CONSERVATION AND MANAGEMENT OF INLAND CAPTURE FISHERY RESOURCES

Edited by

Arun G. Jhingran
and
V. V. Sugunan

Bulletin No. 57 July 1988

भाकृअनुप
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(Indian Council of Agricultural Research)

Barrackpore – 743101 West Bengal India.

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CONSERVATION OF THE ICHTHYOFAUNA OF INDIA

By
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Introduction

The concept of conservation of fish is not new to India . Through several edicts of king Ashok in 246 B.C. the catching fo fish was prohibited by the king during the period of the 3rd Chadurmesi* (Sravana, July-August.,Bhadra, August-September, Asvina, September October, and Kartike, October-November), on the 14th and 15th day of the moon and the first day after the full moon. (vide, Hora, 1950). This closed period enacted in the edicts are based on the remarkable insight into the breeding habits of the common freshwater fishes of India, the peak breeding period of India`s principal food fishes being july, August, and September. Asoka`s prohibition period extends up to middle of November. This extended period is scientifically logical because after breeding in the shallow areas of up-rivers the spent fish fall back to their normal habitats in deeper waters and in the case of *Hilsa* to the estuaries and seas. The young also move down to safer habitats after the rains are over and the flooded areas begin to contract.The young and the spent fish also need protection and it is remarkable that even this was thought of in the remote times.

The Indian fisheries Act IV of 1897 is a land- mark in the conservation of fishes of India. In this act the use of explosives or poison to kill fish in any waters is prohibited. It further gave powers to Government to make rules for regulating the construction and use of fixed engines and weirs, and the dimensions of nets together with modes of using them. In the present century, in 1944, the Imperial (now Indian) Council of Agricultural Research discussed the subject of " Conservation of Inland Fisheries by Legislation" and collected views of all provinces and Governments but no finality was reached on the subject. After independence the Wildlife Act of 1972 provided for the formation of several national parks and sanctuaries in India. However, these parks are primarily for the protection of small and large mammals and birds and the question of affording protection of fish life in India has not so far received the attention it urgently needs.

Endangered, Threatened and Rare Fishes

The Red Data Book

The IUCN (International Union for Conservation of nature and natural resources), the major world agency for conservation of animals and plants have

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Though at present the Hindu year begins in **Vaisakha about the middle of April, in ancient times the year commenced in **Agrahayana**, about the middle of November.*

Lecture delivered in the Summer Institute on the "Resource Management and Conservation of Inland Capture Fisheries of India", 4-23 July 1988, CICFRI, Barrackpore.

published lists of species of fish, amphibians, reptilies, birds and mammals considered by IUCN to be globaly endangered, threatened or rare in the Red Data Book (IUCN First Draft 1978).But this list does not contain the endangered or threatened species of fishes of India. Obviously, the Indian ichthyologists have not prepared a comprehensive list of such species and supplied it to the IUCN. Even in the Red Data Book the details of columns on the total population or trend, habitat, etc. for several species are blanks indicating lack of information on them. The preparation of Red Data Book sheets itself has not been done accurately as authors have not been consistent in the use of different terminologies. Under these circumstances, it is rather not possible to assess the precise status of all but a few threatened taxa.

According to the classification followed in the Red Data Book the status of our vanishing or vulnerable species of fish can be grouped under the following categories :

1. **Endangered**: Taxa in danger of extinction and whose survival is unlikely if the casual factors continue operating.

2. **Threatened**: Taxa believed likely to move into the endangered category in the near future if the causal factors continue operating.

3. **Rare**: Taxa with small populations that are not at present endangered, but are at risk.

Main threats to fishes

There has been severe decline in the freshwater fish fauna of India in general and food and game fishes in particular. This decline is mainly due to indiscriminate fishing, dynamiting of rivers, construction of dams across rivers, over utilisation of waters, cutting down of forest trees, mismanaged farm lands and erosion, pollution by factory chemicals, competition from introduced species and several other reasons.

Habitat destruction : Dams and weirs at higher reaches of the tributaries of the major rivers of India have affected the world famous game fishes, the Mahseers of India. The spawning runs of Mahseers (Tor and Acroissocheilus spp.) have been affected. Mahseers which used to grow to a size of 4 to 5 feet and a weight of 25-30 kg. in earlier days have depleted and now catches more than 5 kg. size are rare. Dams and increased large scale collections of gravel stones (spawning niche of mahseer). silting of lakes and reservoirs are the causes or threats for the decline (Pathani, 1979). The large indigenous carps of Peninsular India, like *Labeo fimbriatus, L. kontius,L. porcellus, Puntius pulchellus, P. dobsoni, P. dubius* and *Cirrninu cirrhosa* are becoming scarce and are replaced by small uneconomic predator species. Depth, width of channel, velocity of water are very important abiotic factors of the environment. Interference with the river discharges has affected the migration, growth and breeding of fishes of very great economic importance to our country.

Over-exploitation : *Notopterus chitala* (featherback) and *Semiplotus semiplotus* which used to be abundant in the large rivers of Assam, Bihar and U.P., and attaining large sizes are becoming rarer these days due to the wholesale slaughter of these fishes by fishermen. *Thynnichthys sandhkhol, Osteocheilus,* and *Osteobrama* spp. of the Godavari and Krishna rivers are steadily declining in catches. *Bagarius bagarius, Pangasius Pangasius* and *Silonia childreni* are overfished in the Indian Peninsula.

Introduction of fast breeding exotic fishes : Common carp introduced into Kashmir Valley has almost exterminated the indigenous schizothoracine fishes. Likewise, *Osteobrama belangeri,* the Loktak fish of Mainpur is fast disappearing due to the introduction of common crap for culture purpose there. In the Govindsagar dam *Catla* has already been replaced by the silver carp introduced there for culture, both species being plankton feeders.

Pollution : Chemical pollution from factories and plantations situated in the Nilgiris, Mysore and Coorg have exterminated certain groups of hill-stream fishes. Certain noemacheiline loaches described by Day from the Bhavani river at Mettupalayam, Coimbatore district, are no longer available there.

Dynamiting and poisoning : Wanton killing by the use of explosives of brood fish in the spawning season has affected a number of food and game fishes especially in the rivers originating in Assam, Nepal, Bhutan, Gharwal and the Himachal Pradesh.

List of Vulnerable Fishes

As explained eariler no efforts have so far been made to compile a list of endangered. threatend and rare freshwater fishes of India. The list of 21 species of endangered and threatend species presented below is a preliminary effort in the direction of compiling a list and the list will have to be continuously revised and expanded as and when further studies on distribution and trend in population fluctuations are discovered.

Endangered fishes

Family : Cyprinidae

1. *Barilius bola* (Ham.)
2. *Puntius chilinoides* (McClell.)
3. *Semiplotus semiplotus* (McClell.)
4. *Enobarbichthys maculatus* (Day)

Threatend fishes

Family : Notopteridae

5. *Notopterus chitala* (Ham.)

Family : Cyprinidae
Subfamily : Cyprininae

6. *Acrossocheilus hexagonolepis* (McClell.)
7. *Cirrhinus cirrhosa* (Bloch)

8. *Labeo fimbriatus* (Bloch)

9. *Labeo potail* (Sykes)

10. *Labeo kontius* (Jerdon)

11. *Puntius carnaticus* (Jerdon)

12. *Puntius curmuca* (Ham.)

13. *Puntius jerdoni* (Day)

14. *Tor khudree* (Sykes)

15. *Tor putitora* (Ham.)

16. *Tor tor* (Ham.)

Sub-family : Schizothoracinae

17. *Schizothorax richardsonii* (Gray)

18. *Schizothoraichthys progastus* (McClell.)

Family : Schilbeidae

19. *Silonia childreni* Sykes

20. *Pangasius pangasius* (Ham.)

Family : Sisoridae

21. *Bagarius bagarius* (Ham.)

Among the most endangered *Enobarbichthys maculatus* Day a Cobitoid loach is known only from a single specimen, the type is in the British Museum. The species might have become extinct, as no other specimen has so far been found since it was first described by Day in 1867.

Barilius bola (Ham.), the Indian trout, according to day is found in "Orissa, Bengal, N.W.Provinces, Assam and Burma". Today its habitat is reduced to the Kosi, Bagmati, and Gandak in Nepal Terai and the headwaters of the Ganges (Menon,1962). It is introduced in the Lonawala Lake by Dr. C.V. Kulkarni and seems to have bred there (Kulkarni,1975) but it is doubtful whether it exists there today. In 1888 Walker in his Angling in Kumaun Lakes recorded it from Kumaon Lakes but it does not occur there either today (Menon,1949).

Puntius chilinoides (McClell.), according to Day (1878),was known to occur along the Himalayas as far to the east as Assam. Walker (*loc. cit.*) found it in Nainital. In 1949 the Zoological Survey of India surveyed the Kumaon Himalayas but no specimen of *P. chilinoides* was found there (Menon, 1949). *P. chilinoides* and *B. bola* seem to have died out in the Kumaon Himalayas with the introduction of Mahseer in the lakes there.

Semiplotus semiplotus, according to Day, is found in the rivers of Assam. Recent surveys reveal that the fish is confined to the upper Assam and hasd declined in number (Sen,1985).

Of the 17 threatened fishes *Labeo fimbriatus* and *Cirrhinus cirrhosa* growing to 45 cm and the Peninsular Mahseer, *Tor khudree* growing to a length of more than a metre are found in all the Peninsular rivers; *L. potail* and *P. jerdoni* are confined to the Krishna and Godavari, P. carnaticus and L.kontius to the Cauvery system and P. curmuca to the Wastern Ghats rivers of Kerala flowing to the west. All of them once formed major fisheries but the dams and weirs constructed along the course of the Peninsular rivers have evidently affected them and have in recent years become scarce and replaced by small sized uneconomic predator species. Interference with river discharges has affected the migration, growth and breeding of these fishes of great economic importance.

In the Himalayan rivers, *Tor tor, T. putitora* and Schizothoracinae fishes are subjected to indiscriminates killing by dynamiting and poisoning and their stocks are steadily declining (Pathani,1979).

Genetic Diversity

Establishment of sanctuaries of refuges are essential not only for the protection of our endangered and threatened spacies of fishes but it is also needed for the preservation of the genetic diversity of the different species of our freshwater fishes. For this it is essential to evaluate the chromosomal and DNA variabilities among the natural populations within the different spices of our freshwater fishes. It may be highlighted that not only every species has its unique set of chromosomes but there is also considerable variability in chromosome number, structure and the DNA content amongst the populations from different geographical and ecological areas of its distribution. In order to ascertain how much natural populations are organised from a genetic stand point, it is necessary to make a detailed study of the chromosomal and DNA variations among the natural populations, within the different species. In some organisms, a number of chromosomally distinct races may be found. This organisation is generally characteristic of species with wide geographical distribution in which a particular chromosome type is uniform across a region with a sharp boundary separating it from other races. Chromosome variations can also be found only in some individuals of a population and may reach a high level in a population or may be a unique event being individually generated and dying with the aberrent form.

Species diversity in eyprinoid fishes

In Indian freshwaters the eyprinoid group of fishes reach their greatest diversity with regard to the number of genera and species and number of individuals. The major carps, catla, rohu, mrigal are used for extensive inland fish culture. The game fishes, the mahseers, *Barbus* (*Tor*) putitora and *Barbus* (Tor) *tor* also belong to this group of fishes.

A total of 177 cyprinoid species belonging to 2 families, 4 subfamilies, and 27 genera are so far known from the inland waters of India.

Out of the 177 species the following 43 species are cosidered of great economic importance. They are grouped into three categories, major, medium and small-size species showing their geographical distribution, drainage-wise.

