marked in Kyrdemkulai (at surface 21.6, at 11m, 30.4 mg/l) and in Sarni (surface 50.5, at 12m, 90 mg/l); it shows a reverse trend in Nelligudda due to the presence of free CO_2 at the bottom year round. pH shows a decreasing trend from surface to bottom in all the small reservoirs studied.

Trophogenic activities at the surface liberates O_2 by the photolysis of water, reduction of CO_2 to carbohydrate, breaking of HCO_3 to CO_3 takes place whereas in the tropholytic zone, consumption of O_2 for the oxidation of bottom organic matters and respiration by the bottom dwelling organism, production of CO_2 due to decomposition processes resulting in subsequent increase in H^+ concentration, conversion of bottom carbonate deposits (if present) to bicarbonates in presence of CO_2 take place. These two opposite processes bring about substantial changes in the water quality resulting in chemical stratification. Thus, the productive nature of a reservoir lies in its chemical as well as thermal stratification.

Diel variation

Diel variation in physico-chemical features is of paramount importance as to throw light on limnological health of water bodies. The more is the degree of variation in these features like temperature. DO, pH, free CO_2, TA, the higher is the productivity of that water bodies as these variations bring about substantial changes in the vertical distribution of zooplankton as well as phytoplankton.

Reclamation of sediment and water quality

Fertilization has not been received so much attention by the researchers in India even atleast in small reservoirs barring some stray incidence. Sreenivasan and Pillai (1979) tried to enhance plankton production in Vidur reservoir by applying superphosphate and got overwhelming results. Superphosphate (SSP) (500 kg) has been applied over 50 ha waterspread having mean depth 1.67 m resulting in an increase of phosphate content in water from trace to 1.8 mg/l and that of soil from 0.242 to 0.328 %. Quantitative improvements in organic carbon and kjeldahl - N have also been observed from the same reservoir both in soil and water with the application of fertilizers. Similar experiment with urea also has been tried. Liming can be practised in small reservoirs having acidic bottom sediment with high organic carbon content and high concentration of CO_2 at the bottom as was practised by Sreenivasan (1971) in an upland natural Yercaud lake along with SSP; an increase in water pH from 6.2 to 7.3 with the decrease of CO_2 at the bottom from 36 to 6.5 mg/l was recorded. The basic objective of fertilization is to increase the plankton density with the resultant increase in primary productivity and can be practised fruitfully in many small reservoirs of India to correct their oligotrophic characters. Sugunan and Yadava (1991 a,b) tried artificial eutrophication in two Northeast reservoirs viz., Kyrdemkulai (80 ha) and Nongmahir (70 ha) by applying poultry manure @ 10 t/ha, urea @ 40 kg/ha and SSP @ 20kg/ha. Thus, a number of reservoirs with low productivity in Northeast, Madhya Pradesh and Western Ghats receiving drainage from poor catchment require fertilization and liming. The same has been practised in China also (Yang *et al.*, 1990). So, greater emphasis should be given in stabilizing status of P, in checking N loss and availability of micronutrients so as to provide a healthy atmosphere for biological productivity in Indian reservoirs.

Estimation of potential fish yield

A fundamental pre-requisite for fisheries management on scientific line is the ability to predict fish yield from a reservoir as it helps the fishery manager with a quantitative basis for resource planning. Several methods have been proposed to correlate fish yield to physical, chemical, biological indices (Henderson et al., 1973). Of these Ryder's (1965) morpho-edaphic index (MEI) has not been very successful to Asian reservoirs (De Silva, 1992). A number of workers have attempted to estimate potential yield using food chain theory and models. Le-Cren and McConnel (1980) opined a transfer efficiency from gross photosynthesis to fish yield ranging between 0.1 and 1.6% in natural waters. It could be rightly concluded that assumption of a conversion efficiency of 0.8 to 10% in small reservoirs (< 1000 ha) would give more precise dependable potential yield from Indian reservoirs.

Plausible management options for environment enhancement

- Small reservoirs are two to three folds more productive than their large counterparts.

- Most of the reservoirs are free from pollution.

- Most of the reservoirs have conducive limno-chemical feature.

- Nutrient status of such small reservoirs can be augmented by producing leguminous pulse/fodder crops in the exposed littoral areas during heavy drawdown phase and puddle them with soil at their tender stage so as to add organic matter as well as nitrogen through fixation by their root nodules. It is economically viable also.

- Sandy basin can be reclaimed with FYM @ 10t/ha especially in reservoirs below 100 ha water spread.

- Acidic basin soil could be reclaimed at least to some extent in very small reservoirs (around 100 ha area) with liming @ 100-200 kg/ha applied once in two years.

- Plant/trees should be planted through community development programmes in the marginal areas so as to invite very conducive environment during scorching summer and to add leaf litters to the water body as hide out for fishes and these will finally be converted to detritus.

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Table 1. Morphometric and hydrographic features of some small reservoirs

Reservoirs	Location (N)	Elevation (m) (asl)	Area (FRL, ha)	Mean depth (m)	Maximum depth (m)	Catchment (km^2)	C/A	Capacity (10^6 m^3)	Shore dev.	Volume dev.
Manchanbele	12°52′	736.11	329	9.5	24.4	1589	435	31.4	2.9	1.168
Nelligudda	12°50′	740	80	3	10	74.69	93		2.3	-
Aliyar	10°20′	320	646	18.2	36.58	468.8	73	109.43	-	1.2
Thirumoorthy	10°28′	326	388	11.5	22.5	80.29	21	54.8	-	-
Sarni	22°8′30″	437	1012	9.29	28.97	353.1	35	92.52	4.0	0.96
Kyrdemkulai	-	679.70	80	4.63	26.4	150	2	3.7	11.65	-

Table 2. Limno-chemistry of some small reservoirs in India

Reservoirs	pH	Sp.Cond (μS/cm)	TA (mg/l)	TH (mg/l)	Cl^- (mg/l)	NO_3-N (μg/l)	PO_4-P (μg/l)	SiO_2-Si (mg/l)
Amaravathy (850 ha)	6.7-9.1	38-63	7-84	18-50	0.4-1.0	Tr	Tr-10	1.4-38.5
Aliyar (320 ha)	6.6-8.8	39-110	16-58	12-44	10-12	Tr-40	Tr-20	2.8-24
Thirumurthy (388 ha)	7.2-7.6	25-38	20-22	10-15	10-12	-	-	-
Manchanbele (329 ha)	7.2-8.6	300-490	96-180	68-86	19-38	1-54	1-280	2.0-22.8
Nelligudda (80 ha)	7.2-9.2	196-453	70-160	60-100	19-34	Tr-240	10-110	3.0-12.0
Gulariya (300 ha)	7.2-8.4	-	38-80	13-34	-	80-200	50-130	5-14
Bachhra (140 ha)	7.0-8.3	149-300	95-190	21-80	14-30	85-180	60-250	6.8-14.0
Baghla (250 ha)	7.3-8.8	63-292	42-106	35-90	14-34	280-330	280-360	2.4-4.9
Nalkari (992 ha)	7.8-8.3	100-120	48-55	40-45	14-19	Tr-70	Tr-60	9.0
Sarni (1012 ha)	6.8-7.7	133-350	62-94	52-53	14-20	10-272	10-70	2.5-6.3
Namana (528 ha)	8.5	379-473	16-58	12-40	8-16	Tr-110	154-163	4.3-17.0
Chapparwara (200 ha)	8.0-8.4	-	76-100	-	-	400-1100	110-160	1.9-8.0

Table 3. Sediment characteristics of some small reservoirs

Reservoirs	pH	E.C. mS/cm	Organic carbon (%)	Total nitrogen (%)	C/N	Available nitrogen (mg/100 g)	Available-P (mg/100 g)
Thirumurthy	6.5-7.9	0.17-4.0	0.28-3.7	-	-	44.0-47.6	0.22-0.40
Aliyar	6.42	-	0.82	0.06	13.9	29.2	3.30
Sarni	5.96-6.94	-	1.05-1.51	0.11-0.19	6-13	40-43	Tr-2.2
Manchanabele	4.59-4.96	0.9-1.34	1.76-1.81	0.12-0.32	6-15	50.4-89.6	0.73-0.98
Kyrdemkulai	5.9-7.6	0.087-0.12	0.29-1.63	-	-	7.7-32.33	0.59-1.12

Table 4. Production potential of small reservoirs (kg/ha/y)

Reservoirs	Potential	Actual
Manchanbele (329)	694	118
Aliyar (320)	250	193.8
Thirumoourthy (388)	268	213
Sarni (1012)	140	56
Nelligudda (80)	840	1825
Kyrdemkulai (80)	571	-
Gulariya (300)	200	150
Bacchra (140)	240	139
Baghla (250)	200	104
Govindgarh (307)	220	60
Kulgarhi (193)	45	7.4
Loni (350)	36	27

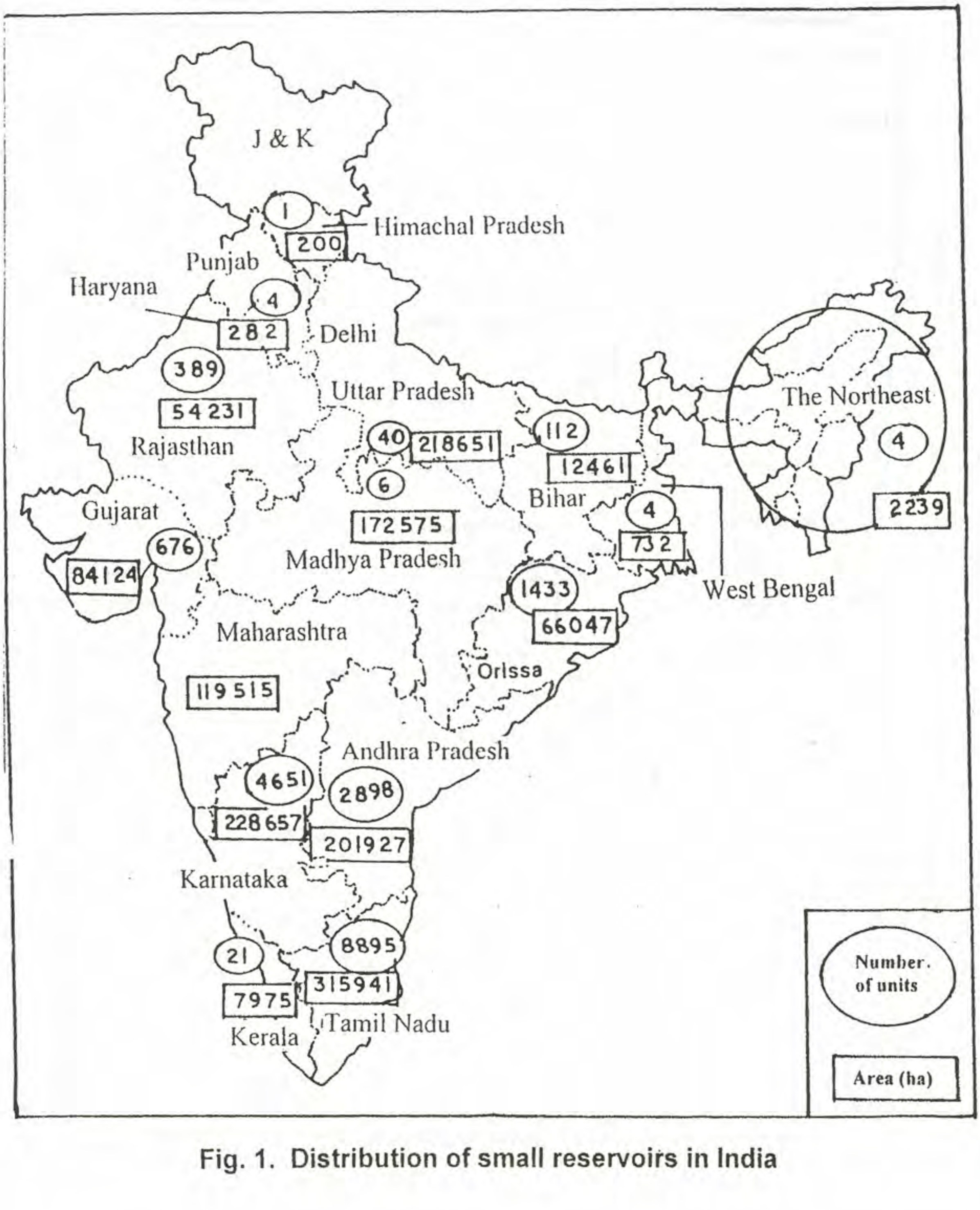


Fig. 1. Distribution of small reservoirs in India

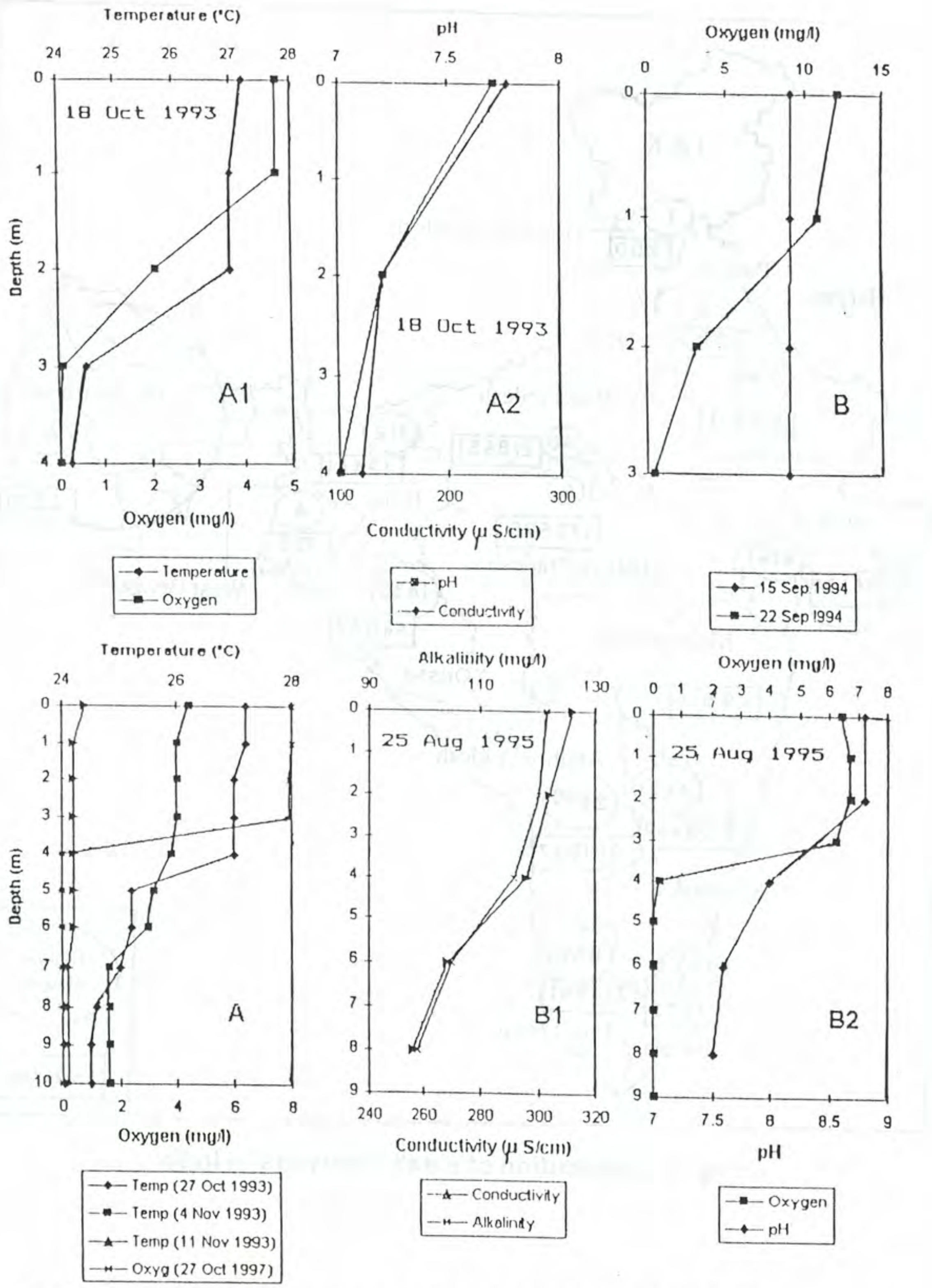
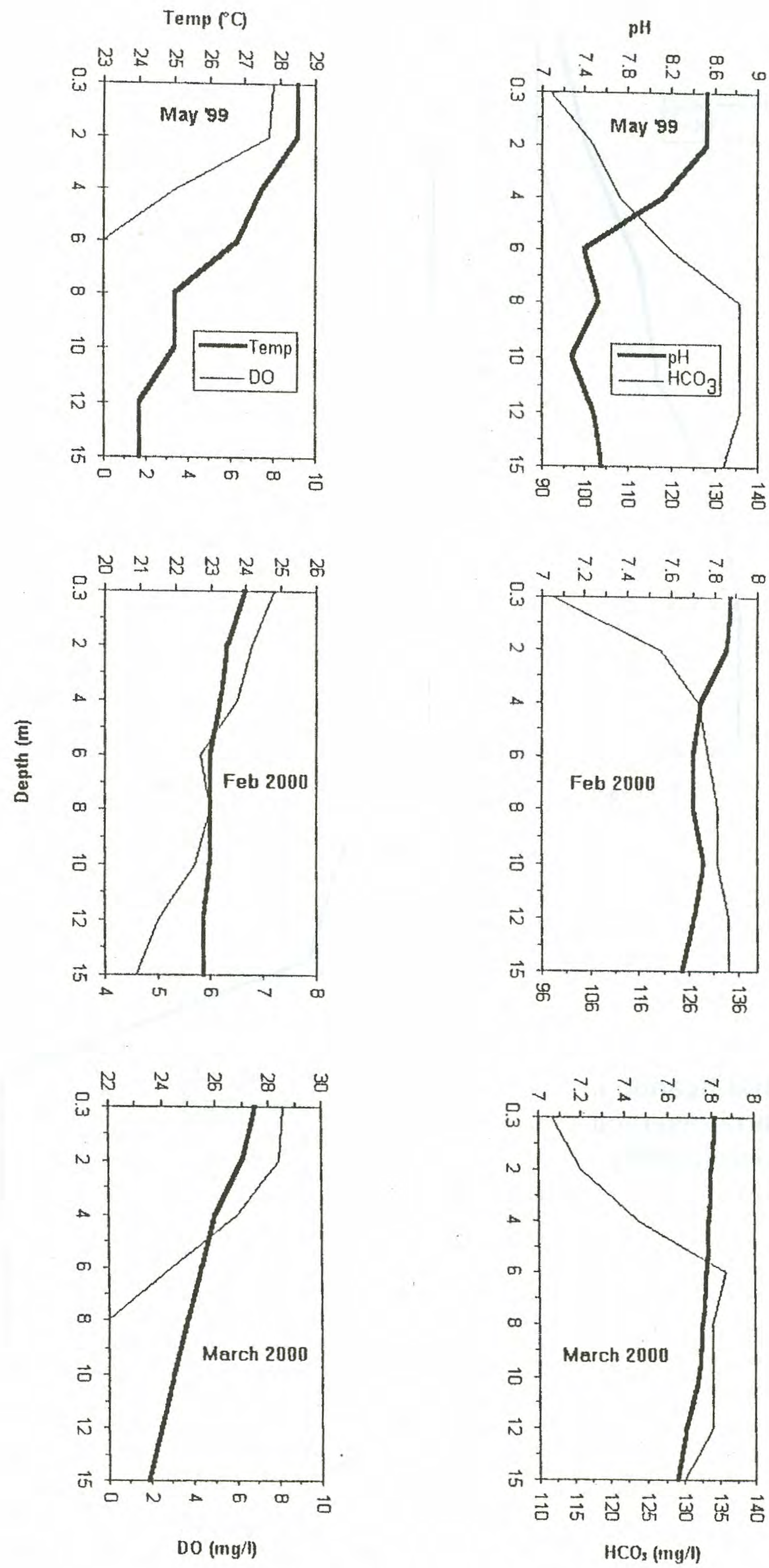
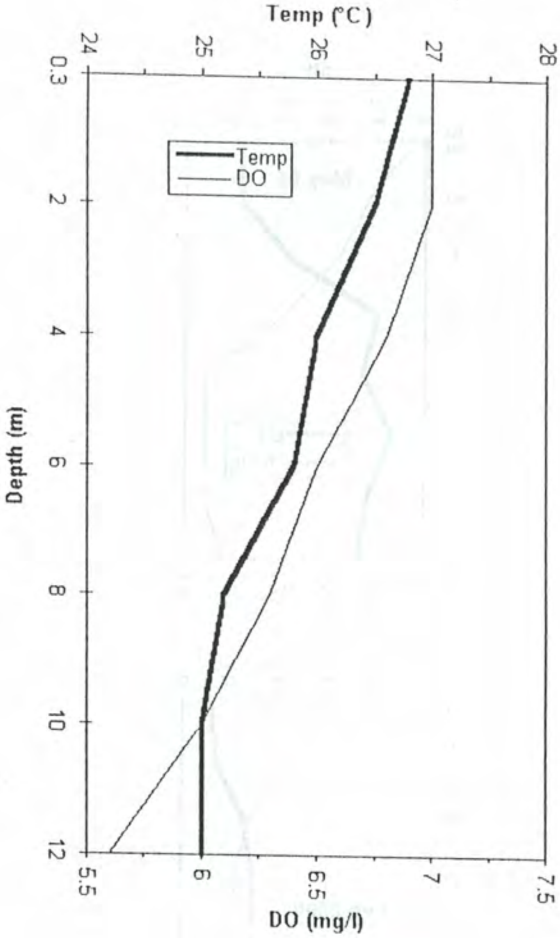
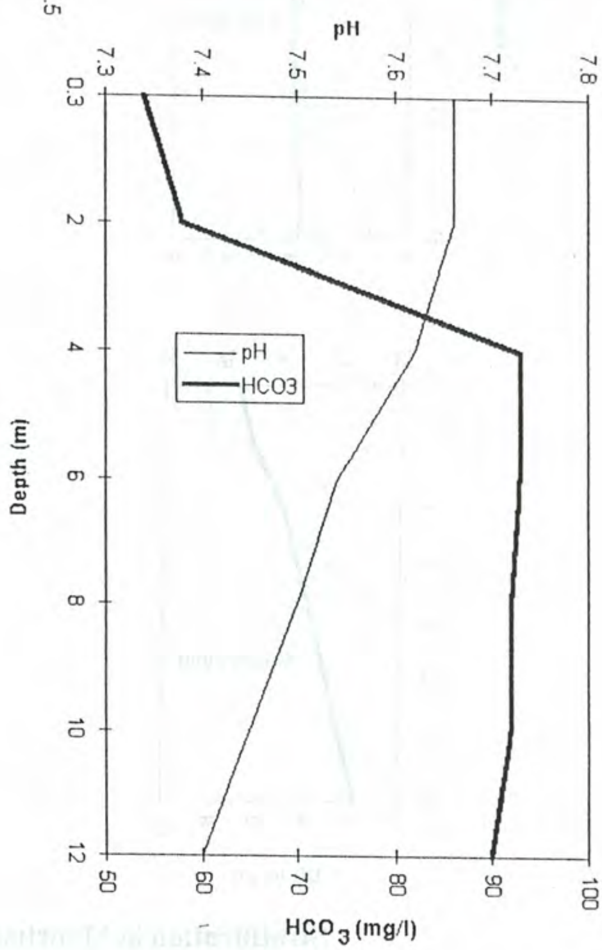


Fig. 3. Vertical profiles of temperature and chemical parameters on chosen dates.



Stratification in Manchanbele (1999-2000)





Stratification in Sarni reservoir (March 2000)

National Training on *Management of Small Reservoirs*
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Yield Optimization in small reservoirs -- Case studies

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Introduction

Reservoirs or man-made lakes constitute an important inland fishery resource of India. Their area is increasing at a galloping pace year after year. According to an estimate, there are 19000 (14,85,557 ha) , 180 medium (527541 ha) & 56 (1,140268 ha) large reservoir. Reservoirs are generally classified as small (< 1,000 ha), medium (1,000 to 5,000 ha) and large reservoirs (> 5,000 ha). Small reservoirs differ significantly from the large and medium ones (Table 1). In large reservoirs, fisheries management lays emphasis on establishing relatively self sustaining populations more or less on capture fishery norms, while small reservoirs essentially require a stocking and recapture policy on an annual basis which is more akin to extensive aquaculture system.

Aquaculture techniques in small reservoirs

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

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^{-1} in 1959-60 although the yield declined drastically in the latter years due to missmanagement. 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. Rannges of key limno-biological parameters of certain small reservoirs on which CIFRI has conducted studies is portrayed in table -2 & range of key chemical parameters for various types of reservoirs based on productivity levels in table 4.