1. Large sized carp forms attaining 500 mm (about 2') and above

Sl. No.	Name of Species	DRAINAGE SYSTEMS										
		HIMALAYAS					PENINSULAR					
		Chindwin (Manipur R.)	Brahma-putra	Ganga – Yamuna	Indus	Chambal	Narmada-Tapti	Mahanadi	Godavari	Krishna	Cauvery	Periyar
1.	*Acrossocheilus hexagonolepis*	+	+	+	–	–	–	–	–	–	–	–
2.	*Catla catla*	–	+	+	+	+	+	+	+	+	+	–
3.	*Chagunius chagunio*	–	+	+	–	–	–	–	–	–	–	–
4.	*Cirrhinus mrigala*	–	+	+	+	+	+	+	+	+	+	–
5.	*Labeo bata*	–	+	+	–	+	+	+	+	+	+	–
6.	*Labeo calbasu*	+	+	+	+	+	+	+	+	+	–	–
7.	*Labeo fimbriatus*	–	+	+	+	+	+	+	+	+	+	–
8.	*Labeo gonius*	–	+	+	+	+	+	+	+	+	–	–
9.	*Labeo pangusia*	+	+	+	+				+	?	–	–
10.	*Labeo porcellus*	–	–	–	–	–	–	–	+	+	–	–
11.	*Labeo potail*	–	–	–	–	–	–	–	+	+	–	–
12.	*Labeo rohita*	–	+	+	+	+	+	+	+	+	+	–
13.	*Puntius carnaticus*	–	–	–	–	–	–	–	–	–	+	–
14.	*Puntius curmuca*	–	–	–	–	–	–	–	–	–	+	+
15.	*Puntius pulchellus*	–	–	–	–	–	–	–	+	+	+	+
16.	*Puntius kolus*	–	–	–	–	–	–	–	+	+	–	–
17.	*Puntius thomassi*	–	–	–	–	–	–	–	–	+	?	–
18.	*Semiplotus semiplotus*	–	+	+	–	–	–	–	–	–	–	–
19.	*Schizothorax plagiostomus*	–	+	+	+	–	–	–	–	–	–	–
20.	*Schizopyge esocinus*	–	–	–	+	–	–	–	–	–	–	–
21.	*Schizopyge progastus*	–	+	+	–	–	–	–	–	–	·	–
22.	*Thynnichtnys sandkhol*	–	–	–	–	–	–	–	+	+	–	–
23.	*Tor putitora*	–	+	+	+	–	–	–	–	–	–	–
24.	*Tor tor*	+	+	+	+	–	–	–	–	–	–	–
25.	*Tor khudree*	–	–	–	–	+	+	+	+	+	+	+

II Medium sized carp species, about 250mm to 450mm(1-1.5 feet)

Sl. No.	Name of Species	DRAINAGE SYSTEMS										
		HIMALAYAS					PENINSULAR					
		Chindwin (Manipur R.)	Brahma-putra	Ganga-Yamuna	Indus	Chambal	Narmada-Tapti	Mahanadi	Godavari	Krishna	Cauvery	Periyar
1.	*Barilius bola*	-	+	+	-	-	-	-	-	-	-	-
2.	*Cirrhina cirrhosa*	-	-	-	-	-	+	-	+	+	+	-
3.	*Cirrhina fulungee*	-	-	-	-	-	-	-	-	+	-	-
4.	*Cirrhina reba*	-	+	+	+	+	+	+	+	+	+	-
5.	*Labeo boga*	-	+	+	+	+	+	+	+	+	+	-
6.	*Osteobrama belangeri*	+	-	-	-	-	-	-	+	-	-	-
7.	*Puntius lithopidos*	-	-	-	-	-	-	-	-	+	+	+
8.	*Puntius sarana*	+	+	+	+	-	-	-	-	-	-	-
9.	*Puntius subnasutus*	-	-	-	-	+	+	+	+	+	+	+
10.	*Schizmatorhynchus nukta*	-	-	-	-	-	-	-	+	+	-	-

III Smallsized carp species about 250mm (10 inches) in size but occurring in large numbers

Sl. No.	Name of Species	DRAINAGE SYSTEMS										
		HIMALAYAS					PENINSULAR					
		Chindwin (Manipur R.)	Brahma-putra	Ganga-Yamuna	Indus	Chambal	Narmada-Tapti	Mahanadi	Godavari	Krishna	Cauvery	Periyar
1.	*Aspidoparia morar*	-	+	+	+	+	+	+	+	+	-	-
2.	*Chela clupeoids*	-	-	-	-	+	+	-	+	+	+	-
3.	*Chela gora*	-	-	+	+	-	-	+	-	-	-	-
4.	*Chela phulo phulo*	-	+	+	-	+	+	+	+	-	-	-
5.	*Chela phulo orissanensis*	-	-	-	-	-	-	-	-	-	-	-
6.	*Labeo boggut*	-	-	+	+	+	+	+	+	+	+	-
7.	*Osteobrama vigoraii*	-	-	-	-	+	+	+	+	+	-	-

From the above list it is evident that despite wide geographical range of some of our cyprinoid food fish varieties or races have not so far been described. Most of the species are simply referred to by their specific names. At morphological level these species are invarient to the taxonomist as no distinctive phenotypic differences are met with across the entire range of their distribution. At chromosal and DNA content level of chromosomes there is bound to be diversity, if proper genetical studies of populations from different drainages are made.

Significance of genetic diversity studies

The importance of conservation of fish germplasm resources and the scope it offers is phenomenal for aquaculturists and fish breeders who can profitably make use of the new genetic variety in their attempts at genetic improvement of stock. The necessity of establishing germplasm reserves has become ever more urgent at the present moment as the pace of destructiion of species in our inland waters increases. Certain genetic varieties of our fishes which at present have no obvious economic value may be needed in the future to fulfil our evergrowing requirements for improved or pest and disease resistant varieties for culture purpose.

Conservation

Preventive measures

I have already mentioned the various major threats to our fishes such as catching and breeding of small young specimens and poaching during closed seasons using dynamite and hand grenades in the higher streams, construction of dams across rivers without provision of fish passes, pollution of rivers and streams, introduction of fast growing exotic fishes and over exploitation of our fish resources. Remedial measures may take several forms. Removal of causes of danger in some cases may be very effective. In the case of overfishing complete reduction in catches or complete cessation of fishing may be needed. Introduction of exotic fishes should only be permitted after exhaustive analysis by experts. All dams should be provided with functional fish passes, fish gates or fish ladders. Capture of fish during closed season, and pollution of rivers, streams, lakes and tanks by human agencies depositing sewage, sullage, domestic effluents, chemicals, dyes, detergents, and silting etc., causing death of fish and fish food should be stopped by enforcing law in all the river systems of the country.

Where depletion of stock of any of the fish of commercial values detected the seeding of the river with fry and fingerlings of the species produced breeding as done in case of Himalayan mahseers (Pathani,1979) and Peninsular mahseers (Kulkarni, 1979) should be adopted. The rehabilitation can be successfully achieved by stocking the depleted waters with fingerlings in the same manner as is done in the case of salmon in Western Europe and America.

Protective measures

For our large carps, mahseers and catfishes which are thereataned, fish sanctuaries or reserves should be established. The question of protection of fish life through establishmant of fish sanctuaries has not received any attention so far.

Deep-pools (not more than 2 metres) in the course of rivers in natural forest co nditions or river stretches where catching of fish is prohibited out of religious sentiments form excellent biotopes for the protection of brood stock of our fishes during periods of low discharges. Several such biotopes exist in all our river systems but practically there is no information available on these.

Likewise, we have several large tanks attached to temples constructed hundreds of years ago under the patronage of Rajahs and zamindars where fishing is prohibited. In addition there are in our country large abanodoned fort tanks like those of Kondapalli in Krishna District of the Andhra Pradesh. These also form excellent biotopes for conservation of fishes. It is essential to indentify all those biotopes before any programme for establishment of fish sanctuaries is drawn up in our country. The Department of Environment of the Government of India has a major project in hand to identify the suitable localities for the establishment of fish sanctuaries to conserve the valuable ichthyofauna of India and to establish large scale game fish hunting (by rod and line) for development of tourism in India.

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FISHERIES OF RIVERS AND RESERVOIRS - PROBLEMS AND PROSPECTS

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Tropical riverine fisheries are characterised by high diversity of fish species. These species, through ages of evolution strikes an inter-species balance at different trophic levels. Thus amongst the carps or catfishes one finds species variation in differnt river systems, but in terms of trophic levels of detritivores, filter feeders and carnivores of different stages of the food chain, one observes a fair degree of stability in balance. Of late, due to various interventions by man in the natural systems, variations are noticed more.

Reservoirs, however, present a much larger variability in natural species mix at different trophic levels. These waterbodies built by man primarily for irrigation and hydel generation are by and large located in rapid gradient sections of minor tributaries of major river systems. These streams rarely sustained a high natural faunistic richness or abundance of high value species. The high productivity offered by organic productivity blooms soon after impoundement's submergence and variable strengths of allochthonus nutrients are therefore, rarely utilised by high value species (except a few carnivores). Either the endemic species partially utilise the different productive niches or stocks of desired species transplanted through specific programmes lead to desired species balance.

The species diversity and trophic level abundances are, therefore, fairly stable in different rivers but highly divergent in man made reservoirs. Multispecies or multigear problems in fisheries management basically refer to problems of identifying resource potential in terms of species mix that make it up and indicating the optimal effort for drawing the potential catch in terms of fishing pattern made up of multitude of gears that exploit the resource.

The classical fishing theory has been developed for stable environments, such as of a sea. Annual fluctuations primarily influence abundances through affecting breeding and early survival. Reservoirs can be considered to satisfy the assumption of stable environment, but rivers cannot be because of many major factors having significant deleterious effect on the riverine environment over the last few decades. These factors are increasing water abstraction, higher pollutional load due to sewage and industrial effluents, high rate of silting due to heavy erosion of catchments caused by large scale deforestation, construction of obstructions on fish migration pathways, such as, flood embankments cutting off breeding grounds of carps, weirs and barrages denying migration of anadromous species.

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The models for estimation of potential yield or Maximum Sustainable Yield, MSY and the effort necessary to obtain the MSY,fall under three broad categories.

(i) ***Analytical models*** - These basically are meant for single species, treated in isolation, ignoring the abundances of its food, predators and competitors. Some effort at developing models upto two species have been attempted also.

(ii) ***Production models*** - These treat a species or a group of species, having few common biological features, as a single biomass. In extreme cases the clumped up total of all species are also treated in preliminary rough analysis.

(iii) ***Ecological System models*** - These models treat the different trophic level productivities as STATE variables and trophic transfer rates as TRANSITION variables linking different STATES. One follows the energy path or sometimes the nutrient (i.e. nitrogen) path in the environment.

The first two centre round indentifying MSY while the latter offers immense scope at multiple levels to identify removal surpluses, which add to MSY.

In the multispecies context, we would concentrate on production models in this lecture.

Utility of MSY estimation

The applicational utility of MSY estimation for a reservoir environment needs to be carefully examined and understood. Stock assessment leads to identifying levels of effort, F (MSY), or exploitation that fish the stocks around the MSY. Fishing at rates higher than F (MSY) leads to 'growth overfishing' which reduces a stock to such levels as to lower yields below MSY. It could also irreparably reduce the natural reproductive potential of the stocks, resulting in 'recruitment overfishing' (Cushing, 1972). In reservoirs, where we take to large scale stocking programmes, such problems are unlikely to arise for selected stocked species, corrective steps being available to compensate for recruitment loss due to fishing.

It, therefore, emerges that one needs to know the 'carrying capacity' of a reservoir or its ecological potential of annual fish yield. Then through some production models and competition models identify species-mix suitable for the intrinsic production capacity of a reservoir environment.

Estimation of potential of reservoir or lakes based on few ecological parameters have been attempted by many workers for tropical situation.

Production models

The basic theory centre round the premises that relative rate of growth of biomass is a function of biomass.

$1/B \; dB/dt = f(B)$

Schaefer (1954) used the simple model

$f(B) = a - bB$

$f(B) = a(B_\infty - B) \quad B < B_\infty$ - (1a)

Pella and Tomlinson (1969) generalised this, by adding an extra parameter, m.

$f(B) = a(B_\infty^{m-1} - B^{m-1}) \quad m > 0$ - (1b)

Fox (1970) arguing that catch per unit of effort (U) does not remain constant as effort increases, proposed an exponential model linking maximum CPUE with effort. This leads to

$f(B) = a\,(\log B_\infty - \log B)$ - (1c)

The fitting and estimation procedure for MSY is rather simple for 1a and 1c but complicated and iterative for 1b for which computer programmes, however, are available. Equation 1a and 1c correspond to catch per unit effort (U=c/f) and effort f relationships, which can be fitted to c and f time series data by regression techniques.

For la : $U = a - bf$

or

$C = af - bf^2$

Leading to MSY = $a^2/4b$ (occuring at $1/2\, B_\infty$)

and effort for MSY = F(MSY) = $a/2b$

For 1c : The exponential model (Fox 1970) employs a saturation CPUE model at high effort.

The equation

$\log U = \log U_\infty - bf$

where U is average CPUE for a period where effort was f and U_∞ is a parameter representing CPUE asymptote as effort tends to very high levels. The equations for MSY and F(MSY) are

$MSY = U_\infty/be$

$F(MSY) = 1/b$

where 'e' is exponential = 2.471828... In this case MSY occurs at B_∞/e (about $0.37B_\infty$)

For 1b : Expressions for MSY and F(MSY) are a little more complicated and are suited to computerised estimation (Pella and Tomlinson, 1969). The MSY - B_∞ relationship depends on 'm'.

The MSY, F(MSY) point on catch-effort curves varies according to value of m (Fig. 1b) and the model (Fig. 1a)

Case I, m=2 : The form 1b reduces to 1a, we get a parabolic catch-effort curve with MSY = $B\infty$ at well defined peak.

Case II $m < 2$: The catch-effort curve is more flat, some what asymptotic with MSY identification difficult. Incidentally, for short-lived tropical species having a prolonged breeding season, we come across such curves (Fig. 1a ii and Fig. 1b)

Case III $m > 2$: The catch-effort curve is bent more towards right with a sharp fall after the peak, indicating fast depletion and decimation of stocks at effort level higher than F(MSY) (Fig. 1b).

The applicational simplicity with much less demand on exacting detailed data makes surplus production models attractive. These could be utilised at single species levels for larger catfishes, such as, *Wallago attu, Mystus aor* and *M. seenghala* in reservoirs and for groups of species at same trophic levels having somewhat similar biological characteristics, such as, life-span, food and feeding habits, reproductive behaviour, etc. Thus minnows, small clupeids like *Gadusia chapra* etc. and murrels could be put in respective groups.

The pooled MSY indicator of these species together is difficult exercise, not well understood so far. Through any trophic dynamic system model involving transfer coefficients from one state to another; one could attempt interpreting and linking these MSY in terms of simultaneous achievability at different trophic levels.

Multispecies models

Competing species or prey-predator type relationships have been modelled mostly with one target species and one or two related species in the other bracket. Anderson and Ursin (1969) have given a predatory-prey model for North Sea, now popularly known as the North Sea model. It is highly demanding in data detail and estimation technique is quite complicated. General competition models of The Lotka-Volterra type (which encompass predator-prey also according to parametric format) have been developed, by extending the simple production function equation, $1/B\ dB/dt = a - bB$ to two (or more) species by adding terms for individual species designated i and j

$$1/B(i)\ dB(i)/dt = a(i) - b(i)B(i) - C(ij)B(j)$$

with more species the number of parameters increase rapidly. For n species, there are n(n+1) parameters; e.g. for 4 species there are 20 parameters. Estimation problems and data demand becomes prohibitive to test the quality of fit and validity of assumptions.

A more acceptable and detailed approach respecting some of the basic consideration of ecological carrying capacities of an environment has been given by May *et al* (1979). The theory is exaustive and vast. Being multidimensional, interpretative appreciation is also more demanding.

May *et al* (1979) have employed the basic logistic model of growth of population for interpretation of predator-prey relationships. The model has relevance for studies in reservoirs, for carnivore catfishes, such as *Wallago attu*, and population of minnows and smaller fishes. Using subcripts (1) for prey and (2) for predators, the dynamics can be indicated by

$$dN(1) / dt = r(1)N(1) (1 - N(1) / K) - aN(1)N(2) \quad - (2a)$$
$$dN(2) / dt = r(2)N(2) (1 - N(2) / bN(1)) \quad - (2b)$$

We could conceptualise the same equations for biomass B instead of population size N. Intrinsic per capita growth of prey is r(1) and predator (2). Environmental limitations of growth restricts the growth rate of prey (2a) to zero at upper carrying capacity (K) of the system in the absence of predation. The model assumes a crude form of Lotka-Voterra type of predation model i.e. per predator consumption of prey is proportional to prey density, or = aN(1). The dynamics of predator population (2b) is controlled by availability of its food i.e. prey and again modelled on logistic equation. The equilibrium level or the carrying capacity of predators is directly related to prey abundance by a proportionality constant, b. In case of biomass, the coefficient, b, depends on conversion efficiency of prey to predator.

The model introduces 'other' causes of removal of prey or predator, than environmental death process, by F(1) and F(2) classically the fishing rates. Yields are related by simple model to density by Y = rFN. A mathematical device to reduce the equations to dimensionless variables is done by putting

$$X(1) = N(1) / K \text{ and } X(2) = N(2) / bK$$

The equations then become, allowing for removal by fishing

$$dX(1) / dt = r(1)K(1) (1 - F(1) - X(1) - vX(2)) \quad - (3a)$$
$$dX(2) / dt = r(2)X(2) (1 - F(2) - X(2) / X(1)) \quad - (3b)$$

$$\text{where } v = abk / r(1)$$

So long as F's are less than 1, Equilibrium levels are given by

$$X^* (1) = \{1 - F(1)\} / \{1 + v (1 - F(2) \} \quad - (4a)$$
$$X^* (2) = \{1 - F(1)\} \{1 - F(2)\} / \{1 + v (1 - F(2)\} \quad - (4b)$$

Showing that if harvesting of predator is at F > 1, $X^*(2) = 0$, $X^*(1) = 1 - F(1)$ and extinction and if harvesting of prey is at F > 1, X (1) = 0 and X(2) = 0 i.e. system totally collapses.

The MSY levels, $Y^*(1)$ and $Y^*(2)$, are given by multiplying equations 3a and 3b by r(1)K and br(2)K respectively.

In the absence of fishing {F(1) = F(2) = 0}, 4a gives $X^*(1) = 1/(1 + v)$ and indicates v = 1 corresponds to simple surplus production model approach of $X^*(1) = 1/2$ or $N^*(1) = 1/2K$ i.e. half carrying capacity.

The above treatment is oversimplistic introduction to the theory of prey-predator relationships. Ecologists have questioned the logistic very vehemently.

Correctives are available, which push back the optimum MSY to less than 1 / 2K e.g. by using Pella Tomlinson model and putting

$$dN(1) / dt = r(1) \; N(1) \{1 - (N(1) / K)^{Z}\}$$

where Z is an additional "phenomenological" parameter (May 1979). For more details on the subject, which has a vast literature, one is referred to May (1976), May (1977), Lett and Kohler (1976), FAO (1978) and the references therein.

The catch-effort curves in such models are in harmony with those derived from generalised production model (lb). There is a tendency for peak to shift to right (Fig. lb) as value of parameter v goes high, (corresponding to m more than 2 in model lb). In contrast many yield curves are known to tilt the other way round (Fig. la). The mechanism that pulls the peak and yield curve of single species analytical models of Beverton and Holt type of Fig. la to type ii of (Fig. lb) (v more than 0) are primarily the relationship of relative recruitment and mortality rates, which are not in-built in single species model.

The questions like

(i) What is the maximum prey yield keeping a prefixed predator yield or vice versa ?

(ii) What possible combinations of Y(1) and Y(2) are possible for sustained output ?

can be considered through the models. Some applicational results in the study of whales and krill are indicated in figure 2. The MSY approach of single species modelling indicates, MSY(1) and MSY(2) for the krill and whales, shown in Fig. 3 as a star; which is not compatible under the interaction prey-pedator model. The objective function could be from ecological output point of view to maximize the total sustainable yield of both 1 and 2 subject to certain economic considerations. May *et al* (1976) suggest introduction of a parameter 'g' to reflect economic value, protein content, edible parts weight. Relative value of the predator and prey of the above is measured by g. The total weighted yield becomes

$$Y^{*} = Y(1)^{*} + g\,Y(2)^{*}$$

The estimation is done through

$$Y^{*} = \frac{C\{1 - F(1)\}\{F(1) + dF(2)\}\{1 - F(2)\}}{1 + v\{1 - F(2)\}}$$

Where $d = gbr(2) / r(1)$

Parameter 'd' has very illuminative interpretation. The effective value of predatory biomass per unit prey biomass is measured by d. In fact the intrinsic relative value, g, is discounted by the biological conversion efficiency, b, and relative rate of intrinsic growth of predator and prey.

The MEI indicator

Morphoedaphic index, MEI, (Ryder 1965) defined as a measure of total dissolved solids (TDS) or its closely correlated measures, such as, conductivity or total alkalinity (Hendersen and Wellcome, 1974; Ryder and Henderson, 1975), per unit mean depth of lake provides a good measure of potential yield from a lake.

$$\log Y = K + a \log MEI$$

where K is a climatic factor and MEI = TDS/mean depth.

Jenkins (1967) had earlier developed similar models linking MEI to potential yield from reservoirs.

$$\log Y = a + b\ MEI$$

However, fits of this simple regression in case of some US reservoirs did not show high degree of fit. Commercial catches showed only 11% variation explained by the model, while sport fishing in 126 reservoirs showed only about 5% variation explained by the model.

Alongwith still simpler model given by Gulland (1970) as Y = k. M.B, where k is a constant lying between 0.3 and 0.5, mostly around 0.4, M the natural mortality coefficient and B the biomass prior to fishing, the utility of these models can be immense.

Linking the Y estimated by MEI indicator and assessing the bioproductivity at different trophic level of a reservoir, such as detritus, benthic, phyto and zoo planktonic, one can link the possible levels of stock the reservoir would take assuming exploitation to remove about 50% of standing stock at optimum level. Studies on prey-predator models for larger catfishes, their prey densities could indicate combined levels of MSY of each. Since the target for developmental considerations would be on lower trophic level species of commercial value such as carps, to produce higher yield and income to fishermen, the models of May *et al* (1976) may be employed for larger catfishes and endemic smaller size prey species. As the minnows and weed fishes (prey) would decline the predator population would automatically go down on the yield-effort curves of types shown in Fig. 3. The vacant niches, hopefully would be filled by the carps stocked at fairly high sizes to escape predation mortality. Hopefully is important since aggresivity in competition between major carps and weed fishes in utilising the growth potential offered by the environment are not clearly understood. The long term effect of such management planning could be a reduction in active tertiary predators such as *W. attu* but fairly balanced populations of *Mystus* species or, other niche specific species feeding on zoo benthos.

The above treatment is a synoptic and oversimplified presentation of the multispecies problem and its solutions through the production model approach, basically for 2 or 3 species. It is the hope that it would excite researchers to take to such studies in the Indian situation by collection of suitable data and applying and testing the models.

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(i) Typical curves of
& Beverton Holt single
Species model.

(ii) Flat peaked curves normally for multiple breeding tropical species.

(iii) The simple logistic Schaefer model.

(iv) Typical curve of Pella-Tomlinson model.

'm' of Pella-Tomlinson model, v of May, *et al*. model.

Prey yields under different levels of effort on prey (F1) and predators (F2)

Fig. 2 (Reproduction of Fig. 2 of May et al 1979)

Possible range for sustained yields of prey or predator. P shows the single species MSY of each. (Based on whale/krill study by May et al (1979)

PRODUCTION BIOLOGY OF RIVERINE FISH

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For better management of fish production or terminal production, knowledge of certain biological parameters viz., food & feeding, age & growth and reproduction biology is of utmost importance. The above mentioned parameters in respect of commercially important riverine fish such as carps, catfishes, mahseers, anadromous hilsa, murrels and featherbacks are discussed in the present communication.

Food and feeding habit of fishes

The food plays one of the most vital roles in the life history of fishes by way of controlling their growth, fecundity and migration. Variation in the seasonal and diurnal availability of the preferred food organisms of various species of fish in any region may govern the horizontal and vertical movements of the fish stocks.

Fishes are also known to change the food habits as they grow, accompanied by correlative changes in the digestive system. Another remarkable feature regarding the fish feeding is its seasonal variation in selection of food and intensity of feeding. The former is linked with the availability of the food in the biotope. Due to this, different dietary pattern of the same fish from various habitat have been reported.

The fishes may be broadly classified on the basis of their dietary habits as (1) Herbivorous, (2) Carnivorous and (3) Omnivorous.

Methods for studying the food of fishes

The gut contents of the fishes may be studied numerically, volumetrically and gravimetrically and by occurrence method. The choice of the method will depend upon the type of the feed of the fish. Volumetric and occurrence methods would be adopted in all cases.

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Procedure for quantitative methods

1. ***Volumetric***

   i) Determine the volume of gut contents in samples by water displacement.

   ii) Sort the samples to kind of items, species or groupwise.

   iii) Obtain the volume of each kind of food item, that it forms in the total volume of food in the series.

2. ***Gravimetric***

   It is like volumetric except that instead of volume, weight of different food items is taken.

3. ***Numerical***

   i) Sort the gut contents to kinds of items.

   ii) Count the individuals for each kind of food items in the sample.

   iii) Summate each of them in series.

   iv) Compute numerical % of each item in the gross total.

4. ***Occurrence Method***

   Method I

   i) Count the number of fish in which each food item occurs.

   ii) Express the above as percentage of the total number of fish examined.

   Method II

   i) Summate the occurrence of each item.

   ii) Find the percentage of individual occurrences (*i.e.* kind of items).

Index of preponderance

The volumetric, gravimetric and numerical methods of analysis emphasise only the quantitative aspects of the gut contents while occurrence method point out only the frequency of occurrence of food items. These methods individually are not suited for grading the food elements unless they are integrated into an index. Index of preponderance (Natarajan & Jhingran, 1961) is such a complete measure which takes both of quantity and occurrence into consideration simultaneously.

If Vi and Oi are the volume and occurrence index of food item (I) for food may be presented as follows :

$$I_i = \frac{V_i \quad O_i}{\Sigma V_i \quad O_i} \times 100$$

Forage ratio

This provides an index as to how the bottom biota is consumed by fishes. Forage ratio represents the ratio of the percent that a given species/genus/group of organisms forms in the total stomach contents of fish sample to the percent that the same kind of organisms constitutes of the total population of food organisms in the bottom samples.

Age and Growth

Studies on age and growth of fish are *sine qua non* for rational exploitation and effective management of the fisheries. Further, the age and growth studies also provide useful information on stock composition, age at maturity and mortality. The various methods employed for age and growth studies of a fish can be broadly classified as under :

a) Known method

b) Counting seasonal marks on the hard parts of the body of the fish such as scales and various bones and back calculating body length in the past years, if the relation between growth of scale and growth of body is known

c) Length frequency distribution or Petersen's method

The first method gives the most authentic information on the age and growth. However, the utility is restricted as this required ponds and various enclosures for raising the fish over a period of time and computing the fish growth by catching them back periodically.