Stocking policy

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

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

During summer months, small reservoirs either dry up completely or else the water level in them get so drastically reduced that through over-fishing no brood stock is left over to contribute to the succeding years' fishery through natural recruitment. Consequently, the entire catch from these water bodies depends on the fishes stocked from out side to offset this loss. Thus, there establishes a direct correlation between the stocking rate and catch per unit effort in such heavily fished waters (Jhingran *et al.*1981, Khan *et al.* 1990 *a,* Selvaraj *et al.*, 1990). Stocking is, therefore, a useful tool for the management of small reservoirs. The number of fish to be stocked per unit area is to be determined on the basis of natural productivity of the system, growth rate of fishes, natural mortality rate and escapement through the irrigation canal and spillway.

A number of methods are in vogue for assessing the potential fish yield from lakes and reservoirs (Jhingran, 1986, Khan *et al.*, 1990 b). Most common approach towards formulation of stocking policy is to assess the potential of the reservoir by any of the methods (MEI, Gulland Model, Trophodynamic model) and adjustment of stocking rate to approach the potential yield. In the Indian context, trophodynamic model is found to be more suitable than MEI approach (Jhingran, 1986, Khan *et al.*,1990 b).Which may be stated as follows:

The Stocking rate = $\frac{\text{Expected production (kg)}}{\text{Individual Growth rate (Kg)}}$ + Loss due to mortality and escapement %

Case studies

To establish a base line for evolving suitable management measures towards fishery developments in small reservoirs, the CIFRI has initiated investigations on small reservoirs of M.P.*viz.* Loni, Kulgarhi, Govind sagar& Naktara; Gulariya , Bachhara & Baghla in U.P. ; Aliyar Reservoir in Tamil-Nadu & Kyrdemkulai in Meghalaya .In these reservoirs , invesgations on Hydrology ,Primary roductivity , Plankton, Macrobenthos ,Macrovegetation &Water & Soil characteristics have been conducted& results are presented in Table- 2.The critical evaluation of these parameters indicates that these reservoir can support moderate to high fish production. However, to elucidate that how fish production can been enhanced by application of scientific management based on ecological parameters , the success story of the two small resrvoirs one located in north India (Bachhara Reservoir) and another in south India(Aliyar Reservoir) is described.

Bachhara Reservoir

Description of the reservoir : The reservoir came into being as a result of damming of the Bachhara rivulet in 1981. The reservoir is situated in Meja-Tehsil of district Allahabad approximatly 55km from the Allahabad. The waterspread area at FSL (111m) above MSL is 140 ha. The gross storage capacity at FSL is 7.42 m. cu. m. & .03 m. cu.m.at DSL respectively. The average depth of the reservoir is 5.22M.An irrigation canal also originates from the bed level of the reservoir. Reservoir does not completely dry up in the summer & maintains a minimum widespread area of about 2-3 ha. The catchment area consists of rocky terrain covered with sparse forest & receiving an average rainfall of 900 mm / annum.

Fish & Fisheries : Fish fauna comprised of 51 species of fishes mainly belonging to carps & catfishes. The reservoir at the initial filling (1980) was dominated by weed fishes, though their population was very sparse. It was auctioned by Irrigation department in 1981 & the contractor fished out all the stock by deploying various types of gears & left over fish-stock by poisoning. Therefore, when reservoir was taken on lease from the Irrigation department by CIFRI in 1985, the entire stock has to be rebuilt afresh by stocking major carps fingerlings. The reservoir was auctioned for a sum of Rupees 63,000 in 1986. The commercial fishing commenced immediatly, resulting in a total catch of 48.5 Qt giving a fish yield of 67.6 Kg ha^{-1}. The low yield was due to incomplete harvesting as the contractor terminated the fishing in middle of the season. The reservoir could not be auctioned in 1987 due to offer of low bidding However,it was again auctioned in 1988 for an amount of Rs 32,300/,& a fish yield of100 Qt or139 Kg ha-^{1}.was obtained.

Estimation of Potential Fish yield & the Stocking rate : The potential fish yield of the reservoir was estimated using trophodynamic model based on energy flow through different trophic levels and standing crop of fish .The annual carbon production estimates for Bachhara reservoir fluctuated between 1250 t and 1402 t during 1982 to 1987. Based on the concept of Odum (1960) that 1.2% of primary production converted to fish flesh is excellent, the reservoir should give a fish yield of 212 to 240 kg ha^{-1}. Against this, an actual fish yield of 67.40 and 139 kg ha^{-1} was obtained, the conversion efficiency being 0.314% to 0.58 % during 1986 and 1988 respectively.

The stocking rate for Bachhra reservoir was estimated on the basis of its potential fish yield of 212 to 240 kg ha^{-1}(1982-1987). Further, assuming that about 80% of the potential yield (173kg ha^{-1}) would be harvestable in view of the drastic diminishing water level. The stocking rate was computed by using the following formula.

$$\text{Stocking rate} = \frac{\text{Gross or total production in (kg)}}{\text{Individual growth in kg}} + \text{Loss due to mortality \& escapement}$$

Growth rate was estimated based on recover tagged fishes. An average growth rate of 400 g per annum was computed for major carps. A loss allowance of 75% was given in view of small size and escapement of fingerlings through irrigation canal, natural mortality and predation by various piscivores. Thus,

$$\text{Stocking rate} = \frac{173}{0.4} + \text{loss} = 432 + 324 = 756 \text{ fingerlings ha}^{-1}$$

The total fingerlings required for an area of 72 ha (half of the FSL) = 54432 , say 55000. Therefore, 55,000 fingerlings of major carps, average size 55 mm (mrigal, 45% ; rohu, 40% and catla 15%) were stocked in 1985, 37000 in 1986 and 63000 in 1987 . The stocking rate was reduced in 1986 in view of profuse breeding of carps in 1986.

Finally, it is suggested that a management calender should be prepared for small reservoirs. This should be based on ecological approach viz., stocking rate based on potential yield, appropriate time of stocking, preferably August, so as to allow 10 to 11 months fattening time followed by complete harvesting of the stock.

Aliyar Reservoir

It is a small impoundment of 646 ha at the full reservoir level and 2.5 ha at dead-storage level, with an average area of 324 ha. Constructed across Aliyar River in 1952 ,with its poor catchment area, it receives its water supply from Upper Aliyar reservoir through a hydroelectric power station at Navamalai and Parambikulam reservoir (Kerala) through a contour canal. The reservoir with its maximum depth of 36.5 m and mean depth of 18.2 m, exhibited the annual fluctuation ranging from 13.15 m in 1986 to 31.03 m in 1987 as against its average fluctuation of 21.0 m. Its ecosystem is devoid of macrophytes.

Fisheries of Aliyar reservoir during 1962-1985

The reservoir was stocked mainly with medium and minor carps such as *Puntius carnaticus, P. dubius, L. kontius, Labeo fimbriatus, L. calbasu, Cirrhinus reba, C. cirrhosa, Acrossocheilus hexagonolepis* and *Tor khudree*. Their contribution ranged from 85.512%(1965-66) to 100% (1962-63) as against the meagre quantity of major carps stocked during the first five years. The production ranged from 2.67 to 54.43 kg $ha^{-1}yr^{-1}$ during the period of 1964-85. The contribution by the miscellaneous uneconomic species has been invariably higher than the major carps. Hence, the net revenue had been also poor during the above period.

Fish Yield During 1985-86

Investigations carried out on the ecology and fisheries of Aliyar reservoir during 1983-85 under the All India Co-ordinated Research Project could delineate the factors responsible for low production. Though the composition of major carps had gone up to more than 98% during 1983-84 and 1984-85, (due to persistent stocking of major carp fingerlings specilly from 1981 onwards.) but , size of fingerlings to be stocked and the stocking schedule were not maintained. Since 1985-86, fingerlings raised in the farm adjacent to the reservoir were stocked based on a planned schedule.

Thus, a major shift from the traditional stocking policy was effected by stocking fingerlings of major carps alone and their size was maintained at above 100 mm (Table 5). The stocking was done in several instalments spread over all the months of the year (Selvaraj *et al.* 1990). Meanwhile, a strict regulation on the mesh size of the nets operated was imposed. Nets with more than 50 mm mesh bar only were allowed to be operated so that fishes of more than 1 kg only were harvested. As a result, there was a substantial increase in the fish yield during the period of 1985-88 (Table 6), consequent to the contribution by the stocked varieties of the major carps (Table7).

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Table 5. Stocking of fingerlings (100 mm) in Aliyar reservoir during 1985-88.

	C. catla	*L. rohita*	*C. mrigala*	*C. Carpio*	*H. molitrix*	Total	Rate ha^{-1}
1985-86	25.729	18,764	16,608	15,243	131	76,475	236
1986-87	23,777	12,248	14,556	18,409	4509	73,499	226
1987-88	71,030	37,679	47,475	45,300	5031	2,06,515	637

Table 6 Fish Landings (Kg) from Aliyar Reservoir during 1985 - 88

	C. catla	*L.rohita*	*C.mrigala*	*C.carpio*	*H.molitrix*	Misc.Fish.	Total Yield	Kg ha^{-1}
1985-86	8,252.25	2576.50	6130.70	4964.75	1.850	3265.5	25,191.8	77.75
1986-87	8.728.75	6639.75	14460.75	6807.75	23.000	346.50	37,006.65	114.22
1987-88	4,464.00	4912.50	5948.50	5468.00	1173.000	4175.25	26,141.25	80.68

Table 7. Contribution of stocked and indigenous species to the total fish yield from Aliyar Reservoir during 1985-88

Period species	Total yield (kg)	Stocked species		Indigenous	
		Quantity(kg)	Contribution	Quantity	Contribution (%)
1985-86	25,191.850	21,925.850	87.05	3266.000	12.95
1986-87	37,006.650	36,660.150	99.06	346.500	0.94
1987-88	26,141.250	21,966.000	84.03	4175.250	15.97
Average	29,446.583	26,850.666	91.18	2595.917	8.82

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National Training on *Management of Small Reservoirs*
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BIOTIC HABITAT VARIABLES IN THE SMALL RESERVOIRS AND THEIR ROLE IN THE PRODUCTION PROCESS

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Introduction

Biotic habitat variables plays important role in production processes of reservoir of which ultimate aimed resource is fish. Fishes are mostly dependent on biotic communities for their livelihood. Biological activity of a biotope is influenced by climatic, edaphic and morphometric feature of reservoir. The geographical location affects the metabolism of a reservoir through nutrition supply, shape of basin and the efficiency with which the climatic factors are able to act in the dynamic exchange. From trophic-dynamic view of freshwater ecology, the measurement of plankton productivity, both at its primary and secondary production levels, becomes essential for proper management of reservoirs. Many workers have suggested that an understanding of the production process of invertebrates will facilitate management of fish stocks of reservoirs. Hanson & Leggett (1982) showed that fish yield is related to the mean standing biomass of macrobenthos in a lake, and thus suggested that a general relationship probably exists between secondary productivity and fish production. The importance of secondary producers to the study of fish dynamics is underscored by their trophic intermediacy between fish populations and energy sources.

The success of organisms in regard with its productivity in reservoir ecosystem is determined in part by the suitability of the environment. Among the most obvious aspects of the environment that affect animal production are the average temperature, the ability of the ecosystem to produce sufficient food of acceptable quality, the character of the substrate and the concentration of respirable oxygen. Effect of these factors in the production processes of reservoir are being dealt under following heads.

Temperature

Temperature influences rates of activity from a molecular to an organismal scale. Many production ecologists have found that rates of secondary production increases with increase in temperature. However, production (P) / mean biomass (B) is thought to rise with increased temperature which may be either linear or curvilinear. 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 rates increase, eggs development times decrease, feeding rates increase. These factors tends to increase productivity of biotic communities in reservoirs at high temperature. But Aston (1973) suggests that egg production by oligochaetes declines at high temperature. Pidgaiko *et al.,* (1972) conclude that temperature variation could have either a positive or negetive effect on the productivity of biotic communities depending upon geographic location and basin morphometry of the reservoir. The temperature regimes of reservoirs in north India are lower than that of south Indian reservoirs.Variation of temperature from surface to bottom has been recorded only 3-4°C for peninsular reservoirs (Nagarjunasagar) where as the same for north India has been registered as 10°C (Konar). This can be attributed to less-marked seasonal differences in temperature as one progress towards lower latitudes.

The reservoirs in temperate region often develop a thermocline with the formation of epilimnion, metalimnion and hypolimnion. But in tropical reservoirs there occurs no thermocline and the bottom temperatures are high. All ill-defined thermal stratification, however, may occure (Table 1) as has been reported by Sreenivasan (1969) in few south Indian reservoirs and Patil (1989) in Waghyanala reservoir from central India.

Table 1.Thermal Features of Some Reservoirs

Thermal features	**South India**								**Central India**
	Pykara	Sandynulla	Amara-vathy	Krishnagiri	Sathan ur	Aliyar	Bhavani-sagar	Stanle y	Waghya-nala
Surface 0°C 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°C 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 Stratifica -tion	Nil	Rare	Nil	Very rare (ill-defined)	Nil	Very rare (ill-defined)	Very rare (unstable)	Rare (unsta -ble)	Rare (unstable)

(modified from Sreenivasan, 1969)

Food Production in the reservoir ecosystem

A community of heterotrophs can fix no more energy than the amount made available to them by primary producers, specially phytoplankton . The rates of production of freshwater benthos and zooplankton are positively related to food availability in reservoir ecosystem fixed through autotrophs. Thus, zooplankton and benthos productions are directly related to rates of primary production. Winberg (1971 b) has been more specific hypothesizing that secondary production (Ps) is about 10 % of primary production (Pp), on the average. This suggests that Ps = a + b Pp, where a = 0 and b= 0.1. But Brylinsky (1980) indicated that phytoplankton primary production is a better predictor of zooplankton production than phytoplankton biomass, but the relationship may not be linear. Thus, this equation probably overestimates zooplankton production at low phytoplankton production and makes underestimates at high phytoplankton production. The relationship between phytoplankton production and secondary production is probably also responsible for apparent relationships between secondary production and nutrient conditions and alkalinity. It should also be remembered that quality of food is important in determining the secondary production of both zooplankton and benthos.

Chemical factors influencing the productivity

Values of certain important chemical parameters of reservoir water and soil suggesting high biological productivity are depicted 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		

Dissolved Oxygen

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 (Sreenivasan 1971). In Konar, Tilaya, Rihand and Tungbhadra reservoirs with low productivity such as Orthograde Oxygen distribution was observed.

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.

In a number of South Indian Reservoirs Sreenivasan (1965,1968 and 1970) 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. Jonasson(1978) suggests that sufficient oxygen is important to benthos production because food cannot be metabolised effiiciently at low oxygen level. Aston (1973) suggests that egg production in freshwater oligochaetes is constant with decreasing oxygen concentration until some critical low level is reached.

Influence of miscellaneous ennvironmental factors and reservoir morphometry

Many workers suggest that secondary production decreases with increasing water flow rate. Selin & Hakkari (1982) have suggested a positive relationship with intencity of solar radiation. Burgis(1971) and Paterson & walker(1974) suggest that high zooplankton and benthos production rates should be found in the most stable ecosystems.

Mean depth defined as the volumn of the reservoir divided by area, is considered the most important morphometric parameter. It is indicative of the extent of 'euphotic-littoral' 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 rather than depth alone and all of which contribute to the potential productivity of biotic communities in the ecosystem. Rowson(1955) has observed distinct inflection in the mean depth curves at 18m (this has been in some Indian reservoir at 10m). This suggests that water mass below this depth serves as a 'nutrient sink' And removes nutrients from trophogenic zone in the form of settling seston and phytoplankton when density stratification is in effect.

The literature generally suggests that shallower reservoirs support higher rate of secondary production (Johnson, 1974 & Brylinsky, 1980). Johnson also suggests that the surface area of a reservoir may be important, since in larger reservoirs the profundal zone is 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 in all other areas (Kajak *et.al.*1980).

Status of biotic communities in Indian reservoirs

Plankton : Generally two plankton pulses have been recorded in Indian reservoirs, one in February-June and the other in October-December. The dominance of various groups of phytoplankton, which always prevailed over zooplankton, seemed to vary from year to year. By and large, the predominant group was blue-greens (mostly *Microcystis*) a group not noted for passing their high productive capability directly to the higher trophic levels. Bacillariophyceae were mainly constituted by *Synedra, Navicula, Fragilaria, Melosira* and *Gyrosigma;* Chlorophyceae contained *Oedogonium, Spirogyra, Pediastrum, Botryococcus, Pandorina* and *Eudorina* as dominant forms.

Zooplankton are predominately represented by Copepodes comprising *Diaptomus* and *Cyclops* while rotifers are represented by *Keratella, Brachionus, Polyrathra* and *Filinia.* The general trends of abundance were found to change due to rainfall and nutrient from runoff. Maximum numbers developed from April-June and minimum in July-August in most of Indian reservoirs. Zooplankton are main food constituent of major carp species as well of weed fishes hence these have major role in the production process of reservoirs for suitably augmenating its fish yields.

Periphyton (Aufwuchs)

Periphyton forms the food source of browsing fishes and takes the form of a brown or green layer at the surface of submerged objects in reservoirs. This group is represented mainly by diatoms, green algae and blue-greens. Periphyton develop best in littoral areas of the reservoir.

Macrobenthic invertebrates

The high shoreline development, variable slopes and vegetation association produce a large number of possible benthic habitats in reservoirs. The maximum concentration of benthic animals in Indian reservoirs (Tungabhadra, Konar, Tilaiya and Loni) has been observed in the depth range of 4-10 m. Below the drawdown limit, redeposition of sediments reduced their number significantly. Krishnamurthy (1966) observed that gastropodes (*Viviparus, Melanoides, Gyrulus*) were predominant in Tungabhadra reservior from April- November, bivalves (*Lamellidens, Corbicula, Parreysia*) in May and October and Oligochaetes (*Tubifex*) in October. Mayfly nymphs (*Pentagenia*) were abundent in summer months influenced by sandy and silty bed of the lotic zone where food was available in the form of bottom ooze containing disintegrated phyto and zooplankton. The diatoms and desmids present at the bottom provided the food. Chironomidae appeared to dominate in humic soils.

Importance of bottom biota as fish food is well established. many of bottom feeding riverine species have adopted themselves to lacustrine conditions. They are *Puntius dubius, P.hexagonolapis, P.kolus, Labeo calbasu, L.dero, Cirrhinus cirrhosa, C.mrigala* and *Pangasius pangasius*. Thus, the benthos represents an important link in the production process of reservoir ecosystem.

Energy Sources and its transformation in Reservoir

Resrevoirs get the utilizable energy for production both from autotrophic energy fixation and allochthonous sources. According to Natarajan (1976), the energy fixed by the producers was in the range of 3,803 to 11,696 calm^{-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. 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 conservations in four reservoirs.

	Bhavanisagar	Nagarjunasagar	Rihand	Govindsagar
1. Location	11°5'N	16°34'N	24°N	31°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 $m^{-2} yr^{-1} \times 10^5$	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) $gO_2 m^{-2} yr^{-1}$	870.890	590.930	377.04	1159.97
(c) Energy cal $m^{-2} yr^{-1} \times 10^6$	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 $ha^{-1} yr^{-1}$	79.200	10.000	4.0	71.4
(b) g $m^{-2} yr^{-1}$	7.920	1.000	0.40	7.14
(c) Energy cal $m^{-2} yr^{-1}$	9.500	1.200	480	8.568
6. Conversion of energy				
(a) Fish/photosynthesis 5(c) - 3(c)	0.290	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)	0.900	0.170	0.105	0.61
8. (a) Photosynthesis (gC $m^{-2} yr^{-1}$)	326.580	221.600	141.39	435.0
(b) Fish yield as (gC $m^{-2} yr^{-1}$)	0.792	0.100	0.04	0.714
(c) % Conversion	0.240	0.045	0.028	0.164

(Jhingaran, 1991)

Table 4 . Energy Transformation through primary production in different reservoirs.

Reservoirs	Location	Incident visible radient energy (cal $m^{-2} day^{-1}$)	Energy fixed by producers (cal $m^{-2} day^{-1}$)		Photosynthetic efficiency (%)		Net energy stored by producers (cal $m^{-2} day^{-1}$)	Energy lost as respiration(cal $m^{-2} day^{-1}$)
			Enegy as Oxygen	Energy as Carbohydrate	Enegy as Oxygen	Enegy as Carbohydrate		
Bhavanisagar	11°5'N	21,30,900	8,781	9,168	0.412	0.430	4,610	4,172
Nagarjunasagar	16°34'N	20,50,300	5,959	6,221	0.290	0.303	3,450	2,509
Ukai	21°15'N	19,55,000	6,175	6,671	0.320	0.340	4,910	1,227
Getalsud	23°27'N	19,25,000	2,721	3,100	0.148	0.161	1,368	1,353

Rihand	24°N	18,83,750	3,803	3,970	0.202	0.211	1,580	2,217
Govind-sagar	31°25'N	17,19,900	11,696	12,210	0.682	0.710	7,626	4,071

(Jhingaran, 1991)

Production processes and energetics of reservoir ecosystem

In a newly constructed reservoir, nutrients leaching from unflooded substrate, submerged forests and other organic matter, effects high initial fertility in the ecosystem. This accelerates the growth of bacteria, phytoplankton, zooplankton and benthos. The maximum productivity in newly fillled reservoirs is obtained within the first few years of their existence. In Rihand and Gandhisagar reservoirs, fish yield reached its initial peak in the fourth year of impoundment. However, this high production is not sustained for long and after a period , ranging from one to several years, it declines nearly half the magnitude of initial phase (Bhukswan, 1980) due to increase in the volume of impounded water and partly as nutrient are used up by aquatic vegetation. Thus, productivity process in the reservoir is getting adjusted to the basic productivity levels of the basin and allochthonous nutrients.

Although variable from season to season, such as considerable allochthonous energy accumulates in the reservoir system which is either deposited accelerating eutrophication or else it enters the food chain in significant quantities. However, reservoirs differ considerably not only with respect to incident light energy but also the efficiency with which this energy is converted to chemical energy by primary producers. Also efficiency of energy flow from producers to different trophic levels of consumers differs considerably from reservoir to reservoir depending upon the qualitative and quantitative variations in biotic communities inhabiting the reservoir.

For trophic -dynamic concept of ecology, Lindeman (1942) suggested that if one could reduce the interactions among components of a community to a common currency (e.g. energy), then one could quantify the interactions and learn to predict changes such as succession with in ecosystems. Lindeman also introduced the major concept that an organism's success in an environment might be a function of its ability to fix and retain energy. Thus, the role of important biotic communities like plankton and benthos may be expressed according to Edmondson (1974) that secondary production cannot be thought of as a distinct process by itself. Rather it is part of a larger scheme of the movement of material through the ecosystem, and this is based on the activities of individuals and populations of animals. Precisely the trophic-dynamic goal of production ecology of reservoir is a formidable goal. But productivity potential of reservoirs can be assessed through chemical parameters, primary and secondary productions, energy assimilation efficiencies at different trophic levels, morpho-edaphic and morpho-drainage indices etc. Accordingly appropriate management practices may be judiciousely applied for augmenting fish yield from reservoir.

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Community Metabolism (Energy Dynamics) in the Context of Fisheries of Small Reservoirs

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Introduction

Reservoirs are manmade ecosystems without parallel in nature. The deep deep water release and fluctuating morphometric and hydrological characters differentiate them from their lake counter parts. Attempts have been made to classify these ecosystems on the basis of either their morphometric features into large medium and small reservoirs or on the basis of their hydrological characters into productive medium productive and low productive. The biotic communities present in these aquatic systems producers, herbivores detrivores, carnivores and decomposers are linked with one another with energy chains. Energy enters the biological system by fixation of solar electromagnetic waves by producers through photosynthesis, and leaves the system as heat of respiration after undergoing a series of conversion and degradation processes according to the, fundamental laws of thermodynamics. The entire functioning of the system depends on these conversion and degradation processes, and the time lag in between. In order to study the energy, dynamics or community metabolism from solar radiation upto the end product fish two types of studies are essential.

1. Quantitative assessment of organic matter synthesised by photosynthetic organisms i.e. transformation of solar electromagnetic waves into chemical energy.

2. The various pathways of energy transformation that ultimately leads to the end product i.e. flow of energy from producers to consumers at different tropic levels.

The first of these processes gives a measure of potential energy resource of the system and the second gives an extent of utilisation of these potential source consumers.

Many workers have studied the flow of energy, in different aquatic ecosystems (Juday 1940, Lindeman 1942, Teal 1957.Odem 1975, Ganapati 1970, Natarajan and Pathak 1980.1983 etc.). These authors have suggested various trophic dynamic models to explain the productivity of aquatic ecosystem. However more critical examination of these processes are necessary in order to formulate the management norms of the best possible utilisation of available energy to enhance production specially in case of small reservoirs which are under human control. Present communication gives a detailed account of energy dynamics of these ecosystems based on the investigations carried out both in large and small reservoirs.