The second method requires the study of scales, otoliths, vertebrae, spines, fin-rays, opercula and cleithra. The easiest way of ageing scaly fish is through their scales. The seasonal changes are reflected in the form of growth zones or checks on the above mentioned hard parts of the fish. The growth may be of two types : narrow zones and wide zones. Under temperate conditions, most of the fishes have annual cycles of maximum growth corresponding to summer when temperature and food supply are most favourable but growth in these fishes slows down to a minimum during winter due to low temperature and scarcity of the food. Generally, a set of fast growing wide circuli and narrow zone circuli constitute an annulus. Contrary to this, in tropical waters, neither temperature nor food supply change considerably with the seasonal rythm, and hence to presume that growth in tropical climate follows an annual pattern similar to that temperate waters, holds little ground save in certain belts where seasons are well-differentiated by marked fluctuation in the temperature regimen. Here, if, the growth checks are formed on the hard parts, they require careful scrutiny and reasoning. The main causative factors in tropical waters are 1) Scarcity of food; 2) Maturity and spawning stress.

Ageing of fish through scales

Accuracy of the scale method depends on three basic conditions; 1) Scales must remain constant in number and retain identity throughout the life of that fish, 2) growth of the scale must be proportional to the growth of fish and 3) annulus must be formed yearly and at the same approximate time each year.

Collection & preservation of scales

Scales for ageing of fish are invariably taken from the area above the lateral line and below the dorsal fin in case of soft rayed fish and at the end of pectoral fin in spiny rayed fishes. Regenerated scales must be discarded. Cleaning of the scales must be done with warm water or 5% caustic potash. Clean scales can sometimes be examined dry, but they tend to curl. To avoid this, clean scales may be kept between two glass slides and their ends tapped. A more recent and satisfactory technique is to prepare an impression of the outer surface of the scale on plastic materials. Scales or impressions can be examined through a microscope or a microprojector.

Types of rings or growth checks

Generally, two types of growth checks are found on the scales (1) annulus and (2) spawning ring.

Characteristics of an annulus

Narrowly spaced bend or circuli immediately preceding more widely-spaced bands or circuli, the latter region being the new growth zone. The circuli are not broken or discontinuous and are generally found in immature fishes.

Spawning annuli

The annuli are characterised by concentric transparent bands in the form of grooves extending to the lateral posterior sides of the scale. In lesser pronounced rings they appear thin light bands.

The annuli are preceded by comparatively thinner and narrower ridges but followed by comparatively thicker and widely-spaced circle.

In the annulus or groove zone, the circuli appear discontinuous.

There is a tendency for the ridges (Circuli) to flare out near the annular zone but are delimitted being parallel to margin groove.

In the apical section of the annular zone, the circuli appeared to be closely approximated along their lengths.

False rings

Sometimes false rings appear along with true annulus due to certain adverse changes in fish environment. However, false rings may be identified by the following characters.

i) False annuli are incomplete and indistinct with irregularities of pattern.

ii) By back calculating the intermediate lengths of fishes through their scales.

Age determination through Petersen's method or length-frequency distribution

This is the simplest method for ageing the fish. According to this method the population of fish having a single restricted spawning; the individual length of each group is approximately normally distributed and the modes of length-frequency distribution of successive age-groups are separated along the length axis. This method has been known to be inadequate especially for determination of age of older size groups due to increasing overlap in length distribution and total absence of certain size groups due to gear selectivity.

Growth

Growth may be defined as an increase in size and in fishes it is indeterminate. This is of two types (i) absolute growth and (ii) relative growth.

Absolute growth

It is the average total size of each age. The absolute growth rate may be determined as :-

$$\frac{W_i - W_o}{t_i - t_o}$$

Where W_o = weight at any time t_o

and W_i = weight at a later time t_i

Relative growth rate

It may be defined as percentage growth in which the increase in growth in each time interval is expressed as a percentage of the growth at the beginning of time interval. The relative growth curve rise slowly at first with an increasing slope followed by a decreasing slope assuming a 'S' shape curve. The point at which the growth rate changes from an increasing to decreasing rate has practical significance in fishery management. The relative growth rate may be calculated as :-

$$\frac{(W_i - W_o)}{W_o \ (t_i - t_o)} \quad X \ 100$$

Calculation of growth

The rate of growth may be calculated by following methods :

1. By tagging or marking of the fish.

2. By Walford growth transformation.

3. By back calculation of the body lengths through scales.

4. By length–frequency method.

Reproduction in riverine fishes

The main commercially important fish fauna of Indian rivers comprise carps, catfishes, mahseers, murrels, the anadromous *Hilsa ilisha* and featherbacks. The mode of reproduction consists of maturity, fecundity and spawning.

Maturity can be defined as cyclic morphological changes which the female and male undergo to attain full growth and ripeness. Fishes have a very diversified reproductive behaviour unparallel to the other vertebrates, some of the oviparous species (clupeoids) discharge millions of ova into the water and leave their further development to the nature. The time of onset of maturity also varies considerably among different species. Generally, the attainment of maturity is related to acquisition of a particular size by the individual and, as a rule, the slower the growth rate of the fish (Tab. 1) the later the onset of sexual maturity and *vice-versa*.

The reasons for this diversified reproductive behaviour are attributable to the internal or introceptive and external or extroceptive factors (temperature, light, food, salinity, shoaling etc.) or to the cumulative effects of both.

A record of the state of maturity of fish examined is often required for many purposes *e.g.* in determining the proportion of the stock that is mature or the size or age at first maturity. It is sufficient to note whether or not the fish is going to spawn, or has spawned in the recent spawning season by classifying into several maturity stages. The most popular classifications are given by Kesteven (1960) and Nikolsky (1963). The same are portrayed in Table II.

Gonado–somatic index (GSI)

This is another useful mehtod, other than the study of intraovarian ova–diameter (Clark, 1934) for determining the maturity stages of the fish. It can be defined as the weight of the gonads as a percentage of the whole body, or the gutted weight. Since the GSI has been reckoned as an indicator of the maturity of gonads, its values should be higher in the breeding season and lower immediately after the completion of spawning. Similar results in the values of GSI have been obtained in fishes which spawn once a year and have a short spawning period like Indian major carps. On the other hand, the dynamics of the GSI is of quite different nature in fishes which reproduce almost round the year (*Oreochromis* spp., certain catfishes) and shed their eggs in batches, therefore, the value of GSI in the latter group does not vary much in different months.

Fecundity

The number of eggs contained in the ovary of a fish is termed individual, absolute or total fecundity (Nikolsky, 1963). Bagenal (1967) modified the definition of Nikolsky by including the number of mature eggs laid in the life span of a fish.

The fecundity of the fishes has been related to body weight, body length and ovary weight and termed as relative fecundity. The concept of relative fecundity allows comparisons of the fertility of animals of different species or different populations of the same species.

The rate of fecundity has been acknowledged by the biologists in understanding the population dynamics of fishes, as fecundity is one of the decisive factors in the formation of a new year class. It has been demonstrated by a few workers that fecundity can be used as a parameter of environmental suitability of the fish. A continuous deterioration in the environment produce qualitative and quantitative changes in the fecundity. On account of this, fishes become smaller in size and attain earlier maturity. The incidence of feeding, food density and feeding efficiency affect the strength of a year class during the critical period of larval stages. The fecundity has been also successfully used in delimiting various populations of the same species.

Spawning

The act of releasing gametes is called spawning. Kryzhanovsky cited by Nikolsky (1963) classified the fishes on the basis of spawning as : Lithophils, Psamophils, Pelagophils and Ostracophils. The spawning behaviour of some fishes is depicted in Table III.

Prabhu (1956) stated that fishes exhibit four types of spawning described as below :

Type A : Spawning taking place only once a year during short period.

Type B : Spawning taking place once a year but with a longer duration.

Type C : Spawning twice a year.

Type D : Spawning throughout the year.

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Table I : Growth of commercially important fishes (mm) at different ages

Species	Age in years								
	I	II	III	IV	V	VI	VII	VIII	IX
C. catla	295	514	716	813	917	–	–	–	–
C. mrigala	276	473	622	732	815	877	957	–	–
L. rohita	310	500	650	740	800	850	890	940	960
L. calbasu	207	311	401	489	557	619	722	765	802
Tor tor	249	320	380	440	490	533	580	–	–
C. marulius	385	533	653	766	825	–	–	–	–
M. aor	333	448	618	751	840	889	941	983	1020
M. seenghala	311	433	544	649	743	833	911	964	1023
Hilsa ilisha	355	415	455	485	505	525	–	–	–
N. notopterus	101	155	215	269	314	331	345	–	–

Table II : Two generalized classifications of maturity stages in fishes, with approximate correspondence between them

From Kesteven (1960)	From Nikolsky (1963a)
I. Virgin Very small sexual organs close under the vertebral column. Testes and ovaries transparent, colourless to grey. Eggs invisible to naked eye.	I. Immature Young individuals which have not yet engaged in reproduction; gonads of very small size.
II. Maturing virgin Testes and ovaries translucent, grey-red. Length half, or slightly more than half, the length of ventral cavity. Single eggs can be seen with magnifying glass.	II. Resting stage Sexual products have not yet begun to develop; gonads of very small size; eggs not distinguishable to the naked eye.
III. Developing Testes and ovaries opaque, reddish with blood capillaries. Occupy about half of ventral cavity. Eggs visible to the eye as whitish granular.	III. Maturation Eggs distinguishable to the naked eye; a very rapid increase in weight of the gonad is in progress; testes change from transparent to a pale rose colour.
IV. Developing Testes reddish white. No milt drops appear under pressure. Ovaries orange reddish. Eggs clearly discernible; opaque. Testes and ovaries occupy about two-third of ventral cavity.	
V. Gravid Sexual organs filling ventral cavity. Testes white, drops of milt fall with pressure. Eggs completely round, some already translucent and ripe.	IV. Maturity Sexual products ripe; gonads have achieved their maximum weight, but the sexual products are still not extruded when light pressure is applied.
VI. Spawning Roe and milt run with slight pressure. Most eggs translucent with few opaque eggs left in ovary.	V. Reproduction Sexual products are extruded in response to very light pressure on the belly; weight of the gonads decreases rapidly from the start of spawning to its completion.
VII. Spawning/spent Not yet fully empty. No opaque eggs left in ovary.	
VIII. Spent Testes and ovaries empty, red. A few eggs in the state of reabsorption.	VI. Spent condition The sexual products have been discharged; genital aperture inflamed; gonads have the appearance of deflated sacs, the ovaries usually containing a few left-over eggs, and the testes some residual sperm.
II. Recovering spent Testes and ovaries translucent, grey-red. Length half, or slightly more than half, the length of ventral cavity. Single eggs can be seen with magnifying glass.	II. Resting stage Sexual products have been discharged; inflammation around the genital aperture has subsided; gonads of very small size, eggs not distinguishable to the naked eye.

Table III : Spawning time, periodicities of spawning and fecundity of certain commercially important riverine fishes.

	Species	Time of spawning	Periodicity of spawning	Absolute fecundity	Relative fecundity
1.	*C. catla*	Monsoon months	Once a year	2,30,831 to 42,02,250	676 to 987
2.	*C. mrigala*	Monsoon months	Once a year	1,81,695 to 18,09,536	1309 to 1837
3.	*L. calbasu*	Monsoon months	Once a year	1,40,078 to 4,40,859	1438 to 1463
4.	*M. seenghala*	Summer and early monsoon months	Prolonged and multiple spawner	1,31,800 to 4,28,376 (on the basis of 4 spawning bursts)	–
5.	*Tor tor*	Monsoon months	Prolonged and multiple spawner	6,677 to 40,000	–
6.	*N. notopterus*	Monsoon months	Once a year	250 to 1377	58 to 98
7.	*C. punctatus*	Monsoon months	Prolonged and multiple spawner	3000 to 26000	–
8.	*C. marulius*	Monsoon months	Prolonged and multiple spawner	2000 to 40,000	–
9.	*C. striatus*	Monsoon months	Prolonged and multiple spawner	3000 to 30,000	–
10.	*H. ilisha*	Monsoon and winter months	Twice a year	40,000 to 13,25,500	828

MAN-INDUCED ENVIRONMENT DETERIORATION IN THE DAMODAR RIVER SYSTEM

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Topography and physical features of the Damodar drainage

The Damodar river system is mainly constituted by the rivers Damodar, Konar and Barakar. In addition a number of seasonal rivulets join the main stream on its course. The Damodar originates in the district of Palamau in the Chota Nagpur Hills in Western Bihar and after traversing a distance of 538 km meets Hooghly in Midnapur passing through Burdwan, Hooghly and Howrah districts of West Bengal. Both the Barakar and Konar rivers rise in the district of Hazaribagh and join the main stream at Barakar and Bermo respectively.

The Barakar has a total run of 225 km and contributes about 40 per cent to the total flow of the entire Damodar. It hosts two dams viz.Tilaiya and Maithon.Entire catchment area of this river system is devoid of any dense vegetation and the bed of the river is absolutely sandy.

The Konar is only 136 km long and runs through a fairly deep valley. The river bed is sandy, profusely mixed with isolated rockey outerops. It hosts the Konar reservoir.