Transformation of solar energy into chemical energy by producers.

The energy source for all the living organism in any aquatic system is sun, which releases energy by nuclear transmutation from hydrogen to Helium in the form of electromagnetic waves in a wide range of wavelength varying between 1A° and 1,35,00 A°. Only a small fraction of this energy in the wavelength range 3,800 A° to 7,800 A° (visible rays is captured by chlorophyll bearing producers. transformed by them into chemical energy and stored as energy, rich organic compounds. The process of transformation of solar energy is represented by basic photosynthetic equation

$$6\ CO_2 + 6H_2O\ \text{solar energy}\qquad C_6\ H_{12},,\ O_6 + 6\ O_2,.$$

or in a general way,

$$n\ CO_2 + n\ (\text{H.donor})\ (C_6\ H_{12,}O)n, + n\ (\text{Oxidised donor})$$

This redox process is endergonic in nature and consequently plants can store large amount of energy in the form of energy rich organic compounds through this process. As the energy stored by the Producers flows to consumers at different levels measurement of rate of conversion of solar energy in the system gives a dependable parameter for the assessment of productivity potential of the system. The efficiency of energy transformation, known as photosynthetic photosynthetic efficiency can be written as :

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

The energy required to synthesise one molecule of glucose through photosynthesis or to reduce six molecules of carbondioxide or to liberate six molecules of oxygen is 709 calories and thus approximately 3.68 cal of energy is required to liberate one mg of oxygen. Measurement of rate of liberation of oxygen (dark and light bottle technique) or rate of carbon fixation (C-14 technique) gives a measure of rate of transformation of solar energy into chemical energy or energy fixed by producers part of energy fixed by producers is used by them for their own metabolic activities and lost of heat of respiration while the remaining part is stored by them (net production) and thus.

Gross energy fixed by producers Net energy fixed +Energy; lost as respiration

The rate of energy transformation by producers and photosynthetic efficiencies in some reservoirs have been presented in table -1.The reservoirs include in the present study differ considerably both in the magnitude of available radiant energy and the photosynthetic energy fixation rate. Available light energy varied from reservoir to reservoir depending on their location (latitude). The light energy was in the range of 1720000 Cal m-2day-1 in Govindasagar to 2150000 cal m-2 day-1in Aliyar and the energy fixed by primary producers ranged from 2566 calm-2 day (Khandong) to 13580 cal m-2 day=1(Aliyar). Thus only 0.137% to 0.682% of the available light energy was fixed by producers in the reservoirs under study Gessner (1960) observed that euphotic lakes in temperate regions have a gross energy fixation rate of the order of 1800 to 18400 cal m^{-2} day^{-1} during period of maximum growth. In lake Victoria the average daily estimate was 26,054 cal^{-2} day^{-1},Talling (!961).Ganapati (1970) noted average daily production of 20054,cal^{-2} day^{-1} and 10598 cal^{-2} day^{-1} 0n Amaravati and Stanley, two tropical impoundment's in southern India.The chemical energy fixed by producers in present reservoirs and the efficiency energy transformation compare well with the finding of above workers. Studies have shown that 41.7 to 80% of the energy fixed by producers was actually stored by them (net production) and the remaining was lost as respiration (Table -!). In addition to the energy fixed by producers some amount of energy also enters the reservoirs through allochthonous sources, from catchment runoff in the inflowing waters. Thus

Total energy available = Energy import from allochthonous sources + Energy fixed by photosynthetic organisms.

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

The biotic communications present in the aquatic system are inter linked with one another. The complex relation's ship of food chain and flow of energy in community metabolism are great importance. A proper understanding of the trophic dynamics of aquatic ecosystem in turn help in formulating policies for stock manipulations. There are two main routes, through which energy flows in an aquatic system, one of which has been emphasised, much more than the other. The first of these involves grazing of green organisms (producers) by herbivores or plant feeders which are inturn taken by predator thereby the energy of photosynthesis is transferred to consumers. This is commonly known as grazing food chain.The second path way which has largely been neglected involves flow of energy from dead organic matter deposited at the bottom through the detrital food chain. The two pathways are shown below:

Energy at first trophic level (producer level)

{ Herbivores ⟶ Predators ⟶ Grazing chain

{ Dead organic matter (Organic detritus) ⟶ detritus feeders (detritivores) ⟶ Predators ⟶ Detritus chain

There is a number of restricting conditions for the transfer of energy from primary producers to secondary or consumers due to distinctively selective feeding nature of consumers. Thus all the energy represented by primary producers is not always utilized directly and the unutilized energy reaches the bottom after the death of organisms. This energy is utilized by the detritus chain.Juday (1940),Lindeman (1957),Teal(1957),Odem (1975) and Natarajan and Pathak (1980) studies the flow of energy in different aquatic systems and have shown the importance of detritus chain.

The patterns of energy utilisation in some reservoirs have been shown in Table-2. Among this three large reservoirs only Govindsagar, where 70% of energy harvest as fish was contributed by primary consumers (mainly grazing hervivores), has shown better utilisation of energy while in Nagarjuna Sagar and Rihand either the available energy is not fully utilised or mainly by secondary or tertiary consumers.The conversion efficiencies either from photosynthetic production to fish or light to fish was much better in Govindsagar (0.20% & 0.0013%) Than the other two.The energy utilisation in small reservoirs Aliyar,Bhavanisagar and Bachhra was mainly through detritus chain and 69 to89% of the energy harvest as fish was contributed by primary consumers. These reservoirs have shown better conversion efficiencies both from photosynthesis to fish (9.132 to 0.355%) and light to fish (0.00083 to 0.00182%). In other two upland reservoirs Khaneng and Umrang the fishery is yet to be established and with very poor yield these reservoirs have not shown any significant pattern of energy utilisation.

Nikolsky (1963) stated "the nearer the useful end product stands to the first link in the food chain the higher yield from the water mass" as the loss of energy will be much higher if the chain is longer. Accordingly, if the water body is dominated by primary consumers (Either herbivores or detritivores) the efficiency of conversion or energy harvest will be better. This can be seen from the results presented in table-2. Odem (1975) and Mann (1969) applied the energy flow models for estimating fish production potential of the aquatic systems keeping in view that in passing from one level to the other almost 90% of the energy is lost according to the laws of thermodynamics. Odem (1960 &1962) observed that in large water bodies, which has wide range of fish population belonging to various tropic levels, the productivity potential can be taken as 1% of gross or 0.5% of then net energy fixed at producer level.

Natarajan and Pathak (1983) calculated the fish production potential of a number of Indian reservoirs taking energy at fish level as 0.5% of the net energy fixed by producers.Applying the energy flow approach the fish production potential of reservoirs mentioned above (as Kcal ha-1yr-1) comes to 316800 in Givind Sagar,143208 in Nagarjuna sagar,65688 in Rihand,347616 in Aliyar, 191352 in Bhavani sagar 318648 in Bachhra 65699 in Khandong and 70992 in Umrang. Thus from 6.2 to 49.0% of the potential is actually being harvested from these reservoirs. Higher values observed in Bhavanisagar, Bachhra and Govind sagar clearly shows better utilisation of energy in these reservoirs.

The energy flow approach of the ecosystem do take into account the various trophic levels but this approach has disadvantage that many fishes are omnivorous and thus cannot be assigned to particular level. Moreover the feeding habits of the fishes also change according to the availability of food. Thus one should be very caution while grouping the consumers at various trophic levels.

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Methods of evaluating primary productivity in small reservoir

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Primary productivity is defined as the rate at which inorganic carbon is converted to an organic form. Chlorophyll bearing microscopic organisms such as phytoplankton, periphyton, algae and also macrophytes serve as primary producers in the aquatic food chain. Photosynthesis results in the formation of a wide range of organic compounds, release of oxygen and depletion of carbon dioxide in the surrounding waters. Rates of photosynthesis in small water bodies are related to phytoplankton abundance and light intensity. Assuming equal light intensities; the photosynthetic production of dissolved oxygen will increase as function of phytoplankton abundance. In fish ponds phytoplankton is the major source of turbidity, so light penetration is generally related to phytoplankton abundance. Hence phytoplankters are limited to shallower depths as their abundance increases and there is a strong vertical stratification of photosynthetic rates and dissolved oxygen concentrations. In intensely manured fish ponds, primary productivity increases in upper layers of water, where favourable light conditions exists, but decreases in lower layers where overshadowing by the plankton reduces light penetration(Hepher, 1962).

On clear days, photosynthesis rates increase rapidly after sunrise and remain high up to afternoon, although the afternoon rates may be somewhat less than morning rates. Cloudy skies always cause a decrease in photosynthetic rates.

The primary productivity in oxbow lakes may be quite different to that of pond ecosystem. The beel ecosystem generally contains large amount of submerged aquatic weeds, so greater photosynthetic rates and oxygen concentrations were noted in the weed beds of the beels.

Factors regulating primary production

The factors which regulate the magnitude, seasonal pattern and species composition in phytoplankton photosynthesis are light, temperature, nutrients, physical transport process and herbivory. Photosyntheticlly active radiation or light from 400-700 um is a most important factor for photosynthesis which provides the major source of energy for these autotropic organisms.

During sunny days, the photosynthesis is generally poor at the surface layer. After a little depth maximum photosynthesis was noted. Rate of photosynthesis diminishes at higher depth due to poor light availability. At very high light levels, photosynthesis may decrease because of light inhibition(associated with photochemical destruction of pigments). The depth at which gross photosynthetic rate is equal to algal respiration rate is called the compensation depth which is equal to 2.5 times the Secchi depth. For deep and turbid lake water the light regime in the top layer of a stratified system is often more congenial for phytoplankton photosynthesis than a vertically well mixed system.

Phytoplankton require N, P, Si, Mo, Zn, Mn, Ca, CO_2 and viatmins for their growth and sustenance. However, the most important are the macronutrients (C, N, P, Si). Phytoplankton growth and photosynthesis are in general congenial in the temperature range of 20 to 25°C. Above 30°C the phytoplankton productivity may be affected adversely.

Methods of estimation of primary production : (A P H A, 1980)

a) Oxygen method by measuring the changes in oxygen and CO_2 concentration (light and dark bottle method)
b) by recording the change in pH
c) Diurnal studies in D.O. Concentration
d) the ^{14}C techniques

Oxygen method

The basic reaction in algal photosynthesis is

$$(CO_2)N+(H_2O)n \xrightarrow[\text{Chlorophyll Catalyst}]{\text{light}} Cn(H_2O)n + nO_2$$

Thus, during photosynthesis, the phytoplankton and other aquatic plants absorb carbon dioxide and liberate oxygen. In oxygen method, clear(light)and darkened (dark) bottles are filled with water samples and suspended at regular depth intervals for an incubation period of 3-5 hours or the samples may be incubated under controlled conditions under artificial illumination in environmental growth chambers in the laboratory.

The advantage of oxygen method is that it provides estimates of gross and net productivity and respiration which can be performed with inexpensive laboratory equipment and common reagents. The DO concentration is estimated at the beginning and end of incubation period. Productivity is calculated on the assumption that one atom of carbon is assimilated for each molecule of oxygen released.

Procedure

1) Estimate the solar radiation with a pyrheliometer
2) Determine depth of euphotic zone (the region that receives 1% or more of surface illumination) with a submarine photometer. Select depth interval for bottle placement.
3) Introduce samples taken from each pre-selected depth into duplicate light bottle,dark bottle and initial analysis bottle, use water from the same grab sample to fill a set (i.e., one light, one dark and one initial bottle).
4) Determine the DO of the initial bottle by Winkler method with Manganeous sulphate, alkaline iodide, sulphuric acid and standard sodium thiosulphate using starch as indicator. DO may also be determined with an oxygen prob.
5) Suspend the light and dark bottles at the depth from which the samples were taken and incubate for 3-5 hours.
6) At the end of the exposure period, estimate the DO of both light and dark bottles by Winklers method or by an oxygen probe.

Calculation

$$\text{Gross production} = \frac{\text{LB-DB}}{\text{T}} \times \frac{12}{32} \times \frac{1000}{\text{PQ(1.2)}}$$

$$= \frac{\text{LB-DB}}{\text{T}} \times 312.5 \ \text{mgC/m}^3\text{/hr}$$

$$\text{Net production} = \frac{\text{LB-IB}}{\text{T}} \times 312.5\text{mgC/m}^3\text{/hr}$$

where LB = light bottle, IB = initial bottle, T = Time in hours.

PQ = Photosynthetic coefficient
Respiration = IB-DB x 375 mgC/m^3/hr

Primary productivity is generally reported in grams carbon fixed per m^2/day. Estimate the productivity of vertical column of water 1 metre square by plotting productivity for each exposure depth and graphically integrating the area under the curve. Using the solar radiation profile and photosynthesis rate during incubation adjust the data to represent phytoplankton productivity for the entire photoperiod.

Primary productivity estimation by recording the change in pH

Primary productivity can also be determined by measuring the changes in oxygen and CO_2 concentrations. In poorly buffered waters, pH can be a sensitive property for detecting variations in the ecosystem. As CO_2 is removed during photosynthesis, the pH rises. This shift can be used for estimating the primary production and respiration. However, the method is not very useful where the aquatic system is highly buffered (e.g. Sea, estuaries etc.) but it has been applied successfully in productivity studies in some lake water.

Primary productivity estimation from diel changes of Dissolved oxygen

The dissolved oxygen content in a water body continually changes over a 24 hour period because of the effects of respiration and photosynthesis and due to slow rates of diffusion. The DO content is minimum during early morning, increases during day time and reaches its peak during the afternoon before declining again during night time. The highest content of DO is found in pondswith the greatest abundance of phytoplanton, However,water of these water bodies also has high rates of respiration, hence they have the minimum content of DO in the early morning.

The oxygen method (light and dark bottle techniques) is widely used for determination of primary production. However, 14C technique is more precise and can be used in cases where the productivity is very low. Moreover, certain bacteria such as green sulpher bacteria, purple sulpher bacteria etc. absorbs CO2 and produce carbohydrate in presence of light, but in this photosynthesis oxygen is not evolved.

The over reaction is as follows :

$$6CO_2 + 12H_2O \xrightarrow[\text{709 K. Cal}]{\text{light}} C_6H_{12}O_6 + 6H_2O + 12S$$

(Purple sulpher bacteria)

Similarly,

$$6CO_2 + 15H_2O \xrightarrow[\text{709. Cal}]{\text{light}} C_6H_{12}O_6 + 6H_2O + 6NaHSO_4$$

(green sulpher bacteria)

Determination of primary productivity by 14C technique

This is a method of measuring carbon fixation by using the radioactive isotope ^{14}C as a tracer. Samples of water are collected from different depths and pH, total alkalinity and free CO_2 content in each are measured.

Borosilicate glass bottles (2 light and 1dark) are filled from these samples and a measured quantity (5 u Ci 14C/ml) of Sodium bicarbonate containing ^{14}C is added to each. The bottle are then sealed and suspended in water in situ for a duration of 3-4 hours. If temperature and illumination at the sampling depths are known, the bottles can be immersed in artificial tanks at corresponding temperature and provided with aritificial illumination at the correct intensity. After in situ incubation, the bottles are taken out, fixed immediately with formalin and taken to laboratory for filtration. The water is filtered to collect the phytoplankton on membrane paper (0.45x10.6 m) in Millipore Filtration unit by applying pressure of about 0.5 atmosphere. The filter paper is treated with Hcl fumes for 20 minutes to remove excess 14C in filter paper and then placed in a vial containing 5 ml of Scientillation liquid. The Scintillation liquid is a mixture of xylene (400 ml/1), Dioxane (400 ml/1), Ethyl alcohol(200ml/1), PPO(2.5g/1) and POPOP(0.25g/l). The activity of 14C in the vial is estimated by a liquid scientillation analyser by measuring the B - radiation.

Calculation

Total alkalinity = T

Free CO2 = A

$$\text{Bicarbonate alkalinity} = \frac{T-5x10^{pH-10}}{1+0.94x10^{pH-10}} = B$$

$$\text{Carbonate alkalinity} = 0.9xBx10^{pH-10} = C$$

$$\text{Then total } CO_2 = A+0.44(2B+C) \text{ in water}$$

Sodium bicarbonate content in the radioactive ampoule = D

$$\text{Then, total } CO_2 = A+0.44(2B+C)+D = E$$

$$\text{Total inorganic carbon} = \frac{12}{44} \times E = F$$

Now if the light bottle count = X_1

Dark bottle count = X_2

Total volume of bottle = X_3, Volume filtered = X_4
Time of incubation = X_5, Total activity added to each bottle = X_6
Efficiency of the counter X_7 = appx. 40%

Then, **Net primary production** =

$$\frac{(X_1-X_2) \times \frac{X_3}{X_4} \times 1.064 \times 100 \times F}{X_5 \times X_6 \times X_7} \quad mgC/m^3/hr$$

Here 1.064 is a correction factor for isotope effect.

Primary productivity for the entire depth of euphotic zone may be integrated and expressed as gram carbon fixed per square meter per day. Using the solar radiation records and phytosynthesis rates, during incubation, phytoplankton productivity for the entire photoperiod may be estimated.

Since, oxygen is not evolved, the oxygen method can not give reliable information about the bacterial photosynthesis. Thus, the 14C technique is the best method for productivity studies of inland waters where different organisms contribute towards the primary production without releasing oxygen in the systems. The primary production of 20 fish ponds, located in 4 districts of West Bengal was studied (Nath, 1986, Nath et al., 1994). Highest primary production was recorded during November-December and during March-May. Maximum production was observed just below the surface. The compensation depth in different centres ranged between 66.5 cm and 128.5 cm. Gross primary production of the ponds ranged from 2.4 to 9.14 gC/m3/day.

Primary production of Hooghly-Matlah estuary was studied during 1982-1993 (Nath et al., 1996). Maximum primary production was recorded at Canning in Matlah estuary, which was free from aquatic pollution. The net primary production of different centres of Hooghly Matlah estuary ranged between 0.241 and 0.523 $gC/m^3/day$ and its average net production was 0.380 $gC/m^3/day$. The gross production of different centres ranged between 0.44 and 0.794 $gC/m^3/day$, while the average gross production was 0.629 gC/m3/day. The flood plain lakes of Ganga and Brahmaputra basins had moderately rich primary production which was contributed both hy phytoplankton and macrophytes, the contribution of phytoplankton being comparatively lower than that of macrophytes. In macrophyte dominated beels, the photosynthetic carbon production was 6.138 $gC/m^3/day$ (Pathak et al. 1989).

Indian reservoirs vary widely in productivity depending on nutrient availability and other factors. Thus, poorly productive Bhatghar reservoir (Maharashtra) had low primary productivity(gross 20.8-145.8 $mgC/m^3/day$, net

10.4-83.3 mgC/m^3/day. However, Ganapati(1972) and Sreenivasan(1972) have reported some reservoirs having higher productivity where GPP values ranged from 1.6 to 3.228 gC/m^3/day and NPP ranged from 1.36 to 1.64 gC/m^3/day.

Fish production potential of small reservoirs

The fish production potential of a water body is dependent on its primary production.

In highly managed water body the fish production may be 2% of its gross primary production. However in large reservoirs, the fish production may be 1% of its primary production.poor conversion was generally noted in ecosystem when carninvorus species dominate where as the fish production may be higher where the first growing harbivorus species (e,g carps) dominate in the system.

According to Odum (1960), the fish production potential = 1.2% of the primary production.

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Biological monitoring of environmental quality with special reference to small reservoirs

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Introduction

Environmental contamination is natural or induced happening in almost every sphere on the earth. Of all the ecosystems water resources have high susceptibility to contamination since anything toxic on the earth finds way to waters by any mean or the other. Reservoirs by dint of vastness and dependable resources converge various human activities for water uses. Eventually ecodegradation of these water bodies has been on the increase due to rapid industrialisation, intensified agriculture and ever expanding habitational pressures.

The multipurpose reservoirs specially the small category of the type, are threatened of agriculture, industrial and urban pollution. Reservoir pollution beside shorting quality waters for human uses reduces life-supporting resources for diversed aquatic flora and fauna. At the point of water dearth " Save the waters" mission focusing pollution detection, impact assessment and remedial measures must be given top priority. Further, the threats to aquatic lives and ultimate biomass production from important resources like reservoirs must be looked into and necessary precautions implemented.

Biological monitoring

Biological water criteria are as important as chemical criteria. The chemical surveys indicate water conditions only of a particular point and time of sampling. Moreover establishment of chemical criteria in terms of toxicity to aquatic organisms is difficult and, indeed, may prove to be impossible. The great host of potentially toxic compounds, the vast numbers of species of organisms, and wide range of effects produced by the physico-chemical factors produce permutations, which may exceed the capability of adequate testing. Further, the results obtained in the laboratory usually are not transferable to the field, where numerous other environmental factors may produce unpredictable and uncountable effects. These contraints and impracticabilities suggest developing a meaningful approach to the establishment of water quality criteria by evolution of biological conditions existing in the pollution affected water resources.

Community structure

An eco-system is composed of abiotic and biotic elements in the nature. The action of abiotic environment and co-action between biotic components maintains the ecological balance with tolerable fluctuations of reparable capacity. An unfavourable change like pollution results detectable change in biological components changing community structure.

Biological indicators

The concepts of "biological indicators" is based on the premise that there are species of animals and plants that inhabit only in polluted conditions. Accordingly attempts for search of indicator species was prompted by the desire to find simple methods of biological measurement of pollution requiring a minimum biological knowledge. In the process of identification of indicator species Partick (1953,1956) suggested use of diatoms because of preservation advantage, wide species spectrum, great range of sensitivity to physico-chemical conditions of water, and also availability of a great deal of information on the types of environment in which many of species ate encountered. Likely use of benthos also has been tested and suggested for use in the" indicator species" concepts of biological testing of water quality (Beak, 1958 & 1964; Brinkhurst, 1966). Oligochaete worms, and in particular the genus *Tubifex* as resistant to organic pollution, have been used by Beeton (1965). Beak (1964) suggested the method of biological quantification by deviding the bottom invertebrates into three classes and providing different values for biological scoring.

1. **Group-1** (score point 3) - very tolerant to polluted conditions and frequently occurs in very large number: *Tubifex sp.*

2. **Group-11** (score point 2) - occurs in both polluted and unpolluted situations but not form very large communities: Chironomoid larvae, *Gammarus and Asellus* and many snails, worms and some leaches.

3. **Group-111** (score point -1) - Intolerant of pollution: May flies, stonefliers, dragon fly larvae, trichopteron larvae.

Biological score is allotted to each sample or samples of each station on the basis if the points and a normal unpolluted sample will score 6 points.

Diversity Index

Diversity indexes are mathematical expressions describing community structure and pertaining summarisation of large amounts of information's about members and kind of organisms present. Several workers have proposed diversity indexes over the years. Fisher *et al.* (1 943) proposed a constant "a" as an expression of diversity. Preston (1 948) stated that frequency distribution of an animal population is nearly log- normal. However, later on it was felt that diversity index should reflect not only the distribution of species but should include the relative importance of each species in the community.

Information Theory: Margalef (1956) proposed analysis of mixed species population by methods derived from information theory. Diversity is equated with the incertainity that exists concerning the species of an individual selected at random from population. The more species present in a community and more equal their abundance, the greater the uncertainity, and hence the greater the diversity.

Brillouin (1 960) gave a formula as a measure of diversity per individual

$$H = (1 / N) (\log N! \ \Sigma \log Ni)$$

where N is the number of individuals in "s" species and Ni is the number of individuals in the i-th species. Assuming reasonably large values of N and Ni , the logarithms of the funtions may be approximated by Stirling's formula to yield

$$H = - \Sigma (Ni / N) \log_2 (Ni / N)$$

The population ratios (Ni / N) is estimated from sample values (ni / n) to yield

$$d = - \Sigma (ni / n) \log_2 (ni / n)$$

Community Health

In recent years the environmental impact assessment has given importance on community health stress evaluation as measure for quantification impact of water quality deterioration and food chain disruption or contamination on physiological functions. The exposure of sub- lethal contaminants results little and unexplicable impact on the micro flora and fauna and macro invertebrates but for cumulative effects on animals of higher tropic level like fish. Besides body contact the contaminants get passage to body and organs through ingestion, digestion, assimilation and excretion.

The exposed fishes in the way of body contact and contaminated food intake accumulates toxic elements like metals and pesticides. The cumulative accumulates beyond tolerance levels interfere normal functions of the affected organs and produced abnormalities in the system of respiration, elimentation, circulation, excretion, reproduction and growth. Examinations of physiological functions diagnoses health abnormalities in enviromnentally stressed fishes.

Respiratory Stresses

In natural waters surfacing indicates respiratory stresses. The laboratory testing of opercular movement confirms the field records. For further details histological examination of gills reveals cellular deformties and extent of damages produced through contaminants.

Alementary Stresses

Retarded growth followed by poor gut content indicates elementary stresses. The reasons may be loss of apetite or disfunction of the elementary system if the liked food items are available in abundance. Histological examination of the tissue structure confirms the elementary picture in fish.

Circulatory Stresses

Circulatory quality and volume of blood bear direct relation with respiration through the RBC count and haemoglobin (Hb) contents. Decreased RBC count and Hb concentration affect oxygen transport for respiratory functions. In case, this condition of declined RBC and Hb continues for long, the affected animal suffers anaemic conditions.

Excretory Stresses

Fresh water fishes possess well developed kidney for high and effective glomeruler functions. Morphological defomities like, degeneration and necrosis indicate excretory failure and the tissue conditions may be assessed through histological examination for confirmation of degree of damages.

Growth monitoring

The term "growth" in living beings defines length/ height/ body area proportionate weight/ biomass gain over a limited period of time. Biologically "growth" is comprehended as compounded effect of physiological activities mainly feeding, digestion, assimilation and conversion with support of enviromnental necessities. The poikilothermic fishes are unique in respect of growth pattern. In minnows *(A. mola, G. chapra, Puntius spp.)* the growth is at very slow pace, while the same is at faster rate in major carps *(L. rohita, C. catla, C. idella)*. Fishes respond very quickly to the natural and artificial feeds and attain faster growth. While on the other hand these creatures withstand food scarcity and starvation for a longer period utilising stored energy. In fish, growth performance depends on various enviromnental and biological factors.

Growth estimation

The relationship between length and weight putforth the conversion value for calculating length proportionate weight and *vice-versa* which is most effective method for estimation of growth performance in fish. The general equation for length- weight relationship is expressed as:

$$(W = aLn)$$

where W= weight, L = length, 'a' is a constant, and 'n' an exponent. Values for a and n are to be determined numerically. The logarithmic formula for expressing length- weight relationship stands as:

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

Data collection

For determining the actual value of exponent (n) in equation W= aLn, length and weight of individual fish should be recorded in millimetre and gram respectively. The sample size should be large to the best of availability. The fishes need be grouped in different size ranges of suitable length. Mean values for each size group worked out and recorded for further calculation.

Calculation

Record Log values of the individual length and weight. Put the values ill the following table and fill-up the columns as required.

L	Log L	W	Log W	Log L * Log W	(Log L)2

Summarise the column and substitute the following equation, where N= the number of individuals (or number of groups in grouped data).

$$\text{Log } a = \frac{\text{Log } W \ (\text{Log } L)^2 - \text{Log } L. \ (\text{Log } L. \text{ Log}W)}{N. \ (\text{Log})^2 - (\ \text{Log } L)^2}$$

Utilising the value for log a find 'n ' in the equation.

$$n = \frac{\text{Log } W - (N.\text{Log } a)}{\text{Log } L}$$

The ascertained Log a and n values now be substituted in formula.

$$\text{Log}W=\text{Log}a+n\text{Log } 1$$

Determine calculated weight by obtaining antilogs of Log a + n Log L values for each individual or group. Select a weight and calculate corresponding length or *vice-versa* .

Add up the values obtained by dividing the actual weight by calculated weight of all the individual or group. Thus, the mean value (k) will be 1.0. If this value is less than one it indicates poor growth of the studied population.

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Fish diseases in open water systems and its remedial measures

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Introduction

Small reservoirs and floodplain lakes 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 epizootic are encountered.

ROLE OF ENVIRONMENT IN FISH DISEASE OUTBREAK

Fish is in a state of equilibrium with the environment and fish disease organism, many of which are always present in the environment. A change in the environmental parameters beyond the tolerance limit disturbs this equilibrium resulting in stress response in the fish and making it vulnerable to disease. The response of fish to stress from the environment is known as stress response. The most extreme response is mortality but below this level there may be several other responses *viz.*,

i) changes in fish behaviour
ii) reduced growth/food conversion efficiency
iii) reduced reproductive potential
iv) reduced tolerance to disease
v) reduced ability to tolerate further stress.

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

Methods for stress diagnosis

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

Primary stress response

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

Secondary stress response

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

The hematological parameters also provide useful information about an animal's tolerance to stress.

Hemoglobin/Hematocrit : It increases or decrease following acute stress can indicate whether hemodilution or hemoconcentration has occurred.

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

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

Tertiary stress response

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

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

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

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

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/1 after one week.

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, hemorrhagic 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 occurs.

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

Suggested reading

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Fish Species Diversity in Indian Reservoirs and need for Conservation

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Introduction

India being the junction of three major geographical realms is bestowed with huge and diverse aquatic resources. Man-made lakes or the reservoirs are the recent addition to the aquatic spectrum of the nation. It is a unique ecosystem representing the characteristics, both fluvitile (lotic) as well as stagnant waters (lentic). Evidently, it is a synthesis of two distinct ecological stands and therefore, provides fascinating aquatic regimes with regards to production and productivity including biodiversity. In India the area under the reservoir resource is very vast, to the tune of more than 3.1 million ha. Of this the contribution by small reservoirs is more than 50% (Sugunan, 1995).

Theoretically, damming of river courses for creating impoundments is considered as a negative factor in terms of biodiversity conservation due to rampant aberrations in habitats. But, looking into the emerging threat perceptions around the rivers of the World the reservoirs may be blessing in disguise for providing shelter to many bio-communities, which otherwise would have vanished. Increasing incidences of man-induced activities around the river systems (*river course modifications, abstraction of excessive water, indiscriminate disposal of liquid and solid wastes, irrational exploitation of biological resources*), densely populated countries in particular have affected the ecological integrity adversely even to the extent of total chaos and beyond repair in many cases. In recent years there has been alarming shift biotic communities including fish faunal structure of rivers and other aquatic systems (Jha, 1999a,1999b, 2000). It is a common sight of late, that large and economically important fish species have paved ways for relatively smaller and less preferred ones. Recent studies conducted by CIFRI in river Ganga (Sinha *et al*, 1998) suggest that the population of many fish species of economic interest like IMC has gone down. Interestingly, however, revival in their population has been observed in reservoirs constructed in the same system or in the natural deep pools.

It is apparent, therefore, that a reservoir performs two distinct functions; firstly, it acts like a sanctuary or saviour for larger species of fishes and secondly, it acts as destroyer of the rheophilic or polythermic endemic fish population. Evidently, both of these functions are diagonally opposite to each other so far as the cardinal principle of biodiversity conservation is concerned. However, it is the question of giving precedence as to which type of species we are interested in- species of economic importance or of aesthetic importance or moral importance or of precautionary point of view.

Status of fish fauna in Indian reservoirs.

The fish spectrum of a reservoir largely represents the faunal diversity of the parent river across which the impoundment has been created. The faunal spectrum of reservoirs have been found to range between 50 and 70 species inclusive of exotic species, which have been introduced in recent years. No fish species could be branded as useless, however, nearly 40 species have been recognized as commercially important. The details of fish diversity from Indian reservoirs are given in Table 1.

Effects of Impoundments on Fish Fauna

Damming of rivers to create multipurpose reservoirs induces many changes in the abundance and composition of fish fauna due to change in habitats, which supports the endemic rheophilic fish species. It has been observed that the fish fauna of the impounded generally becomes impoverished with a distinct predominance of habitat generalists and low densities of riverine species. The growth of polythermic species like common carp generally declines in impounded water due to changed thermal regime (becoming low relatively), low coverage of macrophytes and relatively low abundance of zooplankton. Distinct impacts of an impoundment could be reflected as under:

- Riverine species dependent on rhithral conditions for spawning and feeding such as 'mahaseers', 'Indian trouts' and many others would decline significantly.
- Decline in population of riverine species with inshore spawning and nursery grounds.
- Decline even in those riverine fish population which require low flow-conditions, but riverine conditions are necessary for spawning.
- Increase in the population of 'eurytopic' fish species (habitat generalists), which could survive both in riverine as well as stagnant waters.

Table 1: Diversity of fish fauna in Indian reservoirs

Broad Groups	Species
The Indian Major Carps	*Labeo rohita, L. calbasu, L. fimbritus, Cirrhinus mrigala, Catla catla*
The mahaseers	*Tor tor, T. putitora, T. kudree, Acrossocheilus hexagnolepis*
The minor carp, Indo-Gangetic region	*Cirrhinus reba, Labeo kontius, L.bata, Puntius sarana, P. dubius, P. kolus, P. chagunio*
The minor carp, Peninsular India	*Cirrhinus cirrhosa, Puntis carnaticus, P. dobsonii, Thynichyes sandkhol, Osteobraba vigorsii*
Snow trout	*Schizothorax plagitomus*
Large catfish	*Aorichthys aor, A. seenghala, Wallago attu, Pangasius pangasius, silondia silondia, S. childrenii*
Airbreathing catfish	*Heteropneustes fossilis, Clarias batrachus*
Feather-backs	*Notopterus notopterus, N. chitala*
Murrels	*Channa marulius, C. striatus, C. punctatus, C. gachua*
Forage fish	*Ambasis nama, A. ranga, Esomus dandrica, Aspidoporia morar, Amblypharyngodon mola, Puntius sopore, P. ticto, P. punjabensis, Oxygaster bacaila, Laubuca laubuca, Barilius baraila, B. bola, Osteobrama cotio, Gudisa chapra, Satipina phasa, Chela chela, Botia lohachata, Gara gotyla, Rhinomugil corsula*
Exotic fish	*Oreochromis mossaimbicus, ypopthalmichthys moltrix, Cyperinus carpio specularis, C. carpio communis, Gambusia affinis, Ctenopharyngodon idella*

Investigations carried-out in various reservoirs of India indicate that many native fish species of riverine origin have been affected adversely on account of damming of rivers (Table 2)

Table 2: Impact of impoundments on endemic riverine fish species

Impoundment Region	River system	Negative impact on endemic fish species
Upland,Himalayan reservoirs	Indus (Sutlej, Beas)	*Tor putitora, Schizothorax plagiostomus, Labeo dero, L.dyochelus, C. rebaAarichthys seenghala*
Coastal Orissa	Mahanadi	*Puntius sarana, Tor tor, tor mahanadicus, T. mosal, L. fimbriatus, L. calbasu, Rhinomugil corsula*
Karnataka	Cauvery	*P. dobsoni, P.dubius,P. carnaticus, L. fimbriatus, L.*

		kontius
AP/Karnataka	Krishna	*P. kolus, P. dubius, P. sarana, P. porcellus, L. fimbriatus, L. calbasu, L. pangusia, Tor khudree*
NE States	Brahamputra (Kopili, Umiam, Umrang, Khanthong etc.)	Mahaseers, *Osteobrama belangiri*

The investigations carried-out by CIFRI, Barrackpore also suggest that in many cases there may be positive impact also. Ramakrishna (1994) has described many positive impacts of impoundments in relation to fish species (Table 3).

Table 3. Positive impact of impoundments on certain endemic riverine species

(Ramkrishnaya, 1994)

Reservoir	River	State	Fish species
Tilaya	Damodar	Jharkhand	*Baralius bola*
Nagarjunasagar	Krishna	Andhra pradesh	*Mystus krishnensis, Oestobrama vigorsii Pseudeutropius taakree*
Nijamsagar	Godavari	-Do-	*Tor sandkhol*
Sivajeesagar	Krishna	Karnataka	*T. Khudree* and *T. mussullah*
Pong reservoir	Beas	Himachal Pradesh	*A. seenghala* and *T. putitora*
Vallabhsagar	Tapti	Madya Pradesh	*A. seenghala* and *T. putitora*

Impact of Exotics on native population

Reckless or unimaginative introduction of exotics is known to pose serious problem for native fish fauna in an ecosystem. Accidental introduction of silver-carp (*H. moltrix*) in Gobindsagar, Himachal Pradesh is an eye opener in this direction. A total of 47 brood stock of silvercarp accidentally entered in the reservoir due to washing of Deoli fish Farm on account of flood during 1971, which established in the reservoir with vengeance bein prolific breeder in optimum condition. The net result has been that the reservoir has virtually been converted into a silver-carp reservoir pushing the native fish fauna to the rear. The worst affected fish species has been *Catla catla* as silver carp shared the same niche with regards to food and space.

Conservation options

Development of reservoir fisheries for enhancement of fish production leaves little ground for conservation of endemic fish population, because of stock as well as species enhancement of commercially important fish species. The moot of argument, however, is reservoirs do not have their distinct fish species, rather guided by the species present in the parent river. Evidently, our efforts on conservation should be directed for conserving the endemic population of the rivers. Recent studies suggest that many fish species, which are under threatened category in rivers, have flourished inside the impoundments. Evidently, the impoundments act as an effective sink for certain group of fishes and thus, help in conservation process indirectly.

Introduction of exotics in any form is considered detrimental for the endemic fish population. The dilemma is as to how we can justify the introduction of species from one river system of the country to another and put a ban on the introduction of species brought from other countries. To be precise, introduction of IMC in paninsular reservoir is as against the ethics of conservation, as introducing silver carp in Gobindsagar or tilapia in peninsular reservoirs. It is more a question of priorities being regulated by the local needs, whether we want production at any cost or we would be rational at some point of time so as to strike a balance between biodiversity and production. There cannot be any doubt that India needs enhanced production of animal protein to feed its galloping population. At the same time, however, we cannot say good-bye to our endemic fish population, which is a part of our national heritage. It is necessary, therefore, that certain reservoirs in different river systems should be marked as biodiversity reserves and be kept free from human intervention, because no management is the management so far as the conservation of biodiversity is concerned.

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Scope of pen and cage culture in small reservoirs

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Introduction

Lakes and reservoirs in developing countries produced approximately 2.95 million mt in 1996 representing about one third of inland fresh water catch and relatively small percent of total aquaculture. With the inclusion of small water bodies, this resource system has been identified as a key area for possible expansion both in extent and productivity in developing countries.

In India reservoirs are the prime inland fishery resource. According to one estimate, there are 19,134 (14,85,557 ha) small 180 (52,7,541 ha) medium and 56 (11,40,268 ha) large reservoirs in India (Sugunan, 1995). Reservoirs in India produce fish on an average 50 kg/ha against the yield rates of 200-300 kg/ha in some developing countries of Asia and Latin America (Sugunan, 1997). Yield enhancement in reservoir fisheries can be achieved at very low level of capital investment and lesser degree of environmental degradation compared to intensive aquaculture. Another notable positive point in reservoir fisheries is that it is labour intensive and labour productive activity where the benefit of increased yield is shared directly by the poor fishers.

Fish production from freshwater

The fish production from freshwaters can be achieved through capture fisheries and culture fisheries. Capture fisheries is mainly the exploitation of natural fish stocks, allowing a sustainable annual production from the resource. This is influenced by a number of factors like (a) the nutrient levels in the water entering the system which depends on the natural fertility of the soil in the catchment or the intensity of agricultural practices; (b) the amount of allochthonous organic matter entering the system which will slowly release nutrients to the system as it decomposes, and the residence time of the water within the system which allows the accumulation of higher levels of nutrients in the water column, and thus greater levels of primary production. On the contrary in aquaculture system the culturist has a certain degree of control over the environment in which the fish are grown.

Fisheries management in small reservoirs

Reservoir productivity depends on a host of factors which are abiotic and biotic in nature over which the fishery manager has little or no control unlike in aquaculture system. In many occasions common management practices like stock enhancement, species enhancement and environmental enhancement do not give the expected result in the from of productivity in a reservoir ecosystem. Indian reservoirs are public properties i.e. government owned. In states like Karnataka, Uttar Pradesh etc. small reservoirs are auctioned to private individuals who get the fishing rights for a fixed period. However, no sound stock management norms are followed and this leads to low production from these water bodies. At the peak of summer months most of the small reservoirs get dried up or the water level becomes too low that it encourages over fishing. This leads to such a situation that there may not be any brood stock to contribute to the natural recruitment to fishery for the years to come. To enhance the recruitment to the fishery, stocking the water body with artificially produced juvenile fishes is a common practice. Stocking of suitable fishes and capture of the same becomes the main management measure in reservoirs. It creates a direct correlation between stocking rate and catch per unit effort. In other words in small reservoirs, culture-based capture fishery is followed for improving productivity.

Relevance of enclosure culture in small reservoirs

Despite remarkable increase in carp seed production, the reservoirs remain under stocked. The main reason for such situation is that most of the seeds produced in the hatcheries go to aquaculture industry. To overcome this shortage of stocking material, the fish seed can be produced inside the water body itself through pen/cage culture. Hatcheries are mostly situated far away from reservoirs and the mortality during seed transport is a greater problem. Moreover, such long distance seed transport becomes uneconomical also. Nursery pen or cage to rear stocking material within the system is a better way to overcome the above problems of reservoir fisheries. In many cases even after stocking with sufficient number of seeds, the reservoirs remain unproductive due to the unscientific way of putting the seeds near the spillway which could be easily washed out. Unlike in the case of pond culture, it is not a suitable proposition to fertilize a reservoir. Subdividing the water body into easily manageable smaller compartments with fences (*pens*) or fixing *cages* to rear desirable fish species upto table size to enhance reservoir productivity is now followed in many countries like China, Indonesia, Thailand etc.

Definition of pen and cage culture

Both cage and pen cultures are types of enclosure cultures and involving holding of organisms captive within an enclosed space maintaining free exchange of water. The two methods are distinctly different from one another. A cage is totally enclosed on all sides or all but the top side by mesh or netting, whereas, in pen culture, the bottom of the enclosure is formed by the bottom of the water body.

Advantages of cage and pen culture

Although the initial costs of cage and pen culture may be considerable, their operational costs are relatively low. The advantages of pen and cage cultures are listed below :-

* Put no pressure on the land
* Better utilization of water area
* Fish production is intensified
* Optimum utilization of artificial feed for growth
* Competitors and predators are easily controlled
* Daily observation promotes better management and early detection of diseases or other problems
* Fish handling and mortality is reduced
* Harvesting is easy and flexible

In Malyasia and Singapore, the culture of planktivorous species is said to clean up eutrophic waters.

Disadvantages of pen and cage farming

There may be some detrimental environmental effects of enclosure culture. 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. Other disadvantages are listed below :-

* Affected by rough weather
* Adequate water exchange is not there
* Rapid fouling necessitates frequent cleaning
* Absolute dependence on artificial feeding and food is easily lost through the cage/pen walls
* Small fish from outside can enter and compete for feed or can introduce diseases
* Poaching is easy
* Labour costs are relatively high
* Blockading the spawning areas of wild fishes along the margins

Production methods

It is a general feeling that pen culture is extensive and cage culture is intensive. But as in other aquaculture systems, cage and pen cultures also can be by extensive, semi-intensive or intensive, where extensive method relies solely on the exploitation of natural food. In cage culture extensive culture has proved economical only in a few highly productive environments such as organically loaded canals, and eutrophic lakes (Costa-Pierce and Effendi 1988; Redding and Midlen, 1991; Pantastico and Baldia, 1981; Santiago, et.al.,1991). In semi-intensive system cheaper food materials, usually agricultural by-products or aquatic plants are given to supplement the natural food. It operates on the principle that short falls in natural food are made up through feeding and fertilizing the system. This method of enclosure culture prevails throughout Asia (FAO/NACA, 1995).Intensive culture involves the provision of all or almost all nutritional requirements of the cultured species through the use of formulated feeds. This is followed mostly in Europe and North America principally in the rearing of salmonids and catfish.

Production trends

Ninety-seven percent of the current 13 million tonnes of cultured fish production is from inland waters (FAO,1996) and it is estimated almost 10% (about 1.0 million) comes from reservoir or lake-based cage culture (Beveridge, 1996). In the Philippines, more than 35% of *tilapia* production is from freshwater cages compared to 58% in ponds and the remainder being in pens (Aypa, 1995). Cage aquaculture throughout Asia is increasing with the expansion in reservoir construction. By 1996, more than 25,000 units of net cages were installed in Cirata (Indonesia) alone producing 42,750 t of fish/year and about 4,400 units were producing 4,000 t/yr in Saguling reservoir (Zainal and Effendi, 1997). In the Philippines also it is increasing while in countries like Germany this culture system is facing stringent regulation due to environmental concerns (Beveridge and Stewart, 1997). In China, cage culture has been successfully integrated with waste treatment like in the eutrophic Taihu lake. A survey report from China from 1978-96 indicated that in this 18 year period the area of cage culture expanded at an average annual rate of 71%. During 1978-96 fish production from cage culture per hectare increased by an average 9.8% per annum (Hu & Liu, 1997). In 1980s the Philippines initiated pen culture in the lake Laguna de Bay with a total fish pen area of 4,800 ha, and a production of 19,200 mt obtained as compared to 20,700 mt from the remaining open water fishing area of 85,000 ha. However, later the pen culture declined due to the negative impacts on environment which led to legal ban on such intensive pen culture operations in the lake. In India, pen and cage culture are not yet become as popular as in other countries, especially in reservoirs. Central Inland Capture Fisheries Research Institute conducted experiments in pen culture in the floodplain wetlands (*beels*) of West Bengal and Assam. In Akaipur *beel* of West Bengal, a production of 1308 kg/ha/3months of giant freshwater prawn *Macrobrachium rosenbergii* was obtained in pens. This success led to mass scale adoption of pen culture in *beels* of West Bengal. It is high time that this technology be transferred to the vast area of reservoirs of India.

Conclusion

Enclosure culture is often viewed as desirable as it can generate employment, income and food to support the already available fishery activities. Cage or pen based nursery systems are cheap and easy to construct. Therefore these could be widely used to produce fingerlings for culture-based fisheries. Cages and pens suffer from disadvantages by comparison with pond-based hatchery or culture systems as they are vulnerable to damage by storms and other natural calamities and also cages are more prone to poaching. Environmental capacity models could be used to assess whether proposed cages or pens are likely to have serious impacts on environment or not. Models could also be developed to assess the potential for beneficial increases in fisheries production through enhanced productivity. For adoption of these systems, an integrated resource management or water shed perspective is essential. Environmental, social and economic issues related to these systems will be taken care in this way. Among other things, adequate skills, good markets and clear legal tenure of sites are prerequisites and this implies the full participation of resource users.

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Microbial pathogens and their impact on fish health in aquatic cosystem

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Pathogenic microorganisms and parasites are universally distributed with varying concentrations and virulence. Exposure to infectious agents is a continual process during the life span of any organism. However, exposure to an infectious microorganism does not necessarily result in infection or the manifestation of clinical disease. It depends on the interaction of several factors including the association of disease agent or pathogen , the environment and the status of the host. Artificial propagation of fish has often provided conditions for manifestation of disease in population of fish and subsequent identification of pathogens that have evolved with their hosts in natural environment. Different microbiological techniques have been employed in isolation, identification and characterization of these pathogens and their impact on fish health has been studied. Disease agents in fish populations are thought to exert important effects on host population dynamics through enzootic or epizootic events. The distribution of fish microbial pathogens, their potential impacts on population of fish in aquatic ecosystem and use of various microbiological techniques in pathogen characterization are discussed.

Distribution of pathogen

It is rather remarkable that of the many hundreds of bacterial taxa that the fish must encounter in aquatic system, relatively few are capable of causing systemic infection culminating the disease. Of these, even fewer so called "obligate fish pathogens" depend entirely on the tissues of living fish for their lively hood. A successful pathogen must possess a number of attributes that permit them to attach to, enter, survive in and multiply within the living host. The chances of a single bacterial cell mutating to possess all these necessary attributes is thus exceedingly low. In addition, if replication of the pathogen (e.g fish viruses) is impossible outside the living host, then its chances of contacting a susceptible fish host would be very less. Such pathogen is thus rarely likely to persist in nature, hence the poucity of obligate fish pathogen. On the other hand , if the mutant pathogen (like mutant bacteria) can multiply outside the living host, its chances of contacting susceptible fish host is more. Hence its persistence in the environment as an "opportunistic fish pathogen " would be considerable greater than that of "obligate fish pathogen".

The microorganisms that establish more or less permanent residence (colonize) but do not produce disease under normal conditions are known as "normal flora" or "normal microbiota". Others called " transient flora", may persist for several days or months and then disappear. Microorganisms are not found throughout the entire body, but are located in certain organs/ regions. Once established, the normal microflora can benefit the host by preventing the overgrowth of harmful microorganisms, a phenomenon called "microbial antagonism". When the balance is upset, disease can result from normal flora. The relationship between the normal flora and host (fish) is called "Symbiosis". In the symbiotic relationship called commensalism, one of the organism is benefited and the other (fish) is unaffected. Many of the microorganisms that make up the normal microflora in fish are commensals. These bacteria live on body secretions sloughed off cells and bring no apparent benefit or harm to the fish host. Opportunistics are potentially pathogenic organisms that ordinarily donot cause disease in their normal habitat in a healthy host. For example, organisms that gain entry through broken skin or mucous membrane can cause opportunistic infection. Again if the host fish is already weakened or compromised by infection, the microbes that are usually harmless can cause disease. This is the common picture noticed in fish culture.