The Damodar at the first 280 km of its run has a gradient of 2 m per km; the next 160 km has 0.6 m per km and in the rest of its course the slope is 0.2 m per km. This reveals that the river flows mostly through the valleys and out of the total 22,000 sq.km catchment area of the Damodar basin 18,200 sq. km is in the valley. The annual rainfall over the valley varies between 76.5 and 160.7 cm with an average of 116.3 cm.

Based on topography,Damodar can be divided into upper, middle and lower valley portions.

The upper valley lies between the elevations 700 and 190 meters of length of about 280 km. Rajarappa and Bhandaridaha are the two main gorges in this region and there are a number of pools in between the gorges. The gorges support vegetation around them.

The middle valley stretches upto Ranigunge (a length of about 105 km) and flows btween 190 and 90 meter elevations. The Gowai and Barakar streams meet

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Damodar in this region. Damodar is unusually wide in this region, being about 5000 meter near Panchet. Here the river bed is entirely covered with fine sand.No pool or gorge is present in this region.

The Lower valley is between Ranigunge and confluence. Here, before Durgapur Barrage, the river is 6500 meter wide. Beyond that it becomes gradually narrow with low gradient. Presently, beyond Amta,the river has lost its identity. The Kana Damodar mostly drains the water into the Rupnarayan.

The Chota Nagpur Plateau because of rocky subsoil and eroded top soil does not usually harbour dense forests. But the sparse vegetation is already more or less denuded due to industries, extended urban areas,and firewood consumption by the local tribals. Besides, the unrestrained excavation practices and improper cultivation have destructed the once extensive forest areas within the basin.Presently, the plateau covering an area of 15,500 sq.km has become a wasteland except for about 5000 sq.km of poorly cultivated land. This denuded valley has helped erosion to a high degree with the formation of numerous gullies along the upper and middle valleys. The eroded sand is deposited at a high rate on the river bed.

The D.V.C. schemes over the riverine system

The Damodar Valley Corporation was designed to have 10 dams on the Damodar drainage system to control flood, to generate electricity and to facilitate cultivation over an area of 5 lakhs hectare of land. Presently the river hosts four reservoirs,viz. Tilaiya, Konar, Maithon and Panchet and the Durgapur Barrage covering a total area of about 20,000 ha. The reservoirs feed the total 2304 km long irrigation canals,supply domestic water to Durgapur and to nearer urban areas and to innumerable industries located on the bank.

Inpact of the industries flanked along the banks of the drainage system

The banks of river Damodar house maximum number of industries per unit area. Between the reservoirs Konar and Panchet there are about 40 industries; the reach below Maithon/Panchet dams and upto Durgapur has 30,and the reach above Bokaro accommodates 23 such establishments. All these establishments survive using Damodar river water and their total consumption per day is estimated to be $0.4 \times 10^6 m^3$,when the average flow from the Damodar in this region is only $0.73 \times 10^6 m^3$/day. Accordingly the river water left is only $0.33 \times 10^6 m^3$/day. The total effluent discharge from five major industries under Asansol agglomeration is $91746 m^3$/day whereas three industries under Durgapur agglomeration contribute $112076 m^3$/day. In the lower valley of Damodar the effluent river, water ratio is only 1:1.6, excepting the monsoon months.

A breakup study reveals the quantum of pollutants, the effluents add to the riverine system per day from these few industries. IISCO expels 5800 kg Fe; 370.5 kg tonnes total solids;675 kg phenol; 26 kg cyanide; 2300 kg ammonia and 2150 kg grease from the its 29523m^3/day effluent of cold rolling mill and 14383m3/day effluent of coke-over plant. Carew and Co. exerts 37.5 tonnes of B.O.D. and 106.5 tonnes of C.O.D. load on the riverine ecosystem through its 150m^3/day effluent discharge.Bengal Paper Mill contributes 218 t of solid and 22.5 t B.O.D. through its 46,350m^3/day of effluent.The Hindustan steel adds another 4730m^3/day effluent bearing 82.5 mg/1 phenol; 8.9 mg/1 cyanide; 1220mg/1 suspended solid; 285 mg/1 B.O.D.and 1286 mg/1 C.O.D. Durgapur Project Limited through its 14,000m^3/day effluent contribute 180 kg phenol; 160 kg cyanide; 155 kg sulphide; 2900 kg ammonia; 1000 kg light oil and exerts high B.O.D. load on the drainage system.From the Asansol and Durgapur agglomerations only, the river gets per day 22477 t total solids; 11132 t suspended solid;3141 t B.O.D.; 15 t phenols; 24 t cyanide and 20311 t C.O.D.

Based on the above facts it may be commented upon that the Damodar drainage system is under acute septic condition.

The river system is badly affected by silt deposition.The construction of the existing dams and barrages on the river was over by 1955 when its discharge capacity was 50,000 cusecs which by 1959 was reduced to 20,000 cusecs and in another 30 years, the capacity got reduced miserably further. The water holding capacity of the reservoirs is fast reducing. Their life-span is reduced approximately by 10 per cent over the calculated age. During the last drought the domestic water supply system from Durgapur Barrage to the Durgapur Township had failed due to the formation of levees here and there in the reservoir. Indiscriminate deforestation at the upper reaches of the river has reduced the water holding capacity of soil and the denuded top soil is fast eroded in monsoon due to the torrential nature of the river. The transported sand has now covered the entire bed of the river stretch and in turn the river banks are devoid of vegetation. The percolation rate of water has also increased.

Fish and fisheries of the drainage system

Job et al. (1952) reported that before impoundment the river Damodar and its tributaries and these fast flowing torrential streams sustained only nominal flood fisheries. The preliminary survey carried out indicated that seed resources of economic species were poorest in the upper and middle valleys while they were inadequate even in the lower valley. It was reported that but for one or two pools or gorges, perennial shelter of brood fishes were absent in the entire stretch. Pools formed got silted up within short period due to heavy erosion.

Gopalakrishnan et al. (1966) could establish that the major carps do breed at the headwater regions of the reservoirs in Damodar river system. Natarajan et al. (1968) remarked that the natural recruitment of major carp seed is poor in these reservoirs.

An assessment made during 1962-68(Jhingran and Natarajan, 1969) revealed that despite continuous stocking,there was a general reduction in stock strengths in Tilaiya. Maithon also did not show any correlation to stocking and catch rule. The average production rate in Panchet (2.7 kg/ha) and Maithon (1.9 kg/ha) were also very low.

Job *et al.* (op. cit.) and Gopalakrishnan *et al.* (op. cit.) recorded the presence of brood fishes of major carps and their breeding in the upper valley. Hence, poor rate of natural recruitment of fishes (Natarajan, op. cit.) might be due to the mass destruction of larvae or juveniles by complex industrial pollutants present in the river. The pollution load in the Panchet reservoir must be high as it is the primary recipient of the huge organic and inorganic pollutants the industries expel, which might have resulted in its low production rate as well as the marked reduction in stocking strength. The fish mortality probably occurs at a very slow pace which could not be recorded.

High rate of silt deposition is a major hindrance to aquatic productivity. The deposited silt disturbs the zetapotential regimen at the soil-water interphase and destructs fish food organisms. The suspended silt through Tyndall effect disturbs the euphotic zone of the water body and reduces primary productivity. Maithon receives high rate of silt and its low production rate may be attributed to that rate.

Recommendations

1) Proper riverine condition can be revived only when the entire basin is afforested. This will not only minimise erosion but will help in the gradual regeneration of aquatic weed and ultimately the aquatic flora and fauna. Accordingly a joint project should immediately be taken up by D.V.C.and departments concerned in the affected states,viz. Bihar and West Bengal so that afforestation and matting with herbs on the nude surface could progress on a war footing.

2) Detailed pollution study over the stretches ranging from Konar to Panchet, Maithon to Panchet and Panchet to Durgapur Barrage should be taken up to appraise the pollutional load in relation to fisheries.

3) Pollution studies should be made in Panchet and Durgapur Barrage and further down.

4) Industries discharging effluent in the river should adopt proper treatment measured before draining into the river.

5) Coal washeries are controlled by a Govt. of India undertaking. Hence the firm should take up joint study to minimise the toxicant load they discharge into the river.

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MANAGEMENT NORMS FOR LARGE, MEDIUM AND SMALL RESERVOIRS

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Introduction

Though India's multipurpose reservoirs are important sources of fish production, fisheries development in them have not received adequate attention. In a few reservoirs where some efforts have been made, the yields have not been satisfactory. This situation is mainly due to lack of understanding of reservoir ecology and trophic dynamics, wrong selection of species for stocking and irrational exploitation due to lack of expertise in the field of stock dynamics in relation to fishing effort. Thus the yields from reservoirs remained at low level, the average being 8 kg/ha from large reservoirs (above 5000 ha) and 20 kg/ha from medium reservoirs (1000–5000 ha) (Srivastava et al. 1984).

Trophic changes in man-made lakes

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

The newly formed impoundment inundates vast tracts of forest and agricultural land. The decay of submerged vegetation releases nutrients causing initial fertility leading to intense development of fish food organisms – plankton, bottom microflora and fauna. This initial surge is often spectacular and lasts for 2 to 3 years. This phase is followed by a state of trophic depression caused by the rapid utilisation of nutrients by the flora and the diminishing release of nutrients from the bottom due to sedimentation of the reservoir bed. This phase is marked by low production of fish food organisms and lower fish growth, hence, less production. Its duration is variable and depends on the climatic and hydrological conditions of the impoundment. In Soviet Union the period of trophic depression lasts 6 to 10 years in southern impoundments (upto latitude 55°N) and upto 25–30 years in reservoirs of northern region (Lapitzky, 1965). In Indian reservoirs with tropical climate, trophic depression is expected to be of shorter duration as recorded in Nagarjunasagar, where it lasted only three years (Ramakrishniah, 1987). After the depression period the reservoir recovers with the accumulation of nutrients. The final fertility is reported to be much lower than the initial phase in some reservoirs of USA. However, in reservoirs of India it is found to be of a much higher order exceeding the initial level of fertility (Ramakrishniah, 1987).

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Management measures at pre-impoundment phase

Development of fishery in an impoundment is dependent on the ichthyofauna of the parent river as well as management measures taken before the impoundment. The initial phase of high fertility should be taken advantage of and species which are on short food chain should be planted. Even such species exist in the parent river, it is desirable to strengthen their stock density in the new expanded environment. The trash fishes should be removed from the river stretch using all available methods to weaken their competition to economic fishes. Experience in Indian reservoirs has shown that major carps, especially *Catla catla*, have done extremely well in the new impoundment. Once these species establish in the new impoundment they would give a firm carp base for future development. If any lapse occurs in management at this stage, trash fish populations proliferate paving the way for the establishment of catfish populations. Once catfishes establish, the overall productivity of the reservoir would go down as their niches are on higher level of the long food chain. Effort to develop carp fishery at a later stage would work out to be more with less encouraging results. This aspect has been amply demonstrated in Nagarjunasagar and Tungabhadra reservoirs.

Reservoir bottom should be cleared substantially of trees, bushes and boulders to facilitate operation drag nets and gill nets.

Management measures at post-impoundment phase

Many reservoirs in India came into existence without much attention given to fishery development at pre-impoundment phase. In such reservoirs it is imperative to study the fishery potential based on certain productive indices and classify the reservoir as poor, medium and high in terms of fish production, before developmental measures are undertaken.

Indices of reservoir productivity

Biological productivity in impoundments is influenced by climatic, edaphic and morphometric features. The edaphic features such as extent of drainage area, its rate of erosion and total runoff determine the nutrient load into the reservoir, while climate and basin morphometry determine the rate of their utilisation. It has been recorded in Indian reservoirs that their fertility is dependent more on the catchment than on the basin soil (Natarajan, 1976). Area, mean depth and shore development index are important morphometric factors determining the productivity of the lake. Among chemical parameters total alkalinity, calcium, phosphates, nitrates and total dissolved solids are often used as indices of productivity. The most dependable index of productivity in reservoirs is oxycline in summer. The strength of the oxycline is an index of richness of bottom deposits of allochthonous and autochthonous origin.

Biotic communities

An estimate of qualitative and quantitative abundance of plankton, macrobenthos, periphyton and macrovegetation is essential to decide on the quantitative and qualitative aspects of stocking.

Two plankton pulses are recorded in indian reservoirs - a post monsoon pulse during October-December and a spring/summer pulse during February-June. Phytoplankton is generally dominant and is almost contributed by *Microcystis* in tropical impoundments and *Ceratium* in sub-tropical impoundments (eg. Govindsagar). Zooplankton is contributed by copepods and rotifers.

Benthos is represented by insect larvae, oligochaetes, gastropods and bivalves. The submerged tree stumps, shrubs, boulders, etc. serve as substrata for the periphyton complex comprising green algae, blue-green algae and diatoms.

Potential yield

A first approximation of the fish yield potential is essential to have an idea of the expected harvest before large scale management measures are taken up. Some of the methods are given below.