Generally the number of aerobic, heterotrophic bacterial microflora on the surface of fish equate well the population in surrounding water. Normally a fish can harbor 4×10^3 to 8×10^4 bacteria per sq. cm of skin surface. In fish gills 10^6 bacteria per gm of gill tissue are present (Austin and Austin, 1987). Studies have shown that the fish skin surface and gills are populated by a diverse array of bacteria reflecting the range of taxa normally present in water. Thus the number and type of bacteria will vary in fresh water and marine fishes (Table 1). The intestine microflora are mostly responsible for fish spoilage and involved in spreading diseases. It has been shown that the gut of marine fish contain only few taxa of bacteria namely *Aeromonas sp., Pseudomonas sp.* and *Vibrio sp.,* unlike a large varieties of bacteria present in gut of freshwater fishes. It has been concluded that the bacteria present in gut of marine fishes do not arise solely from the mechanical transfer of organisms from diet but rather that condition in the gut impose selective mechanism which *Vibrios* in particular are able to tolerate.

Many pathogenic microorganisms are universally distributed. In nature, pathogens occur in varying concentration with varying virulence even at a single location. Fish stocks and common pathogen strains have evolved as coadapted gene complexes such that normal microorganisms do not kill the host. High virulence of a pathogen is a non-normal condition of the pathogen due to genetic mutation. Epidemics may burn themselves out because enough hosts die so that their population density decreases and the pathogen can no longer be transmitted effectively. There may be no loss of virulence but only a low rate of infection. Genetically diverse and spatially separated wild fish may be able to resist infection by pathogen. Hatchery fish, being possibly less diverse and more densely packed, may favour transmission of a virulent pathogen that would otherwise subside, perhaps as a result of competition with its less virulent pathogen.

Table 1. Bacterial population commonly found in freshwater and marine water fishes

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

Occurrence of disease in a fish population depends on a spectrum of responses dependant on the intensity of interactions of variables defined for the host, the pathogen and the environment (Fig.1). Often criticized is the overemphasis of the pathogen at the expenses of the host or environment. Absence of pathogens would reduce the potential for adverse environment to influence disease outbreak. Many characteristics of pathogens are directly relevant to the outcome of their interactions with the host and environment. These include whether the pathogen is always associated with infection of the host (obligate) or it has the ability to survive in the absence of the host (facultative). The virulence or the ability of pathogen to cause disease depends on the strain, biotype, serotype or genotype of the agent. The dose or the number of pathogens, their route of entry to host and the duration of the exposure directly influence the severity of subsequent infection.

The environment

The environment is the least defined element among the three factors i.e. fish-pathogen-environment interaction leading to health or disease. Certain components of environment are evident, these chemical and physical characteristics can be measured. The variables include, dissolved gases, pH, temperature, flow, turbidity and contaminants, The biological effects like human interaction is important as they will affect diversity of the biota, which may encourage certain hosts pathogens and other symbionts. Other variables are geomorphology, limnology and hydrology of the aquatic environment, that are critical to fish health.

The common bacterial flora of water and sediment and commonly found in fish, are given in Table 2 and Table 3. The number and types of bacteria recovered from water and sediment reflect the methods employed for count of bacteria (like direct count, plate count, selective media used, temperature, duration of incubation, aerobic/anaerobic conditions etc.) and the physiochemical condition of the aquatic environment. It has been noted that the bacterial number is maximum during the height of summer and in highly eutrophic waters. Winter and clean water or nutrient deficient waters are not conducive to bacterial growth. In unpolluted water, bacterial count is maximum between 10^{1} and 10^{6}/ml in river system. Marine bacterial population have seasonal fluctuation, with maximum number during summer and minimum during winter. Highest bacterial count is obtained constantly from the effluents with population between 5 and 50 times greater than incoming sea water (Austin and Austin, 1987). Such is also the condition in inland fish farming. During summer, the fishes are continually bathed in a dense microbial soup, which may lead to health problems. Again the overfeeding and lack of cleaning permit uneaten food and faces to accumulate at bottom of fish holding areas. Such organic matter serves as an excellent source of nutrient for heterotrophic bacteria , which under go rapid multiplication. This coupled with summer related problems may cause outbreak of diseases leading to heavy mortality in stock, as has been commonly noticed in fish and shrimp farming.

Table 2 The notable taxa of bacteria found in fresh water, Marine water and culturing tank water

Fresh water	Marine water	Cultured marine fish tank/pond water
Acinetobacter	*Vibrio sp.*	*Altermonas sp.*
Aeromonas sp.	*Alcaligens sp.*	*Cytophaga sp/*
Flavobacterium sp.	*Arthobacters sp.*	*Flexibacter sp.*
Morexella sp.	*Pseudomonads*	*Corynebacteria sp.*
Pseudomonas sp.		*Vibrio sp.*
Bacillus sp.		*Pseudomonas sp.*
(Mostly in sediment)		*Lucibacterum sp.*
		Photobacterum sp.

Table 3 Occurrence of pathogenic bacteria indigenous to aquatic and soil environment and commonly found in fish

Organism	Primary habitat
1. *Clostridium botulinum*, non-proteolytic types B,E, F	Temporate aquatic environment
2. Pathogenic V*ibrio* spp. *V.cholerae, V.parahaemolyticus V.vulnificus* etc.	Ubiquitous in warm sea water
3. *Aeromonas hydrophila*	Aquatic environment
4. *Listeria monocytogenes*	Soil, decaying vegetation, ubiquitous in general environment
5. *Clostridium botulinum*, proteolytic type A,B	Soil
6. *Clostridium perfrigens*	Soil (type A), animals (type B,C,D,E)
7. *Bacillus* spp.	Ubiquitous in general environment, in soil, vegetation, water

Susceptibility of fish to pathogen

Even though the fishes are continually bathed in pathogens both in nature and in culture facilities, they do not all become diseased. Several parameters associated with the fish are directly related to the occurrence of disease upon interaction with appropriate pathogen and environmental factors or conditions. these include the factors that are constantly present (constitutive) such as the fish species, genotypes, age, size, developmental stages, nutritional and reproductive statuses and behavior and innate defenses related to immune competence. Additional factors that affect host susceptibility to disease include adoptive factors which result from previous interactions with the pathogen or environment. Among the most important interactions is the acquisition of immunity after exposure to antigen or pathogen.The response of most batches of fish to challenge by pathogens generally reflects a sigmoid curve, both in terms of response to various concentrations and times of symptoms to appear. Some fish succumb in a fairly low doses and quickly. The majority succumb in a fairly narrow doses or a period of time and others require higher doses and resist the disease longer. The normal immune system's response to pathogen and the effects of environmental factors in modulating the immune system of fish are the important areas of research. Variable susceptibility in part is inherited. A wide variation in response to pathogen challenge in wild fish is noted, because of their wide genetic background (Anderson, 1996). The ability of certain fishes to resist pathogens was demonstrated to have high heritability, although strains with resistance to one pathogen are not necessarily resistant to another (Coutant, 1998).. Research is on to identify the specific genes responsible for variable immune responses and resistance to pathogens.

Occurrence of disease

Disease is a process that is characterized by any impairment that interferes with or modifies the performance of normal functions of body, including responses to environmental factors such as climate, nutrition, infectious pathogens, inhertent or congenital defects or any combination of these (Hedrick, 1998). Numerous factors are cause of disease, but how all of them interact is a complex situation. The cause of disease can be grouped into (i) those associated with environmental, nutritional and genetic factors of host and (ii) infectious agents or pathogens.

The incidence of a disease is the fraction of a population that contracts it during a particular period of time. The prevalence of a disease is the fraction of population having the disease at a specified time. If the disease occurs only occasionally, it is called sporadic disease. If the disease is constantly present in a population is called an "endemic disease". If large number of fish in a region get certain disease in a relatively short period of time, it is called "epidemic disease". Disease agents in fish populations are thought to exert important effects on host population dynamics through enzootic or epizootic events. Enzootic diseases can influence host abundance through long-term impacts on physiological processes affecting growth and reproduction as well as survival. Where as epizootic diseases typically affect population dynamics by reducing population in short term events, which if sufficient might result in extinction of the fish species.

Occurrence of different disease problems in fish farming and involvement of different pathogens are presented in Table 4 It is noted a wide variety of pathogenic bacteria are involved in disease conditions and involvement different parasites are excluded in the present discussion. Although occurrence of viral diseases in fish farming has not been reported in India, a wide range of fish viruses have been isolated and identified in other parts of the world (Austin and Austin, 1987).

Table 4 . Involvement of various pathogenic bacteria in various pathological conditions of fish.

1. Exopthalmia (Pop eye condition)	*Aeromonas hydrophila, Edwardsiella ictaluri, Streptococcus spp., Staphylococcus spp. Mycobacteria spp., Nocardia spp.*
2. Hemorrhages in the eye, with blood spots	*Streptococcus spp., Yersinia ruckeri*
3. Haemorrhages in the mouth	*Vibrio anguillaraum, V. ordalii, Pseudomonas anguillaseptica*
4. Hemorrhages in opercular region	*Yersinia ruckeri, Pseudomonas anguilliseptica, Streptococcus spp.*
5. Hemorrhages on body surface with ulcers	*Aeromonas hydrophila, E.ictaluri, Flexibacter columnaris, Vibrio spp., Pseudomonas spp., Mycobacterium sp.*
6. Surface abscesses with blood filled blisters	*A.hydrophila, Edwardsiella tarda, Renibacterium salmoninarum*
7. Whitish nodules on gills	*Edwardsiella tarda*
8. Fin rot and Fin rot	*A.hydrophila, Mycobacterium spp., Nocardia spp., Pseudomonas spp. Cytophaga spp.*
9. Swollen air bladder with filled in liquid	*Vibrio spp.* (Vibriosis)
10. Gas filled hollows in the muscles	*Edwardsiella tarda*
11. Bacterial gill disease	*Cytophaga spp., Flexibacter spp., Flavobacterium spp.*

Disease may be a major controlling factor in the abundance of both cultured and wild fish and therefore should be an integral part of any assessment of these populations. Disease can directly influence performance, susceptibility to predation, success of reproduction and other critical factors required for survival and propagation of a species. These effects can be cumulative and have catastrophic consequences for wild fish population. Artificial propagation of fish has often provided conditions for manifestation of disease in population of fish and subsequent identification of pathogen that have evolved with their hosts in natural environment. An understanding of the epizootiology and pathogenesis of infectious agents has been the result of investigation of disease in aquaculture population and has been invaluable in the management of these population. It has now understood that the occurrence of infectious disease is dependant on various biological and ecological factors. The severity of disease is dependant on a complex interaction among host, pathogen and various environmental factors. This emphasizes the important role that environmental factors play in the pathogenesis and manifestation of disease outbreaks. Therefore determination of the environmental factors that are important for occurrence of disease and the measurement and assessment of these environmental factors is critical to our understanding of disease (LaPatra, 1998).

Factors involved in the dissemination of disease in fish population

Disease in population is a dynamic phenomenon. Fluctuation in the prevalence and impact are dependant on the interactions among host, pathogen and environment. Different mathematical models have been applied to the study of diseases caused by a variety of pathogens in a variety of host population. Mathematical models are used commonly for the estimation of the dynamics of fish population, as in humans and other animals. For short term, single epizootic situation the following equation holds called S-I-R - Model (Reno, 1998), as

$Nt = St + It + Rt$, where N = the population, S = the number of uninfected animals susceptible to disease, I = the number of infected individuals , R = the number of removed individuals , those have died or immune to disease and t = is the Time. At any given time "t", during the course of invasion by a pathogen, this dynamic relationship holds true.

The force of infection or the rate of change of disease in a population is determined as, force of infection or transmission of infection = $ß \times I \times S$, where ß = transmission co-efficient, I = infectious individual and S = susceptible individual. The frequency of contact between an infectious individual (I) and a susceptible individual (S) multiplied by the transmission co-efficient will yield the disease incidence. Transmission co-efficient ß is defined as the efficiency of transfer of pathogen from a single infectious individual to other susceptible individual in the population. (Reno, 1998). The factors that affect the transmission co-efficient "ß" are (a) Host resistance factors like species, age, natural immunity, induced immune status, (b) Pathogen factors like ability of pathogen to infect species, concentration, dose, mode of transmission etc. and (c) Environmental factors like population density, temperature, water flow, water quality etc.

Microbilogical techniques in pathogen and disease diagnosis

As has been discussed a wide range of pathogenic bacteria and viruses have isolated and identified using a variety of microbiological techniques. Some of these commonly used techniques are :

1.Direct bacterial count : Estimation of total bacterial count using fluorescent/ acridine orange staining, epiflusrescence method and Electronmicroscopy.

2.Cultural methods : Used for enumeration of viable bacterial load in the sample. Two methods are commonly used-

(i) Plating method using suitable bacteriological media, by Streak plate, pour plate and membrane filtration technique is used for liquid or water samples.
(ii) Most probable number (MPN) method, using tube fermentation.

3.Physiological methods : This technique is used to measure microbial activity, by using (i) enzyme assays like dehydrogenase, phosphatase, protease, amylase, cellulase etc. enzymatic activities and (ii) by use of radiolabelled tracers (^{3}H, ^{14}C) into cellular macromolecules.

4. Immunological techniques : Different immunological techniques are used for detection of pathogen, their components and antibodies, which help in diagnosis. Some of the commonly used techniques are :

(i) Enzyme immuno assay like ELISA, Dot immunoassay etc.
(ii) Flourescent antibody technique
(iii) Westren blotting
(iv) Immunocytochemical assays
(v) Immunoprecipitation assaya

5. **Nucleic acid based methods :** Different nucleic acid based techniques have been developed and applied which has revolutionized the diagnostic techniques. Some of the commonly used techniques are -

(i) Gene probes like DNA and RNA probes, both radiolabelled
and non-radiolebelled, and detection using hybridization techniques.

(ii) Polymerase chain reaction (PCR) and related techniques like Random amplification of polymorphic DNA (RAPD), Restriction fragment length polymorphism (RFLP) etc.

Conclusion

Knowledge of the various factors that influence the outcome of infection in aquatic animals at cellular and molecular level is limited, including the understanding of host resistance and virulence markers at genetic level. Increased knowledge of the molecular mechanisms may improve our understanding of factors that directly or indirectly affect the pathogenicity and host defense mechanism, so as to develop suitable preventive and control measures to combat disease problems in aquatic animals. It is noteworthy that some active efforts have been made towards development of rapid molecular and immunological techniques for detection of pathogenic bacteria and viruses involved in fish and shellfish disease conditions. However a more complete understanding of the factors that affect the pathogenicity and occurrence of disease in fish/shellfish populations and defination of the interactions of physical, chemical, biological and ecological factors that are required for the maintenance of fish health , remains the present challenge for fish health management in aquatic ecosystem.

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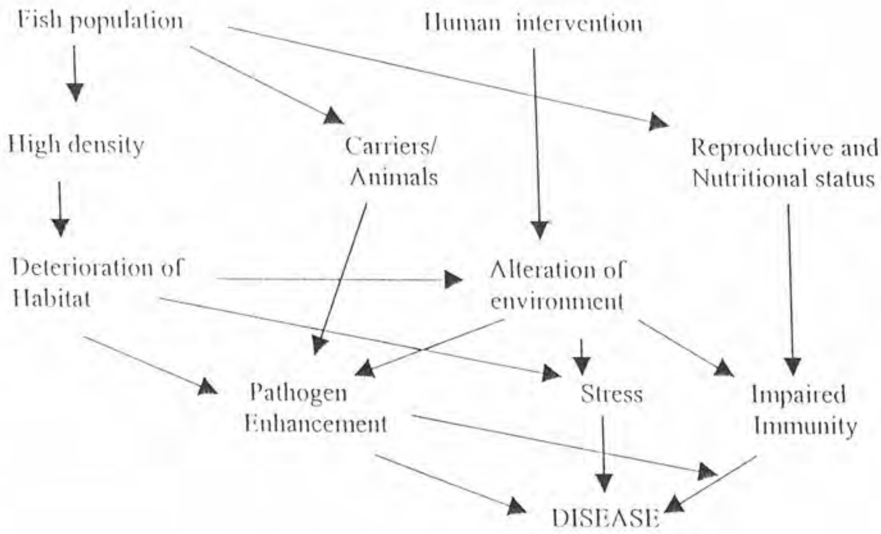
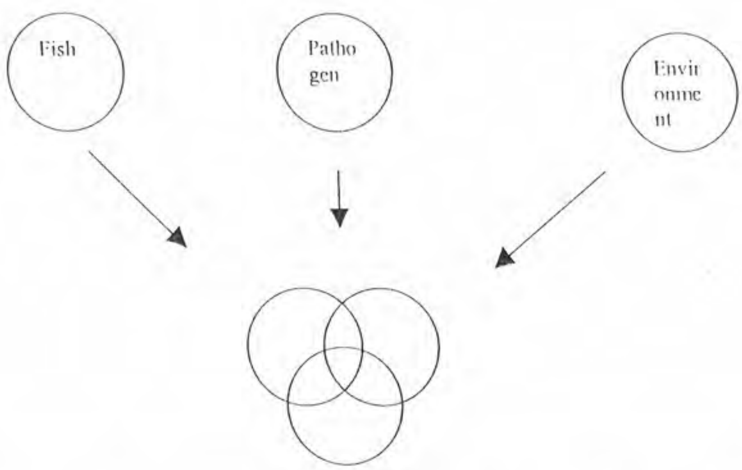
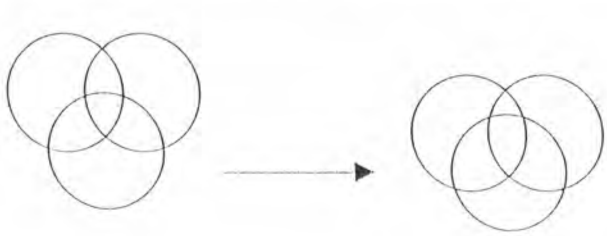


Fig.1 (I). Interaction of variable factors in disease occurrence.



II. Interaction of three variables, Fish, Pathogen and Environment in occurrence of Disease



III.

A. Less chances of Disease in healthy environment even in presence of pathogen.

B. More chances of Disease under contaminated/unhealthy environment.

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Infrastructure and policy support measures vis-à-vis socio-economic constraints in small reservoirs

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Manmade open waters, the reservoirs offer immense potential for fishery activities. Besides, ongoing river valley projects, commissioning of new projects over the years would result in horizontal expansion due to increase in reservoir area and vertical integration due to opening of new avenues for employment through pre-production and post - harvest activities. In India the number and area under small reservoirs is maximum as compared to medium and large. According to latest estimates (Sugunan, 1995) these have an expanse of 1.5 million ha (47% of total area under reservoirs). It forms one of the most important underutilised inland fisheries resource. These have the advantage towards quick enhancement of fish yield due to their small size and easy manipulation of fish species spectrum. Furthermore, availability of proven scientific practices for fish production in small reservoirs (Sugunan and Sinha, 2000) put an accent on their development. Despite awareness of the scientific management practices, their adoption becomes difficult under adverse socio-economic conditions. The socio-economic environment effects management, efficiency and outcome of fishery activities to greater extent. The fishers being, one of the poorest and highly unorganised community of society, the socio-economic environment for reservoir fish production process is not congenial. It has many lacunae, which can only be encountered through requisite infrastructure and favourable policy support. Keeping these facts in mind, the present chapter is devoted to entail the socio-economic considerations and constraints and infrastructure and policy measures to solve them.

Social considerations and constraints

The social considerations in broader sense encompass all features related to a) property regime; b) management regime and c) the fishers.

a) Property regime

The property regime is generally concerned with the ownership or right to use a natural or manmade water resource. In case of small reservoirs the ownership or property regime may be i) open access ii) common property iii) private property iv) multiple user ownership.

i) Open access

Under open access property regime, everyone has equal right of fishing in any water body. No one has the right to exclude anybody from fishing in any reservoir. As a result, due to free entry number of active fishers is large in this regime. Fishing may be irrational, and constraints of no control on a) fishing effort, b) fishing method and c) area of fishing exist. A conservative dictum "everybody's property is nobody's property" (Gordon, 1954) holds true in this property regime, as open access is likely to be abused, misused, and overexploited.

ii) Common property

Sometimes common property regime is confused with open access. The only difference between the two is that former is open access for local or limited users only, not for anyone from anywhere. But the concept of exclusiveness is not pronounced, as no individual can claim the ownership, and independently perform decision-making process for management and other practices. These waters can be managed better than open access. These have limited users due to restriction on entry. Therefore, although the constraints of control on a) fishing effort, b) method of fishing and c) fishing area exist but comparatively less effective than in case of open access.

iii) Private property regime

The private property is said to be exclusive because owner can exclude others from appropriating the property and /or benefits from it. In this sense, private property is commonly conceived as individual property. The property owned by other entities like a co-operative or company is also a private property, as these entities can legally exclude others from using it. Although, due to exclusiveness in use, there may be social injustice, but this type of waters can be managed efficiently, subject to fisheries management acumen of the owner or manager. Under this regime the outcome of the fish production process is directly related to the suitability of method, tenure and terms and conditions for fisheries rights, which may be covered under the policy issues.

iv) Multiple user ownership

Aforementioned, property regimes are explained in the context of single type of users, i.e. resource is utilised only for one production activity. In case of natural or manmade waters it is very rare. It may be used for other purposes also. Reservoirs may be utilised for irrigation, hydropower generation, day to days uses, besides fisheries. Therefore, fisheries management operations should be in relation to other activities, which restrict degree of freedom for any of the activity. During the planning process of any reservoir, the concept of its adoption for fisheries is rarely discussed in consultation with any fishery experts. It limits the scope for fisheries, due to absence of pre-impoundment investigations and post impoundment preparations. Ultimately, these constraints affect fish production of reservoir. Furthermore, the water inflow to and outflow from the reservoir is in accordance with the irrigation schedule for agriculture fields. It may lead to wide variations in water level of reservoir and act as a serious constraint for fish production.

As stated above, the property regimes have serious implications on fish production process. The reservoirs are mostly under the ownership of state departments of Fisheries, Irrigation, Revenue, etc. The departments transfer the fishing rights or lease out these waters to individual contractors or fishers organisations (Co-oprative societies, federations, etc.). The method, tenure and other terms and conditions for conducting fisheries operations are at the discretion of its owners and are owner friendly. There will be number of options for transfer of fishing rights. The method of lease may be through open auction, tenders or direct lease to local fishers' organisation. The most important aspect is the lease tenure, which influence the fisheries management to greater extent. The lease period may be for 1-10 years. For short lease period the fisheries management are more near to aquacultural practices. With increase in lease period, the fishery management practices may diverge towards stocking cum capture fisheries, subject to possibility of auto stocking. Therefore, property regimes have direct bearing on outcome of reservoir fish production process.

b) Management regime

The property regimes are concerned with the right to use any resource, but the problem "how to use the resource" falls under the purview of management. After having the fisheries management rights, the fish production process is managed by different management systems or regimes, under given property regime. These are responsible for implementing the fish production practices and management of overall fish production and marketing process. The management regime may be i) individual, ii) group(s) of individuals, or iii) organisation. The owner of the reservoir may himself manage the fisheries operations or transfer the fishery management rights to some individual or agency. The individual may be contractor, fish trader, commission agent, etc. The agencies may be government department, fisher co-operative, marketing co-operative, etc. Sometimes the fisheries management may include more than one regime for single or different activities. For example, in case of Gobind Sagar in Himachal Pradesh, the fish stock management is done by state fisheries department; fisher co-operatives conduct fishing, while co-operative federation performs the fish marketing functions (Katiha, 1994). The management regimes being responsible for all the decision making processes and execution of the decisions, the results of fish production process are directly related to their expertise, co-ordination and over all management. In the process of reservoir fisheries, management regime involving more than one agency should work in close co-ordination with each other to maximise returns or optimise the profits. The lack of management acumen and co-ordination at any of the stage would slow down the momentum and constrain whole the process.

c) The fishers

The ultimate clientele of any fisheries development programme are the fishers and reservoir fisheries in no way exception. They are the actual working group, who performs the fish production activities. So, the knowledge of their socio-economic conditions is of prime importance. Furthermore, very poor socio-economic status and unorganised nature of this community may act as significant constraint in reservoir fisheries development. The investigations on demographic structure of fisher families revealed cracks in joint family structure. It has given way to nuclear families with small family size. The increase in number of fisher families has enhanced the demand for fisheries requisites, but the investment in this sector is not in concurrence to the increase in demand. Therefore, the percentage of fishers with own fisheries requisites has decreased. The literacy level for fishers has increased over the years. Despite one of the toughest enterprise, involving lot of labour, risk and uncertainty, the returns for the fishers are very less. These factors led to decrease in involvement of fishers in fisheries and occupational shift away from fisheries. Yet, the number of active fishers is high. They have either to share the fisheries requisites with their peers or depend on the contractor or other agency for it. The agencies and owners of the fisheries implements dictate their own terms for providing /sharing these items, Therefore, there is possibility of exploitation of poor fishers. It is one of the important constraints due to socio-economic conditions of the fishers.