Morpho-edaphic index (MEI)

Ryder (1965) proposed morpho-edaphic index combining total dissolved solids (TDS) - an edaphic factor, and mean depth (Z) - a morphometric factor. The relationship is expressed an MEI = TDS/Z. The following regression has been calculated between fish yield and MEI.

$Y = kx^a$, where, Y = fish yield, x = MEI and k = a constant that represents a coefficient for climatic factors and 'a' an exponent approximating 0.5.

Jenkins model : Jenkins (1967) calculated a regression between standing crop of fish and MEI in US reservoirs which has the following form :

$Y = 2.07 + 0.164\ X$, where, Y = standing crop of fish & X = log MEI.

Jenkins and Morais (1971) incorporated some environmental variables and calculated the following equation

$Y = 0.2775 - 0.2401\ X_1 + 1.0201\ X_2 - 0.2756\ X_3$, where, Y = total harvest in kg/ha, X_1 = log area, X_2 = log growing season and X_3 = log age of the reservoir.

Gulland model : Gulland (1971) calculated an equation relating potential yield to virgin ichthyomass which has the following form Y = kMB, where Y = total fish yield, k = a constant which lies between 0.3 and 0.5, M = natural mortality coefficient and B = biomass prior to fishing.

Trophodynamic model : Mellack (1976) calculated a regression between fish yield and gross photosynthesis for 15 Indiana lakes which has the form log FY = 0.122 PG + 0.95, where, FY = fish yield PG = gross photosynthesis.

Oglesby (1977) studied the relationship between the standing crop of summer phytoplankton and fish yield. The equation is log Y = 1.98 + log CHLs.

Drainage Index : Ramakrishniah (1986) considered the importance of catchment in the loading of nutrients and detritus into the reservoir and proposed an index called Drainage Index (DI) which is calculated as :

$$\text{Drainage Index} = \frac{\text{catchment area}}{\text{reservoir area X mean depth}}$$

For 21 reservoirs selected from different drainage systems a regression has been calculated as :

$$Y = 0.8613 + 0.577\ X,$$

Where, Y = log fish yield/ha and X = log DI. It was found to be superior to MEI when applied to Indian reservoirs.

Stocking : Stocking with fast growing species is an important aspect of reservoir fishery management. Stocking policy must give due emphasis on trophic strata in terms of vacant, shared and unshared ecological niches. Gangetic major carps alone are not capable of utilising all the ecological niches. Catla, rohu and mrigal utilise only zooplankton, periphyton and detritus. *Pangasius pangasius* would be a useful addition to utilise molluscs, *Tor putitora, M. aor* to utilise weed fishes and common carp, *C. carpio*, being omnivous, to utilise insect larvae, worms and detritus.

As such there is no indigenous species which utilises the vast resources of Myxophyceae (*Microcystis*) present in tropical impoundments. Though the exotic silver carp is reported to utilise this item (Jhingran and Natarajan 1978), the damage it causes to the indigenous species, its poor keeping quality and the low price it fetches in the market should be kept in view before stocking the species. In Govindsagar it formed the dominant fishery having entered the reservoir inadvertently.

Different stocking rates are being followed in reservoirs. Fish seed committee recommended a stocking rate of 500 fingerlings/ha in the size range of 45–150 mm. On the basis of studies in DVC reservoirs Natarajan *et al* (1971) recommended a stocking rate of 300 fingerlings/ha for reservoirs without predators and 600 fingerlings/ha in reservoirs with predators.

Jhingran et al. (1969) proposed a formula for computing the number/ha to be stocked in reservoirs and is given as $N = \frac{S_1 - S_0}{G} + M$, where, N = number of fish/unit area/unit time, S_1 = fish biomass/unit area at the end of unit period, S_0 = fish biomass/unit area at the beginning of unit period, G = average increase in weight per fish and M = anticipated mortality. It is desirable to keep the size of stocked fingerlings at 100 mm and above for better survival.

Exploitation : Stock monitoring *vis a vis* fishing effort is most important for raising the yield in reservoirs where breeding and recruitment are normal in respect of important species. In reservoirs where there is natural recruitment, management of fishery is relatively easy which involves selection of right meshes and deployment of optimum effort. Such an approach has led to remarkable increase in yield in Bhavnisagar (from 26 kg to 80 kg/ha/yr in 5 years) and Govindsagar (from 25 kg to 71 kg/ha/yr in 5 years) (Natarajan, 1979). Increasing the cropping intensity has also augmented the productivity of *Mystus aor* and *Wallago attu* in Bhavanisagar.

Studies reveal specific size vulnerability for carps and this differ from reservoir to reservoir and is influenced by basin morphometry. To enhance catchability it is necessary to deploy right meshes.

Due to peculiar nature of reservoir bottom, only stationary gear like gill nets are popular in reservoirs. The mesh regulation adopted left weed fishes and medium and minor carps out of exploitation. It is necessary to keep the population of minor carps and weed fishes under check to reduce their competition. Drag netting during periods of low water level under departmental supervision should be undertaken to remove weed fishes.

Several conservation measures, such as limiting size of fish, size of annual catch, observation of closed season for fishing and declaring certain areas as sanctuaries are observed in Indian reservoirs. In reservoirs where there is no recruitment observation of closed season is redundent. Even in reservoirs where there is natural breeding and recruitment, the breeding grounds may be declared as sanctuaries instead of closing the entire reservoir for fishing. By such a step fishermen are not deprived of their livelihood during closed season.

Management of small reservoirs

Small reservoirs pose fewer problems and are relatively easy to manage when compared to large reservoirs. Basically aquaculture techniques are practised on an extensive scale. The upstream stretch of small reservoirs are seasonal and become live only when there is heavy rain in the catchment and these are not conducive for carp breeding. In these circumstances natural recruitment cannot be expected. Stocking the reservoir annually is the only alternative to develop a fishery. the stocking policy must take into account the biogenic capacity of the environment, growth rate of the species and natural mortality through predation and escapement. The stocking rate may be computed using the formula

$$\text{Stocking rate} = \frac{\text{Total fish production in kg}}{\text{individual growth rate in kg}} + \text{loss}$$

Adopting a rational stocking and exploitation policy the fish yield of Gulariya reservoir has been raised from 33 kg to 100 kg/ha/annum (Jhingran 1986).

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ENGINEERING ASPECTS OF CAGE AND PEN DESIGNS

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Introduction

The success of aquaculture in net pens and cages is largely determined by appropriate selection of ideal sites which can provide favourable environmental conditions such as availability of sufficient food, enriched oxygen in the culture medium, etc. for optimum growth of fish. Safe, sound and flawless design of pen and cage structures using indigenous durable materials can assure the structure a reasonable life expectancy, a better growth environment and easier subsequent management. Thus it necessitates the intelligent application of the aquacultural engineering in designing such structures to make them economical, durable, functional and operative. The requirements of biologists in the direction of fulfilling the above objectives should also receive adequate attention.

Net pen enclosure

Selection of site : Selection of a suitable site for pen enclosure is of paramount importance as this aspect largely decides the economic viability and success of the farming system. Hence before undertaking the construction of pen enclosure, it is essential to undertake detailed engineering studies at the site on the following aspects :-

i) The normal depth of water in the watershed (lakes, *beels, mauns*, shallow reservoirs, etc.). Whether the lake and surrounding areas get inundated by flood,flash flood,storm surge etc. and if so, the maximum depth of inundation.

ii) Shape, size and nature of the watershed, whether lotic or lentic.

iii) Infestation of aquatic vegetation, if any.

iv) Characteristics of the catchment area, vegetation cover, etc.

v) River or stream discharge, high flood level in the river, if there is any, adjoining the watershed.

vi) Topographical features of the shore.

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vii) Type of soil, if sandy, loamy, clayey or silty.

viii) Availability of culturable species.

ix) Pollution problem, if any.

x) Accessibility.

xi) Intensity and duration of rainfall in the region.

xii) Prevalent wind direction, its velocity.

xiii) Wave action, if any.

Land topography

The shoreland with reasonable stability and having a gentle slope towards the watershed is considered as most ideal for installation of the pen enclosure. Very steep gradient or closely spaced deep bed undulations pose difficulty in erection and operations. Hence such sites are unsuitable for pen installation.

Catchment area and its characteristics

Catchment area or catchment basin means the areas from which rainfall flows into the drainage outfall, lakes, beels etc. The boundary line of this basin is called the watershed. Surface run-off from the catchment area to the watershed depends on – a) intensity and duration of rainfall b) Land contours, land shape and area c) loss from evaporation, percolation and transpiration by vegetation etc. Floods from a large catchment area take longer time to rise than floods from a smaller catchment area.

Type of soil

The soil should be productive and have sufficient bearing capacity to support the self-weight of the pen structure. The soil showing proneness to erosion or bed-scouring is not suitable for the purpose.

Design forces

The various forces which exert thrusts on the pen structure may be categorised as follows : 1) Direct stresses due to self weight of the structure 2) Occassional operational loading 3) External loadings from drift wood, aquatic vegetation, fouling organisms, etc. 4) Dynamic forces from wind, waves and turbulence.

The expected thrusts from dynamic loads have to be correctly ascertained from meteorological and hydrographical conditions prevailing at site. Wind pressure is the principal force which tends to disturb the stability of the structure. The wind exerts the greatest turning moment to the solid parts of the structure creating greatest stress at the base of the structure. However, the netting round the enclosure offer lesser resistance to the wind action.

The wind force acting on a solid structure can be determined from Van Boven (1968) equation -

$Fw = 0.0965\ AV^2$, where, Fw = wind force (kg), A = area of projected area perpendicular to the wind direction (Sq.m), and V = velocity of wind (m/sec).

The net impoundment structure located in coastal and offshore regions are occassionally subjected to wave forces. Wave height is a function of mean hourly wind velocity, fetch length and water depth (Wheaton,1977). The wave heights expected to exert pressure on net structure located in the above regions have to be calculated from the consideration of (1) the direction and speed of the wind field (2) fetch length and (3) water depth variation along the fetch (Milne,1970).

Layout and design

The design of pen enclosure varies with its location, whether it is to be erected near the sloping shoreline or within the watershed. The pen should, in general, be well designed, rectangular or horse-shoe shaped and considerably longer than their width to facilitate dynamic flow energy in the impoundment.

The main components of the pen structure consist of main support, framework spanning over the supports, stays, bracings and net enclosures. There should preferably be two nets; one on the inside of the pen to form impoundment for fish culture and the other on the outside to prevent entry of predators, debris, etc. The nets are stiffened by headlines, midline and leadlines.

Among the various materials, bamboo is found to be most suitable for erecting the pen structure, particularly to be used in *beels*, *mauns*, shallow lakes, etc. considering its reasonable durablity, low cost, easy availability and handling facility. For larger loading and thrusts often big diameter sal bullah piles or timber dock piles are considered a suitable substitute. Concrete or non-corrosive metallic poles are frequently used for the net enclosure in coastal or off-shore areas. Metallic fabrics made from galvanised steel, aluminium, brass or copper are stretched on the poles on the inside to hold the reared fish.

Floating cages

Fish culture in floating net cages holds more promises of higher return of yield through heavy stocking and intensive feeding. Plenty of oxygen in the aquatic medium, favourable environmental conditions, less exposure to dynamic forces and sufficient food contents in the water are some of the essential requirements for successful fish production from the floating net cages.

Locations

The site of the cage to be installed should preferably be in a protected or sheltered zone essentially free from direct action of wind, effect of turbulence and impact of waves. The ideal site is on the leeward side of the prevailing wind with facility for adequate exchange of oxygenated water.

Cage design

The design of cages vary with the behaviour of fishes to be reared. The pelagic fishes have a general tendency to swim swiftly often in an orbital motion near the surface of water. For such fishes circular, hexagonal or spherical end edged cage may be found suitable. Square or rectangular cages may prove more useful for demersal fishes which prefer to move in midwater and deeper water.

The size depends on the strength and durability of the materials to be used in building the cage, the species to be reared in the cage and the available management facilities.

Cage units

The chief components of the floating net cage are framework, floating units, net cages and anchoring or mooring arrangements.

Framework

The framework supports the self weight of the structure, weight of the wet net, operational loads besides offering stability against wind action, wave thrusts and tidal impacts.Whole pieces of bamboo laced together or wooden framework with heavy timber beams and planks may work satisfactorily for cage size of 8 x 5 x 2 m in moderately calm water. Metallic angle iron frames or galvanised iron pipes with verticals, diagonals and knee bracings are essential components of larger cages used in deeper water requiring more rigidity against the external thrusts.

The floating units

The floating units should be of sufficient capacity to provide adequate floatation and buoyancy. Steel drums, plastic barrels, oil barrels, bundles of bamboo poles, styrofoam floats, ferrocement floats etc., are some of the floatation materials used depending on the environmental conditions. For vertical equilibrium, the vertical force acting upwards on the net cage structure must be equal to the weight of the water displaced by the body of the cage structure. Four 200 litre empty oil drums may be needed to float an iron angle net cage measuring 4x 4x 2.5m.

Anchorage facilities

The floating cage unit may be moored at a fixed location either with the help of large metal anchors or by heavy metallic pegs driven into the bed. Cages closed to the land may be suitably moored to a concrete wall or concrete pillars at the shoreline.

In tidal waters the cage unit should necessarily be anchored by means of several heavy iron anchores. The length of the anchore line should be at least three times the depth of water and the anchor chain/rope should be very strong to resist tension.

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STATUS OF ESTUARINE FISHERIES RESOURCES AND THEIR EXPLOITATION IN INDIA

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The term estuary defined as "Semi-enclosed coastal body of water, which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from the land drainage" includes the mouths of rivers, the large backwater lakes, the tidal creeks, back waters along with the coast and coastal canal systems. India has an estimated estuarine water spread area of 2.6 million hectares with the support of mighty estuaries on east and west coasts, Chilka and Pulicat lakes, and back-waters of Kerala including Vembanad lake and also estuarine impoundments called "bheries" in Sunderban deltaic region of West Bengal. As a whole these estuarine waters are highly productive because of enriched drainage from the land and influx of nutrients from the sea.

Diversities in salinity regimes and other physico-chemical conditions due to varying intensities of freshwater discharges in different seasons and tidal fluctuations throughout the year bring about biological alterations in the estuarine ecosystem. The faunistic population of adaptable characteristics can withstand the dynamic stress in estuarine waters and thus only a few species of high commercial value are dominating the catches from open waters and also grown in impounded environments. The salient features along with production, from capture fisheries of important estuarine resources are described below.

Open estuarine system

Hooghly-Matlah Estuarine System : Hooghly-Matlah estuarine complex has the largest deltaic region in the world. The total approximate area of this estuarine system with its inumerable tributaries and network of creeks is 2,340 sq.km. The mangrove vegetation grown in the deltaic region harbours a potential grazing ground for the estuarine fishes and prawn species. These estuarine sources are highly productive and the total catch from Hooghly-Matlah estuarine system fluctuates within 20,000 - 25,000 t/year. Catch assessment from different zones of the estuarine complex reflects highest production from the lower zone (Zone-III) which contributes 70 to 75% to the total annual landings.

Different types of fishing gears are operated in Hooghly-Matlah estuary. Bulk of the total fish landings are contributed by the bagnet and the percentage contribution by this type of gear ranges between 70 to 80.

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Of special importance in the Hooghly-Matlah estuarine system is the so called migratory fishing practised during the winter in the lower zone. Because of the prevailing calm weather in the coastal belt the fishermen engaged in fishing in upper zone of the estuary migrate to the lower zone for intensive fishing. In the winter fishing centres like Frazerganj, Jamboodip, Kalistan etc. the average catch per unit of effort ranges between 29-156 kg (1987-88) during November to January as against 2.6 kg obtained in the upper and lower reaches during the whole year. The important species in bagnet catches during winter migratory fishing are *Harpodon nehereus*, *Setipinna* spp., *Trichiurs* spp. and prawns mainly *Parapenaeopsis* spp. (Table - 1).

Considerable changes in Hooghly estuarine environment and in the fisheries pattern have been observed after the increased freshwater flow in the system from the Farakka Barrage (Table - II). The yields of purely marine forms (*P. indicus*, *T. jella*, *C. ramcarati* and *L. calcarifer*) have markedly decreased in the lower zone while fisheries of some species like *P. pama* and *P. paradiseus* which were in declining trend have shown a sign of improvement in lower and gradient zone of the estuary.

Wide fluctuation in hilsa catch is an interesting characteristic of Hooghly estuary. However, the landing of the species which remained 1,457 tonnes/year during 1966-67 to 1974-75 showed a sharp rise of 2,126.2 tonnes/year after the Farrakka discharge (1975-78) and has come down again to 1,781.3 tonnes/year in recent year (1984-87). The recent upward trend in hilsa landing can be attribute to the increased effort and mechanisation of the boats.

Mahanadi estuarine system : The Mahanadi estuary is characterised by poor tidal oscillations and flood discharges because of formation of sand bars at the estuarine mouth which restricts the influences of the flood tide upto 30-35 km upstream only. These characteristics are, therefore, reflected in poor production potentiality of the estuary. However, as an estuarine complex including the brackishwater lagoons of about 12,000 ha, Mahanadi estuarine system covers about 30,000 ha area with an estimated annual production of about 550 tonnes/year. The principal fisheries of this estuarine complex are mullets dominated by *M. cephalus* accounting for 31-48% of the total landings, bhetki, sciaenids and prawns. The 1959-60 survey reported 6,900 fishermen actively engaged in fishing activity using 1,700 boats and 56,700 nets in this estuarine system.

Estuaries of the Peninsular India

Godavari estuarine system : Godavari estuary, the major estuary in peninsular India has an area of about 18,000 hectares. Goutami is the main source of the estuarine complex in which tidal influence extends only upto 40-50 km upstream from the mouth region. Formation of sand bars in the estuarine mouth restricts the entrance of tidal waters like Mahanadi estuarine system. The total production from this estuary is estimated to be about 5,000 tonnes. Mullets and prawns form the major catch of the system. *M. monoceros, M. dobsoni, M. affinis, M. brevicornis, P. monodon* and *P. indicus* are the important prawn species available in lower reaches of the estuary.

About 185 species of fishes are available in this estuary of which 72-80% are euryhaline, 12-20% almost marine and 15% freshwater in origin. Mullets form nearly 2/3rd of the total fish landing and are represented by *M. cephalus, M. speigleri, M. dussumieri, L. troschelii, L. oligolepis and L. seheli.* The other fishes of commercial importance are : *Pristiopama hasta, Leiognathus sp., Gerres filamentosus, Caranx sp., Sillago sihama, Lates* calcarifer etc.

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

Estuaries of the North West Coast :

Narmada, Tapti and Mahi are three main estuaries in West coast. Tapti, which earlier used to be an important estuarine source of fish production, has lost its potentiality due to the construction of *Okai* dam in the upper freshwater region of the river system. Nothing much has been done for assessing the fisheries potential of Mahi estuary which at the present state is facing the problem of industrial pollution due to the mushroom growth of industries on both the banks of the system. However, the information collected on the Narmada estuary during recent past stands as follows.

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

On account of a cascade of dams under construction on the Narmada River System with the World Bank aid the entire ecosystem and its productivity is bound to be greatly affected. Pre-impoundment surveys have been initiated by the CICFRI in 150 km strech of the river Narmada in the State of Gujarat.

General consideration :

The open estuarine waters, brackishwater Lagoons and lakes along with hundreds of small coastal streams constitute country's fisheries resources of an appreciable magnitude, besides being the source of seed for brackishwater aquaculture. These fisheries resources are either over exploited or still remain unexploited because of lack of knowledge for management of these open water systems. Considerable efforts have been made in recent years to assess the production potentialities of several important estuarine resources and management measures recommended for exploiting sustained annual yields. However, the country's many of the open estuarine resources are undergoing drastic ecological changes and are expected to turn in to biological deserts because of construction of dams and barrages on upper riverine streches.

Since many of the marine species dominate the catches from the lower estuarine zones it is extremely essential to have a comprehensive understanding of their feeding and breeding migration in and out of estuarine ecosystem. It has also been observed that because of indiscriminate capture of large quantities of brood fishes and the juveniles and also restricting the drainage from the upper reaches of the river system by human intervention, the stock of the estuarine fish have largely been affected. As such with a view to developing the estuarine fisheries for increased yields it is essential that besides conducting biological investigation of different fish and prawn species, studies on various population parameters vis-a-vis the changed ecological conditions, the types of the gears employed and the effort put in may be studied in details for developing suitable management models for the fisheries of the different estuarine systems of the country.

Table-I

Contribution of dominant fish species and prawns (in t) in winter migratory bagnet fishery in lower estuary during mid October 1985 to early February 86 and mid Oct. 84 to early Feb. 85.

Name of the species	Contribution to total catch		% in the total catch	
	1985-86	**1984-85**	**1985-86**	**1984-85**
Harpodon nehereus	4936.0	3864.6	28.1	19.7
Pama pama	3554.0	3213.3	20.2	16.4
Setipinna spp.	1863.5	2042.3	10.6	10.4
Trichiurus spp.	1408.6	4811.0	8.0	24.5
Saina biauritus	569.4	18.9	3.2	0.1
Coilia spp.	392.5	601.2	2.2	3.1
Tachysurus jella	223.2	323.2	1.3	1.6
Ilisha elongata	200.1	330.3	1.1	1.7
Stromateus cinereus	108.1	6.5	0.6	-
Polynemus paradiseus	12.6	61.8	0.1	0.3
Prawns	1216.5	1535.0	6.9	7.8
Others	3096.9	2831.3	17.7	14.4
Total	17581.4	19639.4	100.0	100.0

Speciewise landings (in tonnes) from Hooghly Estuary during three periods

Name of the species	Pre-Farakka Average (1966-67 to 74-75) Zone					Post-Farakka Average (1975-76 to 77-78) Zone					Recent years Average 1984-85 to 86-87 Zone				
	I	II	III	IV	Total	I	II	III	IV	Total	I	II	III	IV	Total
Hilsa ilisha	127.9	132.9	1077.1	119.2	1457.1 (15.4)	101.8	35.8	1813.1	175.5	2126.2 (11.5)	172.0	272.9	1192.7	143.7	1781.3 (7.4)
Setipinna sp.	33.5	3.5	651.1	20.9	709.0 (7.5)	29.9	1.8	1015.9	17.7	1065.3 (5.8)	11.0	24.8	1793.4	14.0	1843.2 (7.7)
Trichiurus spp.	-	0.8	452.0	1.2	454.0 (4.8)	-	0.2	1340.0	0.2	1340.4 (7.2)	-	0.2	2577.4	-	2577.6 (10.7)
Harpodon nehereus	1.7	47.0	1929.1	90.1	2067.9 (21.8)	-	15.5	4249.0	80.6	4345.1 (23.5)	-	1.0	3956.2	-	3957.2 (16.5)
Pama pama	8.6	9.2	192.7	26.7	217.2 (2.3)	7.1	12.7	3088.9	42.0	3150.7 (17.0)	5.4	30.9	1748.5	36.7	1821.5 (7.6)
Tachysurus jella	-	-	176.0	0.2	176.2 (1.9)	-	-	162.7	-	162.7 (0.9)	-	-	537.9	-	537.9 (2.2)
Polynemus paradiseus	5.7	2.6	18.6	30.3	57.2 (0.6)	3.1	37.5	27.7	68.1	136.4 (0.7)	7.2	46.4	47.3	58.5	159.4 (0.7)
Coilia spp.	2.3	1.5	70.9	47.6	122.3 (1.3)	0.2	-	97.2	13.0	110.4 (0.6)	-	1.8	352.7	-	354.5 (1.5)
Ilisha elongata	0.2	0.9	164.2	1.4	166.7 (1.8)	-	-	654.6	0.1	654.7 (3.5)	-	-	310.0	-	310.0 (1.3)
Sciaena biauritus	0.1	0.9	188.8	0.4	190.2 (2.0)	-	-	310.0	0.7	310.7 (1.7)	-	-	261.7	-	261.7 (1.1)
Liza parsia	-	3.2	42.9	3.5	49.6 (0.5)	-	2.5	39.1	8.8	50.4 (0.3)	-	1.3	21.0	-	22.3 (0.1)
Lates calcarifer	-	0.1	24.1	0.3	24.5 (0.3)	-	-	28.8	-	28.8 (0.2)	-	-	7.0	-	7.0 (0.1)
Prawns	367.6	51.8	751.1	167.8	1338.3 (14.1)	233.0	49.3	1145.8	320.8	1748.9 (9.4)	232.9	67.4	1638.8	214.8	2153.9 (9.0)
Others	416.7	57.7	1744.5	232.4	2414.2 (25.5)	318.6	80.5	2672.2	208.5	3279.8 (17.7)	107.2	68.6	7780.4	222.8	8179.0 (34.2)
Total	964.3	312.1	7463.1	742.0	9481.5	693.7	235.8	16645.0	936.0	18510.5	589.8	519.0	22225.0	692.8	24026.6
Freshwater Fishes	-	-	-	-	-	-	-	-	-	-	54.1	3.7	-	2.3	60.1

ROLE OF MANGROVE IN ESTUARINE FISHERIES DEVELOPMENT

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Introduction

Mangrove, the typical forests of the tropical and the sub-tropical regions provide magnificent ecosystem at the sea coast and estuaries (Anon., 1987). The dominant community of the ecosystem is formed by the salt tolerant halophytes facing the influences of two high and two low tides a day. This vibrating ecosystem supports numerous terrestrial, amphibious and aquatic organisms forming a complex association of species, exchanging material and energy within the system as well as between the system and the adjoining coastal waters. But these concepts are recently evolved.

The tidal mangals have been misused for more than the last two centuries as they have been thought to be only neglected coastal wastelands (Azariah et al., 1987). These forests areas have been subjected to indiscriminate and ceaseless exploitation for agriculture, aquaculture, inhabitation, fuel,weed,etc. for short term benefits. None paid any attention towards the biological, ecological, functional, socio-economical and medical values of the ecosystem on a long term basis. Consequently this ecosystem is facing a threat from extinction of certain species, loss of land masses to the sea through scouring, depletion of estuarine fisheries and other hazards. Thus a scientific policy is highly essential for the protection, salvation, and conservation of this dynamic ecosystem.