Economic considerations and constraints

The economic considerations are primarily concerned with valuation of i) inputs utilised in the fish production process, ii) output produced as a result of this process, iii) computation of profits or loss, iv) sustainability of fish production, v) identifying the most crucial factors of production, and vi) optimise the fish production process. The analysis of all these aspects would indicate whether the reservoir fish production is a viable option or not to be undertaken as an enterprise.

Since, the economic aspects are primarily concerned with production and marketing of fish, so, the economic constraints are also related to these activities and may be categorised into a) production constraints including reservoir, inputs, management, financial, and others; and b) marketing constraints covering nature and quantum of product, storage, grading, packing, transportation, malpractices, market information, etc.

a) *The production constraints*

The fish production in reservoir has many problems. The first is about the resources itself, i.e. the reservoir. It is a water body with multiple uses including the primary activities of irrigation and /or hydropower generation and fisheries as subsidiary enterprise. The variation in water level is one of the most important constraints. The fluctuation of water level influences the fisheries adversely. The location of the reservoirs is mostly in remote areas, and the approach is very difficult, which also acts as hurdle in proper implementation of fish production and marketing practices. In most of the reservoirs the availability of inputs, raw materials for construction of boats, fabrication of nets, fish seed, fish feed, etc., is neither timely nor at reasonable rate. It constrains the fish production process, as in the absence or shortage of these inputs the process is paralysed. Being a multiple use resources, management and ownership of the reservoir are generally with departments other than fisheries. It creates problems of conflicting uses. The financial problems include unemployment during few months over the year, lack of institutional credit, unstable quantity and composition of fish catch. The other constraints, which influence reservoir fish production, are poor extension services, lack of knowledge about primary and potential productivity, limnological and physico-chemical characteristics, and latest scientific methods, etc. Measures are necessary to solve these problems through infrastructure or policy support.

b) Marketing constraints

The maximum returns from any production activity are the outcome of efficient production system followed by equally efficient marketing system. But, fishers being highly unorganised and poor community, a poor marketing process follows the fish production, which benefit the market functionaries, the most. the major constraint in fish marketing is the product itself. Fish catch is highly perishable and heterogeneous, so, need sufficient storage, grading, packing and transportation facilities to have better remuneration for the fishers. Furthermore, number of malpractices and limited market information with the fishers restrains them to take up marketing operations.

<u>Infrastructural support</u>

A workable environment for any production process needs suitable infrastructural support. It prompts timely availability of factors of production. In reservoir fish production system, the first factor of production, the land is in the form of water body, the reservoir. If we analyse the constraints in reservoir fisheries, towards first factor of production, the investigations will concentrate on property and management regimes. The labour forms the second factor of production, which may be fisher family or hired labour. Due to disintegration of joint fisher families over time, the labour is generally hired, particularly in the form of professional parties. The third factor of production is capital, which forms the major component of infrastructure. It may be in the form of inputs and other supportive facilities. These may include:

a) Hatchery and fish seed rearing ponds

The fish seed stocking is one of the most important tools for culture-based fisheries management of small reservoir. The availability of required fish seed both in quantity and quality is the necessary condition. For this purpose, the reservoirs should have the facilities in form of hatcheries and fish seed rearing ponds. Rearing of spawn in pens has already been successfully documented in the state of Andhra Pradesh under World Bank project. It has increased the fish production and yield of the small reservoir manifolds, and improved the socio-economic conditions of the fishers. Therefore, the first and foremost important infrastructure support measure is provision for fish seed.

b) Availability of fisheries requisites

As stated earlier, the percentage of ownership of fisheries requisites with fishers is decreasing over time. These are crucial for any fishing process. Therefore, there should be provision of crafts and gear in sufficient quantity for the reservoir fishers. It will increase their fishing effort, degree of freedom and ultimately fish catch. In the absence of enough number of boats and quantity of gear, the fisher has to depend on the private parties for credit, which may exploit them for their own benefit. In case of rearing of spawn in rearing ponds, the fish feed should be available in adequate quantity in order to get proper sized fingerlings in less time.

c) Civil works

In general the reservoirs are situated in remote areas with less communication facilities. This affects procurement of inputs and selling of output. Therefore, the approach to the reservoir should be proper. It will improve the transportation and lead to reduction in production costs and provide better price for fish catch. The other items of civil work may include construction of landing shed, proper inlet - outlets or sluice gates; supply of ice and storage facilities; etc.

d) Marketing system

The studies on fish marketing revealed that the remuneration of fish catch for the fishers is very poor. They receive very small share in consumer rupee and most of it is taken away by the market and other functionaries or middlemen between fish and consumer. In this regard, the infrastructure support to the fishers or fishers' organisation towards direct sale of fish catch from fisher to consumer would be of immense help. It will limit the share of intermediaries and increase fishers' remuneration.

e) Credit system

The fisher community is very poor and they have nothing to invest for purchase of fisheries requisites. Therefore, availability of funds for inputs at critical stages of fish production process would of great help to them on one and on the other save them from the clutches of moneylenders. The institutional credit system can provide them catch linked credit through some sponsoring agency e.g. fisheries/rural development department, etc.

These infrastructure support measures would provide all the necessary facilities and lead way to successful reservoir fish production. On one side, it may reduce cost of fish production through provision good quality inputs in sufficient quantity and at cheaper rate; and on the other increase the returns for fish business through efficient marketing system. Ultimately, it would lead to upliftment of fisher community both economically and socially.

Policy support measures

As stated earlier, there exist numerous constraints in reservoir fisheries. A complementary policy support may provide suitable atmosphere for performing relevant activities successfully. The policy issues become increasingly important in case of resources having multiple uses like reservoirs. Following policy support measures may take care of many of the constraints in reservoir fisheries management.

1. Fishery experts may be involved in planning process of the reservoirs to assess prospects of their adoption for fishery purposes;

2. Being a multiple use resources, all the activities should be performed in close co-ordination to other. It needs a holistic approach involving all the departments and people concerned for overall optimum utilisation of reservoirs resources. For example, the water for irrigation may be released, with prior information to fisheries department and other concerned personnel.

3. The fishing rights of all the reservoirs should be with fisheries departments of respective states. It should be held responsible for transferring the fishing rights and formulation of terms and conditions for the lease.

4. The fishers' organisations should be preferred for leasing out the reservoirs for fisheries. The individual contractor may be discouraged. The tenure of lease should be atleast five years, subject to annual renewal, based on evaluation of performance of the lessee. The lease amount should be linked with productivity of the reservoir.

5. The fisheries management activities should be entrusted to different agencies, depending upon their expertise and labour availability. For instance, state fisheries department should manage the fish stock. Fishers' co-operatives may perform fishing operations and fish marketing may be in the purview of some fishers' organisation having expertise in this area.

6. The fishers should be provided with inputs (gear and crafts) through soft term institutional loans, sponsored by state fisheries departments.

7. Monetary provision should be made for infrastructure development at reservoir sites. The amount spent may be repaid in easy installment alongwith the lease amount.

8. Efforts should be made to minimise the role of fish marketing intermediaries in fish marketing. The fishers' organisations with fish marketing expertise should be encouraged to procure the fish catch and perform the fish marketing.

9. In case of fish marketing by fishers' organisation, fish grading system may be standardised, according to commercial value of the fish. Some minimum support procurement price may be fixed for each grade of fish for different seasons. It will provide better remuneration to fishers and incentive for high fishing effort and fish catch.

10. The extension service should be geared up to provide the latest information about the scientific methods for reservoir fisheries management and governmental development programmes.

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Community - based Co-operative approach for management of fisheries in small reservoirs

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Introduction

There seems to be a growing consensus on the desirability of Co-operative management of open water fisheries. Community-based fishermen may interpret it as meaning a wide range of negotiated agreements between communities of fisheries and various levels of Governement responsible for fisheries management.

Co-operative management is often used interchangeably with other terms, such as joint management, collaborative management and community-based management. This Co-operative management may be a simple partnership arrangement between Government and industry. or it may be a much more complex relationship wherein Government actually transfers authority over the management of the resource to industry, community or regional users. The key feature common to the various definitions of Co-operative management is that there is some arrangement where responsibility for management is shared between Government and user groups (Sen and Nielsen 1996).

Community-based Co-operative management

Among the various interpretations of Co-operative management one which is gaining increasing importance in fisheries is community-based Co-operative management. This is a system wherein authority and responsibility over local resources is shared between government and local resource users and/or their communities. It is based on the notion that proprietary rights to the common fishery resource should be allocated to those communities who are mostly dependent upon that resource.

Community-based Co-operative management, of course, is not a new concept. Many traditional pre-industrial fishery based communities embraced

Co-operative management of some kind. While some commercial exchange was associated with these systems, they were for the most part artisanal, subsistence fisheries which were either ignored or legislated away during the emergence of industrial fisheries.

Co-operative management : conditions for success

A renewed interest in community-based Co-operative management has arisen because of the failure of contemporary mostly centralized management regimes to either conserve the stocks or satisfy the needs of fishermen.

Community--based co-operative management may be appropriate for open-water fisheries

* Parties have clear motives compatible with public interest;

* Parties agree on the problem/situation/context that has to be addressed;

- Respective, agendas are compatible well defined, and openly acknowledged;
- Participants in a fishery are organized, ready to participate and speak in a united voice;
- Appropriate representative organizations and necessary infrastructures are in place.

Major common elements relating to characteristics for successful self governenting Institutions are:

i) the community of eligible users is clearly defined;
ii) there are clear geographic or other boundaries to the resource system over whi.ch the users have control and the community of users is able (informally or formally) to exclude outsiders;
iii) the communities involved are highly dependent on the resource and are vulnerable to non-sustainable use;
iv) the resource users are relatively immobile: if the resource is overused or the resource system is damaged, the users cannot easily move to another location or another livelihood; users are able to enforce management rules both against each other against outsiders;
v) although users may not be homogeneous in a cultural sense they share relatively homogeneous interests in the resource;

vi) users invest their own resources in activities such as enhancement and enforcement the costs of management add mismanagement are borne by those who benefit directly from the resources.

Benefit of community - based co-operative management

Pinkerton,(1989) have drawn a number of conclusions for successful co-operative management:

1. Creates co-operation among individual fishermen and local fishing, groups in planning the improvement or conservation of local fish stocks;

2. Creates the commitment among local fishermen to share, both the costs and benefits of their efforts toward enhancement and conservation;

3. Of allocation decisions, creates an appropriate vehicle of conflict resolution among, fishermen; it increases; motivation to negotiate sharing of access which is perceived as equitable;

4. Enhances the position of fishermen so that a more equal negotiating relationship exists between local fishermen art other water resource users;

5. Creates a higher degree of organization and mutual- commitment among fishermen so that they have a more, equal bargaining relationship with fish buyers;

6. Creates a willingness among both fishermen and government to share data about the resource, and therefore to reach collectively a more complete understanding of the resource;

7. Creates a willingness among both fishermen and government to explore options for regulation which reduce inefficencies for fishers;

8. Of regulations. creates greater trust between fishermen and government and a greater sense of control on the part of so that motivation to invest in competitive gear for first capture is reduced;

9. Creates a higher degree of trust between fishermen and government and improved ability to develop and successfully implement enforcement repines that fishermen perceive as appropriate and legitimate;

10. Creates a higher degree of trust between fishermen and government and greater willingness on the part of government to allow a range of self-management responsibilities to be assumed by fishermen.

Successful co-operative management can lead to better, more informed decision, reduce conflict and uncertainty over resource use, and increases public awarness and understanding. Moreover, it builds a sense of community which can empower , and build capacity among local citizens and organizgation to work toward community economic development in general. In other words, it moves us beyond the traditional magement goals of maximizing the biological productivity (MSY), and economic yield (MEY) of our fishery domains and brings us closer to the more elusive goal: management for optimum social yield. or OSY, with *optimum* meaning the optimum sustainable well-being for a fishery's human participants.

Fishermen Co-operative Society - the People's Organisation for Co-operative Management

If development depends on mobilizing people, then people's participation is an essential element within a process which its people. People's organisation (Society) is a group of people at village or community level with specific activity for its member's benefits, to serve their community or to activate the policy of the government or non-governmental sector. The group formed may have either the government's rules of its own rules and regulation as a framework for the group activities. The group may be registered according to law as a legal body or exists as informal group, *e. g*. Occupational Group, the Women Group etc.

The essential element of such organisation requires people's participation willingly in Co-operative management. There are many ways to encourage people's participation in the organization for Co-operative management are ;

1. Use active rather than passive, and practical rather than theoretical methods. Involve everyone - assign tasks which ensure everyone is involved in Co-operative management.
2. Begin with an activity which is of interest to all. Building a community map is a good start. Provide a simple outline. Each member can input his or her house on the map.

Other resources and landmarks can be added as required.

3. Use small groups. Small, homogeneous groups where mutual trust and concern are more co-operative and supportive, at least initially.
4. Provide meaningful data and information. For those with no or little

education, statistics and academic information cannot be interpreted. Simple graphics, models, numbers and charts should be used.

5. Facilitate access to wear information. Take the group to library, a government office, and school or on field trips where they can increase their knowledge base and learn where to go for information in the future.
6. Conscientize the group! Only when political awareness has been raised, are people willing and mentally able to help themselves. Thus creation of awareness of the forces that oppress them is one of the most powerful forces for action, and collective action is necessary to achieve progress against oppression. Participation is the way to collective action.

At the end, the levels and effectiveness of peole's organization (Society), depend largely on individual group organizers, leaders, members and facilitators. Not everyone is temperamentally suited to working with people in participatory way, and not all can learn the skills which facilitate participation. Careful selection and effective training are both needed for people's organization to become a reality as strong vehicle for rural development.

Important elements of People's Organization (Society) for Co-operative Management

In promoting people's organization, the following important elements should be considered:

1. People's organization should be aimed to focus on the rural poor, those individuals living at or below the subsistence level such as smallholders, tenants, small fishermen, tribal minorities, and include women, men and children.
2. Participation of the rural poor is most effectively promoted through the formation of small, informal and homogeneous groups of 6 to 15 members who share common social and economic levels, and are willing to organize around a common activity which addresses a sharedproblem or interest.
3. For long term effectiveness the principle of self help organization should be safeguarded by developing leadership, managerial capabilitty and mobilization from within the group. People should themselves select their members, leaders, office bearers and functionaries, and decide on their own rules and activities. Undue dependency of outside assisstance should be progressively eliminated.
4. Self-identified, income-generating and/or employment activities will create economic benefits which will facilitate self-reliance and

long term viability. Group savings and productive investment should be encouraged, with credit provisions where necessary.

5. The recruitment and training of suitable group promoters/group organizers as catalysts for group formation and guidance should be seen as a temporary input for about 1-2 years.
6. Where feasible, non-government organizations (NG0s) should be given a primary role in project implementation in collaboration with key government agencies. Expreience has shown NG0s more operationally flexible, and more able to adapt quickly to local needs.
7. Participation by the beneficiaries in all project activities is essential. This includes problem identification, planning (decision-making), implementation, monitoring and evaluation, and feedback interpretation. The methods used to encourage participation are not natural - they must be learned and training must be provided over suitable periods of time by qualified personnel.
8. Projects should be small in scale with a high potential for replication. Initial activities should focus on strengthening the group economically and socially, with the development of effective linking mechanisms and preferential policies for the delivery of inputs and services to project beneficiaries. The promotion of low-cost initiative which are financially sustainable have the highest potential for replication. Investment-oriented activities may follow later.

PARTICIPATION

Participation is a process by which people become involved at all stages in their own development, studying their own situation and making decisions in

* research
* planning
* implementing and managing
* decision on the distribution of benefits to ensure equitable sharing

Participation of people towards the achievement of group goals occurs at three levels. At the lowest level people's contribution is merely a passive giving. A more meaningful level of participation is organization of a group around a common concern. At the highest level of participation the concept of empowerment to internalized, and people begin to take control over situations that affect their own lives.

RESEARCH

Participatory research is a process investigation carried out by partners in research who together study situations in dual process of data collection and learning. It is an on-going, action-oriented approach which forms an integral part of village development, and provides a more accurate and authentic reflection of the reality of village life. Participatory research suggests viable solutions.

Steps in Research

1. Identify problems
2. Select methods and design work plan
3. Collect and compile data
4. Analyze and present findings
5. Draw conclusions and make recommendations

PLANNING

Planning is deciding on the best way to reach a goal. Participatory planning is a process of collective decision-making by partners in, for example, a village development project, about how to use resoruces and plan activities to teach a specific objective.

Steps in Planning

1. Define the problem
2. Set goals and objectives
3. Identify resources
4. Prepare plan of action
5. Plan budget

MANAGEMENT AND IMPLENENTATION

The purpose of management is to enable people (in group, organization community and as individuals) to become self-reliant, creative and self-motivating. This implies enabling people to:

- reach their goal
- change their existing situation
- take control of situations that affect their lives.

In this sense, management has to take into account the meeds, the dignity and the voice of the people.

The underlying beliefs are:

* People must participate in decision making

** People have the motivation, ability and reidine@s to take responsibility to work towards change

*** People are not by nature passive or resistant to their own needs and goals. They can become so as a result of previous experience.

Steps in Management and Implementation

1. Study the plan and commit to action
2. Carry out the actions
3. Monitor and review
4. Solve problems as they arise
5. Market products and share benefits

MONITORING AND EVALUATION

Participatory monitoring and evaluation (M & E) is an integral part of village development projects, where people are actively involved in a continuous feedback system to see whether activities are done according to the plan. Data are collected and analyzed to assess the impact of activities in terms of the project obiectives. The system covers all aspects of the projects namely processes of operation, performance of those involved, progress achieved quantitatively and qualitatively, resources used, and the impact both on the life of intended beneficiaries, and on the local environment.

Steps in Monitoring and Evaluation

1. Identify areas, organize and prioritize
2. Develop indicators
3. Develop monitoring and evolution materials; assign responsibilities
4. Collect data, analyze, and provide feedback
6. Report and disseminate

As mentioned earlier, development is a process of change. It involves improvement in factors which living and quality of life of the people. Planned change aims at specific improvements in the provision of basic needs. as well as better quality of life. Unplanned change can result in negative impacts, such as environmental degradation, centralization of power and control, loss of status. Participation development enhances the human potential through a dual process of education and planned action.

Development efforts should improve both the quality of life and the standard of living by addressing people's basic needs. This will mean:

1. Increase in productivity and ensuring equitable distribution.
2. Improving services for the well-being of all;
3. Reducing drudgery through appropriate technology; and
4. Increasing choices and opportunities for the release of creative potential, particularly of the underprivileged.

Areas of change. Change is a continuous process which occurs around and within us all the time. Development process affect three major areas of change: 1) Environment (Physical and Social); 2) Economic; and 3) Political.

Special considerations, harnessing human potential to promote development is basic to working together especially with poor people. All sections of the population have specific contributions to offer - enthusiasm and energy of the youth, the tempering wisdom of the elders, make zeal for economic growth, women's concern for family welfare and subsistence production. Special efforts need to be made to protect and enhance the interests of marginalized groups (minorities and disadvantaged sectors) by making special provisions, recognizing and acknowledging their contributions, and considering their concerns. These may include women, isolated rural households, children, the elderly and people with disabilities, All these can and should have the chance to make special contributions in participatory development.

COMMUNICATION IN GROUP/PEOPLE'S ORGANIZATION

Communication, broadly speaking, is the process by which human beings share information, knowledge, expertise, ideas and motivations. Development, on the other nand, is not a matter of technology and gross national product but the attainment of new technology and skills, the growth of a new consciousness, the expansion of human mind, the uplift of the human spirit and infusion of human confidence.

Communication is defined as the process by which human gain mutual understanding through the purposive use of verbal and nonverbal symbols. It is the process of affecting, influencing or changing knowledge, attitude and behaviour. Communuication is the means by which an activity is organized, behaviour is modified, change is effected, information is make productive and goals are achieved. The importance of communication as one of the basic tools in management for accomplishing organizational objectives. In fact, it is the key to managerial effectiveness.

Human communiucation is a form of social interchange for a mutual purpose. It is through communication that man is able to interact with others in his society. By communicating with others, he relates himself with them.

Through this, socialization becomes possible. Thus without communication, there will be no society.

__Functions of Communication in a Society__

1. **Information**. This is the collection, storage, processing and dissemination of news, data pictures, facts and messages, opinions and comments needed to enable an individual to understand and react knowledgeably to his environment as well as to make decisions.

2.**Socialization.** Communication provides a "common fund of Knowledge" which people use in order to operate as effective members of society and to foster social cohesion and awareness so that they will be actively involved in the social life of their community.

3.**Motivation**. Communication stimulates individual choices, aspirations and community activities which help achieve the goals of society.

4. **Debate and Discussion**. Communication provides opportunities for prople to exchange facts which are needed to discuss and clarify public issues and to promote greater interest in local, national and international affairs which are common concern.

5. **Education**. Communication transmits knowledge that develops intellect, character, and skills.

6. **Cultural Promotion.** Communication promotes the development and dissemination of cultural and artistic products for man and preserves them of the future.

7. **Entertainment**. Communication provides entertainment.

8. **Integration**. Communication provides the individual and groups access to messages which they need in order to know and understand and appreciate each other.

Communication Methods in Group/Organization

In regard to selecting the best means of communication, communication programme should include the following requirements:

1. Express the needs and character of the organization;
2. Grow in a climate of trust and confidence;
3. Form an integral part of each task;
4. Be stimulted to share information;
5. Be directed to purpose and person; and
5. Keep the lines of communication as clear and direct as possible.

Conclusion

Co-operative management is a broad concept or goal, not in itself a precise prescription for better management. Community - based co-operative management refers to a somewhat more tightly defined concept, wherein authority and responsibility over local resources are shared between government and local resource users and/or their communities.

Organizational Communication Methods in Co-operative management

METHOD	ADVANTAGES	DISADVANTAGES
TELEPHONE	Verbally fast Permits question and answers Convenient Two-way flow Immediate feedback	Less personal No record of conversation Message might be misunderstood Timing may be inconvenient May be impossible to terminate
FACE-TOFACE	Visual Personal cantact Can "show and explain" Two-way flow Immediate feedback	Timing may be inconvenient Requries spontaneous thinking May not be easy to terminate Power or status of one person may cause pressure
MEETING	Can use visual Involves several minds at once Two-way flow	Time consuming Timing may be inconvenient One person may dominate the group
MEMORANDUM	Brief Provides a record Can prethink the message Can disseminate widely	No control over receiver Less personal One-way flow Delayed feedback
FORMAL REPORT	Complete, comprehensive Can organize material at writer's leisure Can disseminate widely	Less personal May require considerable time in reading Language may not be understadable Expensive One-way flow Delayed feedback

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PRACTICAL

National Training on *Management of Small Reservoirs*
organised at CIFRI during Feb.12 - 21, 2001

STANDARD METHODS FOR BIOLOGICAL EXAMINATION OF PLANKTON AND BENTHOS

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Physical and chemical characteristics of water bodies affect the abundance, species composition, productivity and physiological condition of aquatic biota in reservoir environment. Biological methods used for assessing water quality include the collection, counting and identification of aquatic organisms. Whenever practicable, one should collect their own samples. Much to the value lies in personal observations of conditions in the field and in the ability to recognise signs of environmental changes as reflected in the various aquatic communities. The primary orientation is towards field collection and associated laboratory analysis to aid in determining the status of biotic communities under field conditions and to adjudge the influence of environmental conditions.

Plankton

The term *Plankton* refers to those microscopic aquatic forms having little or no resistance to currents and living free-floating and suspended in natural waters. Planktonic plants, *Phytoplankton* and planktonic animals *Zooplankton* are covered under plankton. Because of their short life cycles, plankters respond quickly to environmental changes and hence their standing crop and species composition are more likely to indicate the quality of water mass in which they are found and also to the biotic productivity of higher trophic level.

Sample collection

Establish a sufficient number of stations in as many locations as necessary to define adequately the kinds and quantities of plankton in the waters to be studied. If it can be determined or correctly assumed that the plankton distribution is uniform and normal, use a scheme of random sampling to accommodate statistical testing. Collect composite samples and use appropriate statistical tests to determine population variability. In shallow area of 2 to 3 meter depth, subsurface samples collected at 0.5 to 1.0 m may be adequate. Daily vertical migrations occur in response to sunlight and hence samples may be collected daily depending upon availability of personnel or when this is not possible, weekly-bi-weekly, monthly or even quarterly sampling still may be useful for determining major population changes.

Sampling procedure

Collection of plankton samples may be done by plankton net made of standard bolting silk cloth no. 25 (Mesh size : 0.03-0.04 mm). Preferably samples should be taken from all the extremities and middle points of a waterbody by collecting 50 litres of water through graduated enamel mug and filtering the same through plankton net. Concentrated plankton thus obtained are then adjusted to 10 ml and preserved in 5% solution of formaldehyde. Also plankton samples may be collected at three hourly intervals round the clock for diurnal studies on monsoon, winter and summer seasons. Label sample containers with sufficient information to avoid confusion or error.

The settled volume of plankton should be recorded in graduated tubes after 24 hrs. of sedimentation or instant centrifugation. The volume concentrated varies inversely with the abundance of organisms and is related to sample turbidity.

Sample analysis

Qualitative and quantitative analysis of collected samples is to be done in the laboratory as per well accepted counting method of individual species by using ***Sedgewick-Rafter*** counting cell. After shaking the vial containing concentrated plankton samples a sub-sample of 1 ml is quickly drawn with a wide mouthed long dropper and poured in plankton counting cell of 1 ml capacity. All the plankters encountered are represented in absolute number. At least three counting are made for each sample and data are presented in average values. Group-wise and .species-wise representation of different forms are tabulised and percental values are to be worked out for estimating plankton productivity and population dynamics of specific waterbody. Quantitative estimation should be done as under :

1. Take a microscope with suitable oculars and objectives.
2. Take Sedgewick - Rafter counting cell or prepare a similar one of area 50 mm X 20 mm and depth 1 mm showing mm square rulings.
3. Note down the volume of plankton concentrate.
4. Shake well the plankton concentrate and transfer 1 ml to counting cell and cover it with rectangular cover glass.
5. Count plankters space-wise, genera-wise or group-wise in 10 square and find out the average. Ten counting units must be taken at random. Average number of plankters per counting unit of 1 cu mm should be

worked out and no plankters should be shown as zero in the computation. The number of plankters in terms of species/genera/group per litre can be computed using the formula as under.

$$ni = \frac{(a\ 1000)c}{l}$$ where

ni = Number of plankters (in terms of species or genera or group per litre of original water)

a = The mean number of plankters per counting unit of one mm^2
c = Volume of concentrated plankton in ml
l = Total volume of water (filtered) in litres

Benthos

Benthic macroinvertebrates are animals inhabiting the sediment or living on or in other available bottom substrates of water ecosystems. Although they vary in size but macroinvertebrates are considered historically by definition to be visible to the unaided eye and are retained in sieve standard No. 40 which will retain only macroorganisms. This specific sieve is useful for standardization of bioassessment for species composition, taxa richness, diversity evenness, trophic levels and major taxonomic spatial and temporal patterns.

Sample collection

After gaining a thorough understanding of the factors involved with a particular body of water, select specific areas to be sampled. Most taxas are not distributed uniformly over the bottom since different habitats (sand, mud and gravel or organic material) support different densities and species of organisms. Even on a relatively homogenous bottom, animals tend to aggregate. Therefore, take replicate samples to evaluate this variability. Use at least three replicate samples per station to describe the macroinvertebrate community. Ideally, conduct a baseline survey to determine station, substrate characteristics and the number of samples necessary to achieve the desired level of accuracy.

Bottom sampler

Ekman dredge is best suited as a sampler for bottom biota for soft bottoms. Two sizes of this sampler are available namely 15.2 x 15.2 cm and 22.9 x 22.9 cm. The former is more convenient from the point of view of sampling. Where, however, the bottom is hard. Peterson grab with an enclosure area of about 0.08 sq.m. may be used.

Collection procedure

1. Collect samples by ***Ekman dredge*** from randomly chosen stations.
2. Each sample may be transferred to suitable containers like enamel buckets or other larger sized containers.
3. Take sieve No. 40 which will retain macroorganisms.
4. Take suitable quantity of dredge material from the bucket and place it in sieve. Wash it with liberal quantities of tap water or water from other source.
5. Transfer the residue (macro-organisms) into a wide-mouthed bottle. Repeat the same procedure for other parts of sample.
6. Preserve the material in 10% formalin, if detailed analysis has to be done at a later
date.

Quantitative evaluation and computation

1. Transfer small portions of screenings into petri dishes or shallow porcelain dishes.
2. Segregate the organisms into species, genera or groups according to the nature of the investigations.
3. Count them per qualitative identity under one or more of the above heads.
4. Compute for each individual group or for all groups the number of macro-organisms per square metre, whichcan be done as follows.

$$N = \frac{n}{ah} \quad \text{where}$$

N = Number of macr o-organisms in 1 sq.m.
n = Number of macro-organisms per sampled area
a = Area of Ekman dredge in sq.m.
h = Number of hauls

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National Training on *Management of Small Reservoirs*
organised at CIFRI during Feb.12 - 21, 2001

WATER AND SOIL ANALYSIS OF OPEN WATER SYSTEMS

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Maintenance of a healthy aquatic environment and production of sufficient fish food organisms in a water body are 2 very important factors for boosting fish production. To keep the water body conducive for fish growth, physical and chemical parameters like temperature, transparency, pH, dissolved oxygen, total alkalinity, free CO_2 and nutrient elements like nitrogen and phosphorus may be monitored regularly. Where the physico- chemical factors are in normal range, the water body is usually productive, but when they are present in quantities above or below the optimum range the fishes and other aquatic organisms may be under stress which may lead to fish disease or fish mortality in due course.

1. *Temperature*

The temperature is noted with the help of a centigrade thermometer or by temperature selective electrode. Optimum range for carp growth : 23 - 30^0 C.

2. *Transparency*

Transparency of a water body is recorded with a *Secchi disc*. Dip the *Secchi disc* in water until it is invisible. Note the depth of the disc from water surface in cm. *Optimum range* : 20 - 50 cm.

3. *Water pH*

The pH of water sample may be determined accurately by using a pH meter which has been standardised against two buffer solutions of known pH. Optimum range : 7.4 - 8.2.

4. Dissolved oxygen

Winkler's method

Reagents

i.) Alkaline iodide : Dissolve 500 gm NaOH and 150 gm Potassium iodide in one litre distilled water. Keep the reagent in polyethylene container.

ii.) Manganous sulphate: Dissolve about 480 grams of Manganous sulphate in one litre of distilled water.

iii) N/40 Sodium thiosulphate : Dissolve 6.205 grams of pure Sodiumthiosulphate in one litre of distilled water. Add 1-2 beads of NaOH as stabiliser. Keep in a ambre colour glass bottle. This thiosulphate solution may be standardised against N/40 $K_2Cr_2O_7$ solution.

iv.) N/40 $K_2Cr_20_7$ soulution : Weigh 1.226 grams of pure $K_2Cr_20_7$ and dissolve it in one litre distilled water. Place 25 ml of dichromate solution in a conical flask, add 1 ml alkaline Iodide, acidify with 2 ml conc. H_2SO_4 and keep in dark for 10 minutes. Dilute the distilled water and titrate the iodine with the (N/40) thiosulphate using starch as indicator. Adjust the strength of thiosulphate to exactly N/40.

v.) Starch : Take 1 gm soluble starch in 100 ml water, boil for one minute. Add a few drops of acetic acid as stabilizer.

Procedure

Collect water sample in 125 ml D.O. bottle, add 1 ml of Manganous sulphate solution and then 1 ml of alkaline Iodide solution. Replace the stopper and keep the bottle in dark for 10 minutes. Then add 1 ml of conc. H_2SO_4 and shake to dissolve the precipitate. Transfer 50 ml of the solution to a conical flask, add 1-2 drops of starch solution and titrate the solution with N/40 thiosulphate to a colourless end point.

Calculation

No. of ml of thiosulphate required x 4 = ppm of 0_2

Optimum range: 5 - 1 0 ppm.

Ion selective electrode method:

Electrode is first calibrated and then reading is taken accordingly.

5. Free $C0_2$

Reagents

i. N/44 NaOH

Prepare 0.1 N NaOH by dissolving 4 gm of AR NaOH per litre and standardise it against 0.1 N H_2S0_4 using phenolphthalein as indicator. Dilute 100 cc of this 0.1 N NaOH to 440 ml with distilled water. This is N/44 NaOH. Store it in a polyethylene bottle.

ii. Phenolphthalein indicator

Dissolve 0.5 gm phenolphthalein in 100 ml 50% alcohol.

Procedure

Take 50 ml of water sample in a conical flask, add 2 drops of phenolphthalein indicator.
Add N/44 NaOH dropwise till the solution turns slight pink.

Calculation

No. of ml of N/44 NaOH required x 20 = ppm of free $C0_2$
Optimum range for carp culture ponds : 5 - 10 ppm.

6. Total alkalinity

Reagents

i). N/50 H_2SO_4
ii). Methyl orange indicator solution.

Procedure

Take 50 ml of water sample in a conical flask and add 1-2 drops of methyl orange indicator. Titrate with N/50 H_2S0_4 until the solution turns pink,

Calculation

ml of N/50 H_2S0_4 consumed x 20 = ppm of total alkalinity.

Optimum range : 80 - 150 ppnl.

7. Total hardness

Estimation

Total hardness is determined by titration with standard ethylene diaminetetra acetic acid (EDT'A) disodium salt using Eriochronie black-T as indicator. The end point is from reddish brown to blue (APHA, 1980).

Optimum range-: 20 ppm and above

8. Dissolved Inorganic Phosphate

Reagents

i. 50% H_2SO_4

ii. Ammonium Molybdate (1 0%)

iii. Acid ammonium Molybdate

Add 15 ml of 50% H_2SO_4, to 5 ml of 10% ammonium molybdate.

iv. Stannous chloride solution Dissolve 1 gm stannous chloride AR in 100 ml of glycerine.

v, Standard phosphate solution.

Dissolve 4.388 gm KH_2P0_4 in 1 litre distilled water. This stock solution is 1000 ppm phosphate.

Dilute 1 0 ml of this stock solution to 1 litre with distilled water. This is 10 ppm phosphate.

Procedure

Place 50 ml of water sample in a Nessler tube, add 2 ml of acid ammonium Molybdate and 2 drops of stannous chloride. Mix and wait for 10 minutes. Measure the blue colour in a spectrophotometer at 690 rim. Similarly take four standard phosphate solutions in Nessler tubes and develop the blue colour by adding ammonium molybdate and stannous chloride. Measure the colours of the standard solutions by spectrophotometer. Determine the phosphate content of sample from the calibration curve drawn from standard phosphate solutions.

Optimum range for carp culture ponds: 0.2 -0.6 ppm

9. Nitrate nitrogen

Reagent

i) Phenoldisulphonic acid
ii) 12 N NaOH
iii) Standard Nitrate solution (1 0 ppm)

Dissolve 0.722 gm of KNO_3 in distilled water and make upto 1 litre. Dilute 10 ml of this stock solution to 100 ml containing 0.01 mg N/ml = 10 ppm N.

iv) Aluminium sulphate solution (10%).

Procedure

Evaporate to dryness 50 ml sample in a white porceelaein basin on water bath. Cool and add 2 ml of phenoldisulphonic acid and rub it with a glass rod. Wait for 5 minutes and add 2 ml of Aluminium sulphate solution. Now add 12 N Na0H solution slowly until it is alkaline. Add 20 ml distilled water and filter the solution. Take filtrate, make up the volume to 50 ml. Measure the yellow colour of the solution by spectrophotometer at 410 nm . Prepare four standard solutions of nitrate from the standard nitrate solution (10 ppm). Evaporate the solutions to dryness, add phenoldisulphonic acid, mix by glass rod and then add 12 N NaOH to make the solutions alkaline. Dilute with distilled water and make up the volume (to say 50 ml). Measure the colour of these four solutions by spectrophotometer at 410 nm. Prepare a standard curve from the standard solutions. Determine the concentration of unknown solution from the standard curve.

Optimum total nitrogen content in carp culture ponds : 1.0 - 2.6 ppm.

10. Specific conductivity

Specific conductivity of water sample may be estimated easily by using a conductivity meter.

Optimum range for carp culture ponds : 250 - 1 000 μmho/cm.

SOIL ANALYSIS

Collection

Collect soil samples from several locations of the water body by Ekman dredge. Mix the samples. Dry the samples in air. Powder it with a wooden hammer, strain through a 2 mm and then a 80 mesh seive and again air dry. Analysis may be done with the air dried sample but result should be expressed on the oven dry basis.

1. Soil pH

Electrometric method

Procedure

Take 10 gm soil in 50 c.c. beaker and add 25 mi of distilled water. Shake for half an hour. Dip the electrode of pH meter in the suspension and take the pH reading.
Optimum range : near neutral (6.5 - 7.5)

2. *Organic carbon*

Reagents

i) N $K_2Cr_20_7$
Weigh exactly 49.04 gm of AR $K_2Cr_20_7$ and dissolve it in 1 litre of distilled water.

ii) N Ferrous solution
Dissolve 278 gm Ferrous sulphate or 392.13 gm Mohr salt in distilled water, add 15 ml conc. H_2SO_4, and make up the volume to 1 litre. This solution should be standardised against N $K_2Cr_20_7$ so that 1 ml Ferrous solution = 1 ml of N dichromate.

iii) Diphenyl amine indicator.
Dissolve 1 gm Diphenylamine in 200 ml of conc. H_2SO_4 and 40 ml of water.

iv) Phosphoric acid (85%)

v) Conc. H_2SO_4

Procedure

Take 1 gm soil sample in a 500 m] conical flask. Add 10 ml of N $K_2Cr_2O_7$ and 20 ml of conc. H_2SO_4 . Allow the mixture to stand for 30 minutes. Dilute with water 200 ml and add 10 of phosphoric acid. The excess of dichromate is titrated with N $FeSO_4$ using 1 cc of diphenylamine as indicator. The end point is green from a bluish colour.

Calculation

(10 - Nos. of ml of $FeSO_4$ solution required) x 0.3 = Organic carbon
Optimum content in carp culture ponds : 1.0 - 2.5%

3. Available phosphorus

Trough's method

Reagents

i) 0.002 N H_2SO_4
Dilute 100 ml of standard 0.02 N H_2SO_4 to 1 litre. Adjust the pH to 3.0 with ammonium sulphate.
ii). 50% H_2SO_4
iii) 10% Ammonium Molybdate
iv) Acid ammonium Molybdate reagent
v) Stannous chloride solution.
vi) Standard phosphate solution (1 ml = 0.01 mg P.)
The methods for preparing reagents are the same as given for determination of phosphate in water.

Procedure

Place one gm air. dried soil sample in a 250 ml bottle. Add 200 ml of 0.002 N H_2SO_4 (pH-3), shake the mixture for 30 minutes in a mechanical shaker. Keep it for 1 0 minutes and filter. Take 50 ml of filtrate in a Nessler tube and determine its phsophate as for water.

Calculation

ppm of phosphate in solution x 20 = mg P/ 1 00 gm soil.

Optimum content in carp culture ponds: 9-19 mg/100 gm soil.

4. *Calcium carbonate*

Rapid Titration method

Reagents :

i.. N HCI : Dilute 175 ml of conc. HCI to 2 litres.
ii. N NaOH: Take 80 gm of NaOH in 2 litre of water.
iii. Bromothymol Blue indicator.

Procedure

Take 5 gm soil sample in a 250 ml bottle. Add 100 ml of 1 N HCI and shake for one hour. Allow to settle the suspension and pipette out 20 ml of the clear liquid in a conical flask. Titrate it with N NaOH using Bromothymol Blue indicator till it is just blue. Note the reading and carry out a blank taking 20 ml of 1 N HCI in a flask and titrating it in the same way.

Calculation

(Titre for blank - Titre for soil solution) x 5 = % $CaCO_3$
Optimum content in carp culture ponds : 1.2 - 2.5%.

5. *Available Nitrogen*

Reagents

i. 0.02 N H_2S0_4
Dilute 1 00 ml of 0. 1 N H_2S0_4 to 500 ml with distilled water.
ii. 0.02 N NaOH
Dilute 1 00 ml of 0. 1 N NaOH to 500 ml with distilled water.
iii. Methyl red indicator
Dissolve 0. 1 gm methyl red in 25 ml of ethyl alcohol and make up the volume to 50 ml with water.
iv. 0.32% $KMnO_4$
Dissolve 3.2 gm of $KMnO_4$ in 1 litre distilled water.
v. 2.5% NaOH Disssolve 25 gm NaOH in 1 litre distilled water.

Procedure

ii) Place 10 gm soil sample in a 500 ml Kjeldahl flask. Add 100 ml of 0.32% $KMnO_4$ solution, 100 ml of 2.5% NaOH, 2 ml of liquid paraffin and some glass beads. Distill the mixture and collect the distillate in a conical flask containing 20 ml of 0.02 N H_2S0_4 and a few drops of methyl red indicator. Collect about 75-80 ml of distillate. Titrate the excess of 0.02 N H_2SO_4 with 0.02 N NaOH to a colourless end point.

Calculation

(20 - No of ml of 0.02 N NaOH) x 2.8 = Available nitrogen (mg/100 g soil).
Optimum content in ponds : 50-65 mg/1 00 g.

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National Training on *Management of Small Reservoirs*
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LABORATORY METHODS ON FISH PATHOLOGY

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ANATOMY OF FISH

Knowledge of the anatomy of fish is essential for the study of fish diseases. It is essential to know the normal anatomical features of various organs and tissues to assess the modifications that occur due to parasitic infection or infestation.

Normally the head of a fish merges into the trunk. The head is constituted of the mouth having the lower and upper jaws. Around the mouth some fish species have barbels. The upper side of the head has two nasal appertures behind which there are two eyes.

The trunk of the fish body is covered with scales. There are some genus like *Mystus* which are scaleless. The lateral line, sensory in nature is formed by small openings in the scales, and located on both sides of the body. The fins are located in the trunk region. They are the paired pectoral fins and ventral fins and single dorsal, anal and caudal fin. The fins are supported by fin rays. The skeleton of the adult bony fishes are ossified and the skeleton of head, trunk and fins can be differentiated. The trunk skeleton is composed of a number of spinal vertebrae. Each has a cylindrical body with a saucer shaped cavity at each end. From the upper side of the vertebrae two erect prominencies surround the spinal canal containing the spinal cord. These prominences join above the canal to form a spinous process. From the lower side of the vertebrae two spines project down and are joined to the ribs in the region of the body cavity. The fins are supported by a large number of tiny bones.

The muscles are also of different types in the head, trunk and fins.

Digestive system

It starts with the mouth cavity which goes into the spacious pharynx. The pharynx open out bilaterally into five branchial slits covered with variously shaped branchial rakers which stand out from the inner side of the branchial arches. The pharynx leads by a short oesophagus into the stomach or into the intenstine. From the stomac extends the pyloric caeca. The intestine is of variable length and remain coiled inside. The liver is a big and prominent organ inside and is attached to the intestinal loop. It's color is normally greyish red. The gall bladder is situated on the dorsal side of the liver. The pancreas lies diffuse over the liver or around the stomach. The spleen is usually small and is joined either to the liver or to the intestine and have a dark reddish color.

Circulatory system

The heart is located under the gills towards the ventral side. From it the aorta opens out through an enlargement called bulbous arteriosus. After a short course in the anterior region of head the aorta ascends and branches into 8 branchial enteries. From each branchial artery, which runs through outer periphery of the branchial arch, arteris enter into the branchial filaments in which they branch into a dense network of capillaries. The blood from the gills is carried away by eight branchial veins which join above the gills and form two long arteries which connect the head and then the aorta descends. The aorta descends under the spine and forms a arteries supplying the internal organs and the muscles with blood.

Gills

The gills are placed on either side of the head in the branchial cavity. On each side there are four branchial arches. On the convex side of the brachial arches there are forked bright red branchial filaments.

Kidney

The kidneys lie between the swim bladder and the roof of the body cavity. They are elongated in shape, brownish red in color.

Air Bladder

The air bladder fills up the space above the digestive system and gonads and overlaps the kidneys with its upper end. The swim bladder consists either of one or two compartments. The gonads lie by the sides of the body cavity and reach a considerable size before spawning. A sexually mature male has opaque, creamy testes. The ovary of a sexually mature female has a transparent membranous envelope containing spherical eggs.

Skin

The skin consists of two basic layers, the dermis and epidermis. The epidermis is normally covered with a layer of mucous. The dermis is interwoven with a multitude of pigment and fat cells. The scales are formed and are embedded in the dermis. The majority of our fish have cycloid scales.

Eye

The eye in the majority of fish is large. The eye ball rests in the eye socket. The sclera has a rigid outer covering. In the eye ball there is a spherical lens. The space behind the lens is filled with a transparent gelatinous vitreous humor.

Nervous system

The nervous system consists of the brain, the spinal cord peripheral nervous system, and the autonomic system. The brain is enclosed in the cranial cavity in the upper part of head behind eye.

All these organs and tissues of fish can act as substrate or a habitat for colonization by various protozoan, helminth and crustacean parasites.

Examination of fish organs for pathogens

The fish sample is first examined on the external surface and then it is dissected through the ventral surface to exhibit the various internal organs for study.

Skin

- The external surface of the skin of the fish sample is examined by a magnifying lens or if it is a small fish under dissecting microscope.
- Then smears of the external surface of the skin is made and examined under microscope.
- After completing the above examination the fish is skinned for observation of dermal and subcutaneous cysts or other pathogens of the skin.
- Examination of the skin is done because it serves as the habitat for the pathogens *viz.*, bacteria, ciliates, myxozoans, gyrodactylids, metacercariae larvae, copepods and fungi.

Gills

- The gills are dissected out after removal of operculum.
- Gills may harbour bacteria, flagellates, ciliates, myxozoans dactylogyrids and fungi.

Eyes

- The eyes are carefully removed from their orbits with a bent forceps or scalpel.
- It is investigated for bacteria, myxozoa, trematode and fungi.

Brain

- It can be examined fresh or in histological sections.
- It may harbour, bacteria, ciliates, myxozoans or fungi.

Muscle

- Muscle areas which look, discolored, swollen or hardened should be teased apart under magnifying lens or dissecting microscope for detail examination of isolated muscle fibres.

Digestive canal

- Cut the oesophages just behind the oral cavity.
- Pull out and straighten the gut along its whole length down to anus when it is again cut through.
- Open the gut wall by scissors with a blunt tip.
- Intestinal wall may be kept for sections.
- The intestinal cavity harbours bacteria, ciliate, flagellate, myxozoa, trematodes, cestodes, acanthocephala, nematode and fungi.
- The intestinal wall is the habitat of various developmental stages of protozoans.

Peritonial cavity

- It is opened by a curved cut begining at the anus and following its upper broder to the dorsal edge of operculum, returning to the anus along the mid ventral lines.
- The fluid or any foreign body should be examined.

Liver

- It is a massive organ lobed on either side of the anterior portion of the gut.
- Squash preparation of liver may be made.
- Histological sections may be made.
- Liver harbours bacterial cysts, myxozoans, fungal cysts, encapsulated larvae of various worms.

Kidney

- It is located just below and pressed to the vertebral column divided into the anterior and posterior kidney.
- It is examined through contact smears or histological sections.
- Kidney harbour myxozoans, bacteria.

Heart

- Very prominently seen in the anterior portion of the body ventrally placed.
- It harbours various myxozoans.

Examination of fish for protozoan parasite

Myxozoan parasites

The white cysts of myxozoan parasites are frequently located in the gills, scales, skin and other internal organs of fish. To examine these parasites the spores within the cysts are stained. The spore size, shape, location, number and shape of polar capsule, shape and size of sporoplasma etc. are the identifying characters.

Test sample: Fish with white spots in gills.

Collection, fixation and staining

Cysts are carefully teased out of the fish tissue and fixed in 70% alcohol.

Procedure : (Fresh preparation, Lugols' iodine preparation)

- For contact smear the different organs are smeared on a clean glass slide with a drop of 0.5% normal saline solution. The smear is covered with a cover slip, paraffin sealed and examined under microscope.
- The cysts, when present are teased out with sterile forceps, kept on a clean slide and pressed to release the spore.
- Spore suspension is made in 0.5%saline solution.
- Both the fresh smear preparation and fresh spore preparation are covered with cover slip and sealed with wax.
- If Lugol's iodine preparation is made, the fresh smear is stained with a drop of Lugol's iodine stain and then covered with a cover slip and sealed.
- The slide is then examined under different magnification of microscope.

Result :

i) In fresh preparation the detailed morphology of the spore without shrinkage is seen.

(ii) In Lugol' iodine stain, the polar capsule and coils of the filament are distinct. The iodinophilous vacuole in the sporoplasma of spore stain brown.

Procedure : (Staining)

- A thin uniform smear of spore is made on a clean slide.
- It is semidried and fixed in methanol.
- The smear is air dried.
- Washed in distill water thoroughly.
- The smear is covered with Geimsa stain (2 drops of commercial stain in 1 cc of distilled water) for 25-30 minutes.
- The stain is then drained out and washed with neutral distilled water.
- Slant and dry the slide

Result : In Geimsa staining, the sporoplasm stains prominent blue along with the nuclei. The polar capsule also stain blue.

Urceolariid ciliate

Urceolariid ciliates *viz., Trichodina* sp. and *Tripartiella* sp. are frequently found in the gills of fishes. There identification in fresh smear from gills is easy as they move about freely. But for species identification they are to be stained permanently by Kleins' Silver Impregnation technique.

Collection, fixation and staining

Test sample: A fish with pale cream coloured gills.

- Scrappings from the gills of living diseased fish are taken and a thin smear is made on a clean grease free slide.
- The smear is air dired.
- Place the slide on a staining rack and pour 2% solution of Silver nitrate for 7-8 minutes in a dark place.
- Wash thoroughly in distilled water.
- Place the slide on a petri dish with distilled water and treat under ultra violet lamp for 20 minutes. It is necessary to place the petridish on a white background.
- If ultraviolet lamp is not available place the petri dish in direct sunlight for 30 minutes on a white backgrotund.
- Wash in cold water and air dry.
- Mount in DPX.

Result : The denticles of the ciliate, which are the primary identifying character and radial pins stain brown.

Examination of fish for Helminth parasite

Collection, fixation, preservation and staining

Procedure : (Collection)

Monogenetic trematode like *Dactylogyrus* sp. infest gills. They are carefully teased out under dissecting microscope into watch glass containing normal saline. Digentic trematode and cestodes may be infesting various organs of the body. They are also similarly removed and placed in normal saline.

Procedure : (Fixation)

Trematodes and cestode parasites are fixed in AFA (Alcohol Formal Acetic Acid). Small worm like monogenetic trematodes are fixed directly in watch glass for 3-5 minutes. Bigger specimens of digenetic trematodes or cestodes are put on a glass plate and quickly pressed with cover slip. AFA fixative is gradually poured drop by drop through the side of the cover slip and fixed for 3-5 minutes. Nematodes and acanthocephalans are fixed in corrosive sublimate fixative.

Procedure : (Preservation)

Trematodes and cestodes thus fixed should be washed with 70% alcohol and then preserved in 70% alcohol.

Nematode and acanthocephalan parasites thus fixed should be treated with iodinated alcohol to remove all traces of Mercuric chloride and transferred to 70% alcohol.

Procedure : Staining (Trematode and Cestode)

Semichons carmine method

- Take the preserved specimens in a watch glass.
- Wash thoroughly in 70% alcohol
- Place in diluted Semichons' carmine for 3-5 minutes or more according to thickness of the specimens.
- Destain in acid alcohol and wash throroughly in 70% alcohol.
- Dehydrate through 90% and Absolute alcohol grades.
- Clear in Xylol.
- Mount in Canada Balsam or DPX.

Haematoxylin staining method

- Take the preserved specimens in a watch glass.
- Wash thoroughly in 70% alcohol.
- Hydrate through down grades of alcohol upto distilled water.
- Pour few drops of stain on the specimen and keep for 5 minutes.
- Then replace the stain with distil water with 2 to 3 changes.
- Then dehydrate through 30% to 50% alcohol 1.0 min each.
- Destain in 70% acid alcohol until specimens turn light reddish purple, changing the alcohol, if noticeable color appears.
- Then treat briefly with stronger acid alcohol.

- Wash thoroughly with 70% alcohol till specimen turn bluish.
- Dehydrate through 90% and 100% alcohol grades.
- Clear in xylol.
- Mount in Canada Balsam or DPX.

Procedure : (Staining Acanthocephalan and Nematodes)

Because of the impervious cuticle, specially nematodes are difficult to stain. But if one wants to stain these specimen the staining methods described for Trematodes and Cestodes can be followed. Only care has to be taken that during staining and dehydration sufficient time gap is given.

However for studying unstained specimens Lactophenol method can be used.

Lactophenol method

- Place the preserved specimens from 70% alcohol on a slide.
- Trace of alcohol is removed.
- Mount with a drop of Lactophenol and observe after 2-5 minutes in the microscope.

Procedure for preparation of Fixative and Stain

Alcohol Formal Acetic Acid (AFA) Fixative

Alcohol 95%	:	50 cc.
Commercial Formalin	:	10 cc.
Glacial acetic acid	:	02 cc.
Distilled water	:	40 cc.
Corrosive sublimate acetic acid fixative		
Mercuric chloride saturated aqueous solution	:	10 cc.
Glacial acetic acid	:	10 cc.

Harris Haematoxylin stain:

Haematoxylin powder	:	01.0 gm
Absolute alcohol	:	25.0 cc.
Aluminium ammonium sulphate	:	15.0 gm
Distilled water	:	250.0 ml.
Mercuric oxide	:	0.5 gm.
Glacial acetic acid (optional)	:	2 to 10 .0 ml.

, First dissolve the alum in distilled water and haematoxylin in absolute alcohol. Then heat the alum solution to boiling. Remove from heat and add the stain solution slowly with stirring.The solution while still hot, stir in mercuric oxide when a deep purple colour appears. Cool rapidly and filter. If acid haematoxylin is required add acetic acid. Stain is now ready for immediate use.

Semichons' Carmine Stain

Take in 50 cc of glacial acetic acid in a flask and add carmine powder upto super saturation.Plug the flask with cotton and heat to boiling. Then cool under tap water and filter the stain. The filtrate is the stock stain which can be diluted with 70% alcohol as desired.

Examination of fish for crustacean parasites

Parasitic copepods and branchiurans

Procedure : (*Collection*)

For the copepod parasites like *Ergasilus* present in gill filaments the best method is to tease them out of the filaments with a needle carefully so that the attaching bulla remains intact. Male copepods are often invisible among the mucus of the gills. Flushing the branchial chamber with a dropper on to a petridish often help in collecting males.Copepod parasites are invariably covered with mucus. If the parasite is directly transferred into the preservative the mucus will harden and stick on the body. This would make detail study difficult. The mucus can be removed if the specimens are placed in a dilute solution of sodium carbonate for 5-10 minutes and then rinsed with a dropper.

Live specimens of branchiuran *Argulus* sp. moving on fish body are collected in a petridish with normal saline.

Procedure : (*Preservation*)

Copepods and branchiurans are preserved in either 70% alcohol or preferably 4% formalin.

Procedure : (*Fresh preparation*)

- Take out the specimen on to a watch glass.
- Transfer the specimens to a cavity glass slide.
- Pour 1 to 2 drops of Lactic acid in the cavity and wait for 5 minutes.
- The specimen is now sufficiently cleared from its opacity and relaxed.

- Examine under the microscope.

Procedure : (Staining)

- Take out the specimen on to a watch glass.
- Pour cotton blue stain and leave for 1 minute.
- Transfer the stained specimen to a cavity slide.
- Pour 1-2 drops of Lactic acid to clear it and put a cover slip.
- Examine under microscope.

Examination of fish tissue (Histopathology)

Histology is the study of microscopic anatomy of the organism and morphology of tissues. The importance of histology in fish and prawn disease investigation lies in the fact that firstly it can demonstrate the location and morphology of the pathogens in tissue with the aid of a microscope, secondly the purpose of histology is to demonstrate changes occurring in various tissue due to disease.

Preparing specimens for histology

Procedure : (Fixation)

- The desired tissue of diseased fish or prawn is cut into small pieces preferably 4 to 5 mm square size.
- These pieces are put in vials and fixed in 10% formalin. The volume of the fixative should be at least 20 times the sample size.
- Fix the samples for more than 24 hours.

Procedure : (Embedding)

- The fixed samples are washed thoroughly in tap water.
- Trim the samples into smaller size of 0.5 x 0.4 x 0.4 cm^3 size.
- Decalcify the hard tissue (gill and muscle) in decalcifying solution. Then soak them in 5% sodium sulphate (Na_2SO4) for 1-5 hours and then rinse in tap water for 10-30 minutes.
- Dehydrate the tissue through ascending alcohol grades 30, 50, 70, 90, 100%.
- Then put the tissue in xylene to clear opacity from the dehydrated tissue making them transparent.
- Put the tissue in half xylene half paraffin for half an hour.
- Put the tissue in full paraffin for one hour for proper infiltration.

- The tissue is then embedded in paraffin which is allowed to solidify round the tissue.

Procedure : (Preparation of tissue blocks for sectioning)

- Tissue embedded in paraffin are trimmed in square block for sectioning.
- The blocks are fixed in block holder of the microtome .

Procedure : (Sectioning)

- The prepared paraffin blocks containing sample tissue are cut at 4-5 mm thickness in the microtome.
- The ribbon containing tissue is put into a box.
- The required size of ribbon is carefully transferred.

Procedure : (Stretching of tissue)

The ribbon is put in warm water (45-50^{0}C) placed in a big petri dish to stretch the tissue of wrinkles and make it flat.

Procedure : (Preparation of slide)

- The required size of ribbon is cut and transferred to microscopic slide covered with Mayer's albumen and containing a little water. The ribbon strip is then oriented on the slide as desired.
- The water is then drained out and the ribbon on the slide is then air dried overnight. The slide is now ready for staining.

Procedure : (Staining Haematoxylin and Eosin)

- Put the slide in xylene to dissolve the paraffin.
- Then hydrate the tissue in descending grades of alcohol starting from 100, 90, 70, 50, 30% and water with each step of 5 minutes duration.
- Rinse in water for 5 minutes.
- Stain in Haematoxylin for 5-10 minutes.
- Rinse in water.
- Dehydrate through 50%, 70%, 90% alcohol.
- Counter stain in Eosin.
- Wash in 90% alcohol.
- Dip in Absolute alcohol
- Clear in xylene
- Mount in Canada. balsam or DPX.

National Training on *Management of Small Reservoirs*
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Graphic Media Preparation

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1. *Definition of Graphics*

Graphics are instructional materials that summarize significant information and ideas through some combination of drawings, words, symbols and pictures.

Drawing or sketching, of course, is used to make the original copy for all kinds of diagrams, graphs and most charts. Sketches in rough form are used for most of the layouts and in more refined form are basic to the figures and symbols used in posters, cartoons and comics and pictorial graphs. Symbols are a form of visual shorthand which is used extensively on many diagrams and signs. Words and numbers are used in practically all graphics to supplement and clarify meaning or as in graphs or tables to present quantitative information. Pictures or life like sketches are key elements in many charts and posters to convey the idea or story represented.

Thus, the term "graphics" involves a variety of visual forms, principal among which are drawings and symbols in some form gives an idea of the variety of charts, graphs and specific types.

The graphic media includes following forms:-

1.1 Graphs

1.2 Charts

1.3 Flip charts

1.4 Posters

1.5 Flannel board and cut outs

1.6 Bulletin board

1.7 Exhibit

2. *The Graphic Media for Extension work*

2. 1 *What can graphic media do?*

Like the other media; graphic media alone cannot assure learningt. They should be considered as only one tool to help in doing better job : Properly used, they can be a powerful stimulate to communication. Instructional skill that combines proven Extension teaching methods with good. subject matter and good visual aids provide an ideal situation for learning.

Graphic media as good visual aids can do quite a variety of things to help the communicator.

1. It can arouse and hold interest so that important points are communicated : when the audience is alert and receptive.

2. Good visuals can help to teach more upto 35 per cent.

Used to explain, emphasize and compare and to attract attention, they reinforce other Extention methods and materials in improving the efficiency as well as the effectiveness of the teaching process.

3. Facts communicated with the aid of visuals are remembered longer upto 55 per cent longer.

4. Visual aids can save time, enabling audiences to grasp ideas more effectively and faster rapid transfer of ideas and concepts is becoming more and more important in the fast-moving world of agricultural technology.

2.2 *How to use graphic media in Extension*

The most importance in case of graphic media in extension are suitable for using especially in rural area because of these reason -

- No need of electricity
- Everyone can produce easily
- Operation versatilely
- These are inexpensive materials

Extension worker should determine the graphic media for fruitful use depending on the purpose and number of target audience. The personal approach makes for greater accuracy in solving problems since the steps to solution can be more clearly planned to meet specific needs. This method also keeps the extension worker in close touch with formers and with their current problems. The teaching situation here will be on this basis - personal interest.

In group situation, this method brings together in one place a number of persons who have similar problems or interest and that group learning can be rapid, effective and fun. This approach, enlarged photographs, flipbooks; flash cards, flannelboard with cut out and other visual media can tell the story step by step effectively and realistically.

In mass method of extension, visual media must be designed with their basic purpose in mind - to create awareness of an idea or to build interest in it. For example the objective is to introduce new system of fish culture into your area. Simple attractive posters are to be put up where large numbers of people gather or pass will call attention to the new practice or ask for information from your office. Bulletin board and Exhibits set up at the market or near the store will serve as silent "salesmen" of the idea to the farmers.

3. *Basic Design of Graphic Media*

3.1 *Legible lettering*

Lettering plays an important part in the appearance and effectiveness of the visual. Legible lettering involves three major factors : size, spacing and style.

Size

To be sure that you consider the distance to the east row in your audience in using the following chart as a guide in determining the proper letter size

Lettersize	**Viewing distance**
1/4 inch.	8ft.
1/2 inch.	16ft
1 inch	32ft.
2 inch.	64ft .

These sizes refer to the height of the letters. while using both upper and lower case it is essential to determine the size by the height of the lower case .

Spacing

Spacing of letters seems to be the most difficult task for the average extension worker. There are two common systems for spacing letters linear and optical. Space letters optically, equal measured distance between all letters do not look equal, regardless of measurement.

And remember; vertical lettering might fit the layout of schemes but it will be very difficult to read.

Style

Select a readable letter style, boldness or thickness of the letter also determines ease of reading. Lettering should not be too too tall and skinny or too short and squatty. A good rule for line thickness is a out one-fifth to one-fourth the letter height.

Don't mix styles of lettering in the same message. The only exception, would he the use of a different style for emphasis.

3.2 *Simplicity*

Charts. graph, and diagram may include large amount of information and be acceptable in a printed report or for a manual. Therefore, evaluate the suitability of all items one consider for inclusion in the visual materials and try to limit the selection or design to the presentation of one idea at a time. Subdivide or redesign lengthy. or complex, data into a number of easy to read and easy to understand related materials. Drawings should be bold simple and contain only key detail.

3.3 *Unity*

Unity is the relationship that exists among the elements of a visual when they all function together.

3.4 *Emphasis*

Eventhough a visual treat a single idea; is a simple developed, and has unity, there is often the need to give emphasis to a single element to make it the centre of interest and attention.

3.5 Balance

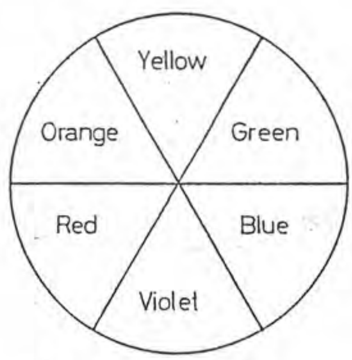
There are two kinds of balances

- <u>*Formal balance*</u> is identified by an imaginary axis running through the centre of the visual dividing the design so that left and right side become to equal..

-<u>*Informal*</u> balance is asymmetrical; the elements create an equilibrium without being static

3.6 Colour

Colour can create the desired mood or atmosphere for the message. Colours have meaning to express appropriate meaning for the subject.
All colours originate from the three primary colours. (red; yellow and blue)
These primaries can be mixed to produce the secondary colours (orange, green and violet). These six colours can present on the colour wheel like this



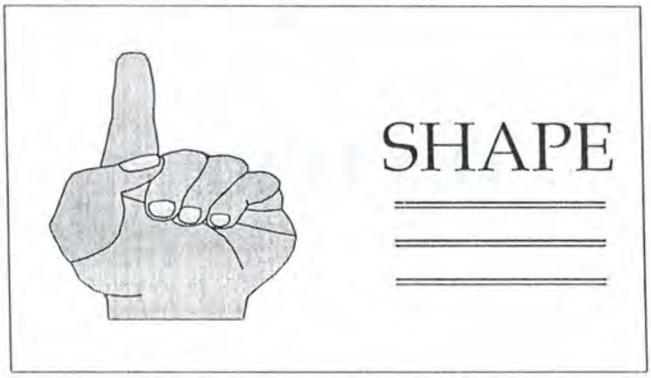
COLOUR WHEEL

Other emotional impacts o f specific colours have been identified. Some common ones are: red - danger or action; orange -warmth or energy; blue - aloofness or clarity; green - freshness or restfulness; violet - depression; and yellow cheerfulness.

When selecting colour for visual materials, attention should be given to three matters. First the hue, the clioice of a specific colour (red, blue, and so on). Second, the value of the colour, meaning how light or dark the colour should appear in the visual with relation to other visual elements. Third, the intensity or strength of the color for its impact, or coordinated effect.

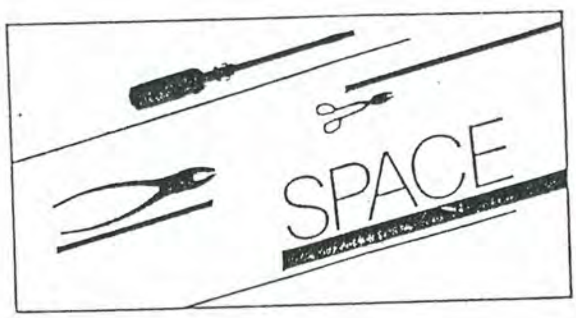
3.7 Shape

An unusual shape can give special interest to a visual.



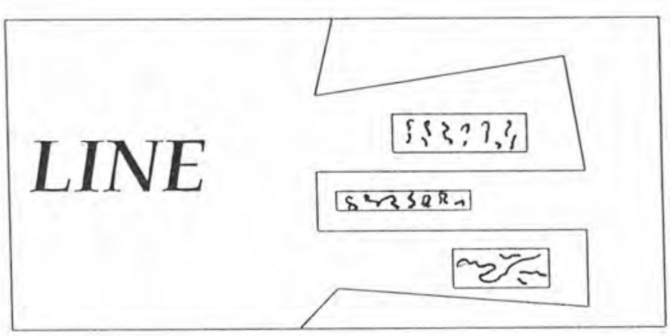
3.8 Space

Open space around visual elements and words will prevent a crowded feeling. Only when space is used carefully can the elements of design become effective.



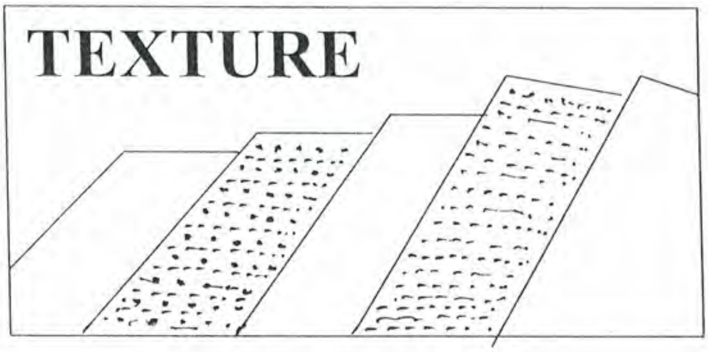
3.9 Line

A line in a visual can connect elements together and will direct the viewer to study the visual in a specific sequence.



3.10 Texture

Texture is a visual element that may serve as a replacement for the sense of touch and can be used ill much the same way as colour to give emphasis or separation, or to enhance unity.



4 *How to prepare and use of graphic media*

4.1 *Graphs and charts*

Graphs are diagrams or lines representing numerical quantities used for quick comparisons and contrast of statistical information . The many possible variations in graph types can be reduced to three basic forms : circle; bar and line. Many special subtypes is based on one or another of these forms such as pictorial graphs or the others.

Line_graphs are particularly valuable in showing trends and relationships. But when the reader should note specific quantities. The identifying feature is two scales, one measure is vertical, one horizontal.

Each point drawn on the line graph has a value on the vertical as well as the horizontal scale. A single line can be used to indicate growth or expansion, while two different lines. More than two or three lines on one chart, however ; often cause confusion and even misinterpretation by the viewer. It is preferable to break down the material into a series of simple charts and present them step by step.

Bar graph In comparing the magnitude similar items at different times or in showing relative sizes of parts of a whole bargraphs are particularly useful, Bar graphs are composed of a series of horizontal or vertical measured bars spaced along a marked scale. These permit statistics to be presented clearly and rapidly in an interesting, logical ways.

Circle or Pie graphs are made in the form of a circle with the entire area divided into segments, each presenting some part of the whole. They always represent whole amounts and their segments are shown as percentages of the whole Pie graphs can be used to show use of waterbody, use of time, distribution of a particular fish crop, and so on. Segments are usually shaded, crosshatched, or coloured to improve contrast. Percentages are always shown on the various segments.

Pictorial graphs are widely used because of their ability to attract attention. They are basically line or bar graphs with symbols related to the data that replace the lines or bars graph, each symbol represents a given amount.

Charts an important purpose of is to present visually ideas or concepts which are likely to be difficult to understand if presented in oral or written form. Charts can also highlight important points of presentations. There are many forms of charts.

Flow-chart present sequences in time or step by step progression and are useful for showing everything from the mixing and application of herbicides to the various inputs. They are often combined with text, using arrows, numbers, or other symbols to show progression from one step to the next.

Time chart or table chart . Anything that is recorded or presented in a ta u ar form is table chart. For example, it may be illustrated to compare yield of maize from various demonstrations.

Tree or stream chart. In it the divisions or sub-divisions arerepresented by a trunk of a tree with branches and sub branches, a stream or river and its tributories.

Oganization chart show diagrammatically how the various units and personel fit into a given corporate structure. A series of connecting line depict chain of command and working relationships. They are excellent for explaining the staffing and functions of any enterprise.

4.2 *Flipcharts or Flipbooks*

The flipcliarts or flipbooks combines some of the advantages of the paper pad;chalkboard, flannelboard and flash cards. It is used to develop a story or a lesson in a progressives step-by-step sequence which makes learning easier.
Some flipbooks are made with paper pages fastened between two hinged covers. The covers fold back, forming an easel or stand. A string, attached to the bottom

of one cover fits into a groove in the other and holds the book in an upright position. Each sheet of paper has a sketch or words to tell a portion of the story.

The pages are turned back or flipped, to expose the next picture. A simple form of flipbook can be made by merely stapling or sewing sheets of paper together at the top.

It is possible to use a flipbook to show steps in producing a crop. One page might show how aquatic weed is cleared. The next might show control of predators the next liming. The next pages would show stocking, feeding sampling and harvesting.

The drawings may be made with, crayon, India ink, water colour or paint Notes may be written on the backs of the pages to guide the speaker as the discusses the picture exposed to the audience.

It is possible to increase the usefulness of a flipbook by painting the inside of one cover with chalkboard slating and covering the inside of the other cover with flannel. This provides greater variety in visual presentation by permitting you to draw pictures or write words with chalk or to use flannel - graph part to introduce or summarize the story. Other variations also are possible such as magnetboard backing and legs.

4.3 *Flash Cards*

These are the series of cards which when presented before the audience in proper sequence tell a complete story. Each card is of about 10" to 12" in size and contains a picture or diagram. Each individual card is "flashed" before the audience accompanied by the verbal commentary. The extension worker or the student who wants to use them holds the same in hand and flashes the card one after another.

Preparation of flash cards. Planning for the preparation a brief story should be writen. The story should end with suggestions or morale that leads to action. A suitable title should be selected for the story. The story should be divided into a number of scenes, which are to be presented in a number of individual cards. Different scenes which remain abstract in the preceding stage appear in appealing visual forms. Art paper is cut into pieces of 10" x 12". The figures may be (1) "Jetman" or (2) Match stick. Flash cards using "Jetman" are called "Jet Series' Other catagory may have protographs, drawings, pictures and diagrams.

4.4 Posters

A poster serves first to inspire the people. As long as it remains in the village it will serve as a reminder to villagers. While making a poster the following points should be taken into consideration:

1. It should do special job.

   a. Promote one point (say how to manure paddy).

   b. Support local demonstrations.

   c. Support local exhibits.

2. It should be planned for the people who are supposed to do the job.

   a. Contain dramatic pictures that will stop people and make them look.

   b. It should tell the story in a single glance

      (1) It should have few words.
      (2) Simple idea.
      (3) One idea.
      (4) Bold letters.

   c. Present picture everyday living.

   d. Should be in pleasing colours.

   e. Should be in good size i e. 33" x 30" in size.

   f. Must be timely.

So a poster should contain three main aspects

1. It should announce the picture of a project.

2. It should set out conditions.

3. It should recommend action.

Posters should be placed where people pass or gather and these should be followed by meetings, demonstration etc.

4.5 Exhibits

Exhibits perform functions other than straight subject matter teaching. Certainly, the experiences shared in planning and constructing exhibits, especially by youth groups, contribute in many ways to growth of the individual. Also, exhibits can be very helpful in reporting and interpreting. Extension work to non-farm people exhibits plays important role.

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