Mangrove of the country

In India mangrove ecosystem is existing in the coasts of Kutch and Cambey in Gujarat, in Konkan and Malabar coasts as patches, and in the estauries of Cauvery, Krishna, Godavari, Mahanadi and Hooghly-Matlah system. In addition, one-sixth of the total mangal of the country is available in the Andamans and Nicobar group of islands. In 1963, the total mangal area was reported to be 700,000 ha which was reduced to half (356,500 ha) by 1975 (Blasco,1975) due to mass scale destruction and controversy over the inclusion of plant species within the mangals. India is losing 1.5 m ha of forest land every year. Likewise the estimated 0.59 m ha of mangrove forest of the country also is now suffering from the same fate.

Plant wealth of the mangal : The Sundarbans comprises the largest mangrove area in India and accommodate the maximum number of species. According to UNESCO there are 53 of true mangrove species in the world and 30 of them are available in

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the Sunderbans (Naskar, 1988) apart from 44 species of mangrove associates, 10 species of obligatory mangroves, 11 species of sand dune/beach flora, 33 species of weed flora, 9 species of non-littoral plants and the well naturalist introduced 5 species.

This macrophytic community shows heterogenity in its distribution in different formative zones and among themselves they vary from haline grasses, herbs, twinners/climbers, shrubs to tall trees (Naskar, 1988). specific niches exert differential role to the nektonic population. Stiltroots, pneumatophores and atomosing root branchings being the silt deposition to form land masses and tide pools. This provides excellent harbourage to the drifting juveniles of fishes and prawns, and substrate for the growth of their food organisms.

In addition, litter diposition rate and their decomposition pattern dependant on the species of plant and the seasons create niches acceptable to the fish and prawn seed at a varying degree. Research in this line has just been initiated. Moreover, the type and the nature of plant are responsible for guano deposition at places by way of inviting birds. Enrichment of soils with guano encourages congregation of fish and prawn seed in the region.

Fungal Communities : From the Sunderbans 184 species of fungal flora have been recorded. These play a role for the decay of organisms. On one hand vegetative matters become avaiable to the fishery through food chain and on the other hand some fungi damage the prawn fauna in particular.

Bacterial community : So far, 13 species of bacteria have been recorded from the mangrove litters. All are not pathogenic rather some of them hasten the proces of composting of the leaves and nutrients release. Among the nine pathogenic species recorded from fishes and shrimps only *pseudomonas* sp. occur in the mangrove litters while other 8 species are transmitted from host to host in the open estuary. This accounts for congenial environment of the mangrove ecosystem to be preferred as natural nursery grounds.

Parasitic protozoan community : In the Sunderbans, the extent of protozoan infestation on the fish and prawn seeds is yet to be worked out. Presently, 4 species of flagellates, 17 species of rhizopods, 4 species of foramineferans,5 species of sporozoans, and 1 species of ciliate as parasites have been recorded and the role of such protozoans in the fisheries is being studied.

Cnidarian and Ctenophoran comminuties : More than 18 species of ctenophorans of the Suderban mangrove ecosystem either directly predate upon the seeds or compete for the food with the estuarine fauna in the tide pools, mud or phytotelmates especially during summer. They partially control some predatory fishes.

Helminths and nemerteans : The Sunderbans mangal has been observed to include a single species of planarian, 12 species of parasitic cestodes, more than 68 (2 parasitic) species of nematodes and 2 species of nemerteans.

Annelids, sipunculides & echiurids : About 50 species of annelids, one species of sipunculid and 4 species of echiurids of the Sunderbans mangal though form the food items of larger fishes mainly of *Lates calcarifer*, some in turn are harmful to the seeds of prawn and fish.

Echinoderms : Three species of ophiuroids, three species of astroroids and two species of holothuroids recorded in the Sunderbans are enemical to the fishery as they either predate or compete for food. But their abundance is quite low. However their larval stages form food to the fishes.

Ectoprocta, entoprota and hemichordates : The role of bryozoans, *Lingula* sp. and *Saccoglossus* sp. is insignificant since they occur only few in numbers.

Molluscs : About 25 species of bivalves, 26 species of gastropods, and 12 species of cephalopods occur in the Sunderbans. Wherever their abundance is more the seed abundance of prawn and fish has gone down due to competetion for food and shelter. The fishery is least affected by the cephalopods. But gastropods invade the tidepools and phytotelmates as local fauna and feed upon lab-lab whereas bivalves depend mainly on filter feeding of planktonic forms. Thus, the gastropods do more harm to the fishery. Their decomposing flesh is utilised by the shrimps and crabs. Even their empty shells are used by the hermit crabs (*dardamus* sp., *bargus* spp, *Eupagurus* sp., etc. who in turn compete for food with the shrimps.

Arthropods : Insects contribute significantly to the ecosystem. The larvae & nymphs form the food items of many fishes whereas aquatic beetles and others compete for the food. There are about two species of orthopterans, 16 species hymenopterans,8 species of hemipterans,1 species of hompoteran, 16 species of coleopterans, 30 species of dipterans, and some species of lepidopteran besides unidentified species of Collembola, Diplura, Thylanura, Isoptera and Ephimeroptera . There are about 8 species of Acarina which cause damage to fish and prawn as that of Isopoda like Bopyrus sp. Sphaeroma sp. *Cirroptana* sp.

About 7 species of Amphipoda encourage the growth of prawns and lab-lab feeder fishes Stomatopods compete with the shrimps and there are more than 2 species existing in the ecosystem. Likewise, *Balanus* sp. and *Lepus* sp. among *Ciripedia*, and *Concostraca* sp. among Ostracoda occur in the system as comepetitors.

As earthworm does, the three species of ghost shrimps encountered in the mangals improve the soil fertility through casting of moulds, and aerating the soil through burrowing holes. Thus, their existence in the system is beneficial to the fishery comprising about 12 shrimp species,4 crab species, and 20 fish species of commercial importance. Besides other 6 species of prawn, 30 species of crab and 100 fish species of noncommercial nature also seek food and shelter in the system. Due to rare representation *Palinurus* spp. do not form practically any fishery of the mangals.

Vertebrates : Mangrove ecosystem provides hiding places for the shrimps and mullets to escape predation by the carnivorous fishes which in turn controlled by the crocodiles. The frogs of the region fall prey to the snakes and save a sizeable quantity of juvenile fishes and prawns of the mangals. While avian droppings on the mangal soils enhance production of fishes and prawns, many birds unfortunately prey upon the aquatic fauna . The tigers consume catfishes and crabs and directly promote the commercial fisheries. Indirectly also they support the fisheries as they guard the natural nurseries from human exploitation and destruction of the woodland. They control the populations of deer, monkey and other herbivores and in turn save the mangal flora from denudation and subsequently the fisheries.

Algae : Mangal having saline sedimented humus soil encourages Cyanophyceae as the base for the growth of Chlorophceae which require high nitrate and phosphate in a consolidated soil. Cyanophyceae consolidates the soil particles and on oxidation release inorganic phosphate and ammonical nitrogen which readily gets converted into nitrate by the action of microbes. Bacteria,blue-green algae, green algae, and diatoms act as nitrogen fixing and sulpher reducing agents in the tidal mangal soils. Plenty of algal forms are present in the plankton and benthos of the mangals to attract fishes and prawns for their feeding.

Integrated role of the biotic communities

The chief producers on the land and the inter-tidal zone are the halophytes whereas in aqutic and semiaquatic niches, plankton, benthic algae, and periphyton are the major producer groups.These communities either directly contribute matter and energy to the primary consumers like, *Macaca* sp., 16,000-17000 birds and innumerable insects on land; and to zooplankton, benthic fauna, insects, annelids, etc. in the water phase. The producer groups again interchange the nutrients among themselves through the medium of soil and water.

The secondary and the tertiary consumers like, *Felis* sp. *Batagur* baska, Lepidochelys sp., etc. on land and molluscs arthropods, echinoderms, fishes, porpoises, snakes,*Varanus salvator*, etc. in water and marshes live upon the primary consumers, *Panthera tigris tigris* among terrestrial forms and *Crocodilus porosus* among aquatic species predate and control the communities of primary ,secondary and tertiary consumers. The heterotrophic organisms especially the upper level consumers contribute to the humus and organic detritus of the tidal mangrove whereas the lower form of consumers and the producers are responsible for the enrichment of the soil and water (Fig. I). The consumers through their decay release matter and energy for the producers again and in the food chain, the fishery occupies the intermediate place while soil and water act as the central reserve for nutrients.

Miscellaneous effect of the mangals

Tanin liberated by the mangals hardens the egg cases of the fishes and shrimps and provides better survival for the hatchlings while wax from mangrove leaves and hymenopteran hieve controls predatory aquatic insects.Salinity rise regulates the torture of frogs on the juvenile fishery of the region.The mangroves are rich in yeast concentration and their enzymatic activities break down the cellulose and the hemicellulose from the mangrove litters and pectene from shells of dead crustaceans respectively, making carbohydrates, proteins,etc.readily available to the growing prawns and fishes who feed on the detritus.

The mangroves purity the aquatic system from hydrocarbon pollution. Innumerable pores and holes created on the earth surface by their protruding and sprouting roots and by the ghost shrimp enrich mangal soils with nitrogen through the process of aeration. Moreover,exposure of the water logged areas during low tide also facilitates aeration of the mangal soils. The mangrove protects its wealth from the oceanic surges and the seeds of prawn and fish from drifting by the tidal longshore,and rift currents

Conclusion

Thus, the mangal which behaves like a mother protecting and nurturing the juvenile fishery to develop into commercial fishery needs conservation and careful utilisation.

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COMMON FISH PARASITES ENCOUNTERED IN ESTUARINE WETLANDS AND THEIR CONTROL MEASURES

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Introduction

The estuarine wetlands in India exhibit a wide ranged environmental condition and sustain a rich fishery of fin-fishes and shell-fishes. As such, for sustained yield, parasitological studies are very important aspects of managing fisheries of such wetlands. Further, in this type of capture-cum-culture fishery, fishes face changes in environment which have both advantages as well as disadvantages. Worth-mentioning advantage for the fishes is losing some parasites which cannot tolerate the change in salinity of water. The great disadvantage faced by the estuarine fishes in the impoundment is the ecological imbalance; as fishes are poikilothermal in nature they become subject to 'stress' and face great trouble to maintain their homeostasis and as a result they become easy prey of the parasites. As such, the present communication deals with common fish parasites encountered from estuarine wetlands and their control measures.

Ecological consideration of estuarine wetlands from the view point of aquafarming

Wetlands between Hooghly and Raimangal estuaries can be classified into three distinct groups according to their ecological variations. Compared to low saline and transitional wetlands both organic carbon and phosphorus (measured in the form of pentaoxide) were found to be low in high-saline wetlands which reflected in the phosphate content of water as well. However, salinity of water in the high saline wetlands was much higher than other two zones. Excepting salinity of soil and water not much of difference in physico-chemical parameters could be found between low-saline and transitional wetlands. From the biological view-point amphipods were mostly encountered as benthic organisms of high saline wetlands whereas taenids were the common benthic organisms of low-saline wetlands. Both taenids and amphipods were recorded from transitional wetlands. Production potential of these lands were alike; from the physico-chemical point of view also not much of difference in the pH, DO and alkalinity of these waters could be recorded. In general, estuarine wetlands between Hooghly and Raimangal estuaries were found ecologically suitable for growing estuarine euryhaline species. After monsoon impoundments of transitional and low-saline zones were also found to be suitable for growing carps and *Oreochromis mossambicus*.

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The ecological aspects are important as it is seen that the various physico-chemical factors have profound impact on the composition and distribution of the parasitofauna which is evident in the present study.

Fishes grown in estuarine wetlands

On the maintenance of homeostasis estuarine fishes are classified as euryhaline and stenohaline; the former can tolerate wide fluctuation of salinity but the latter cannot (Nikolsky, 1963). Eventually fishes gown up in estuarine wetlands are in general euryhaline species. However, in low-saline wetlands where salinity generally does not exceed 10 ppt, carps (Indian major carps and Chinese silver carp) are also stocked after monsoon when salinity drops down to 5 ppt or less. In estuarine wetlands *Oreochromis mossambicus* is also stocked as consumers' preference. Common carps are also grown in low-saline wetlands. It may be mentioned here that carps are never stocked in high saline wetlands where salinity is more than 10 ppt even after rains. However, the main thrust lies on the culture of *P. monodon*, the foreign exchange earning commodity, in all the impoundments of Hooghly-Raimangal estuarine complex.

Relationship between hosts and parasites

Before the relationship between hosts and parasites is discussed, the nature of parasitism needs little consideration. Parasites are either obligate or facultative in nature. The latter can live without a host for a part of its life cycle but obligate parasites always require a host for their sustenance. Obligate parasites may not always be dangerous as some helminths can help their hosts, but such parasites can be the cause of extermination of the hosts when environmental conditions do change (Nikolsky, 1963). As such, successful parasites keep the hosts alive so that they can grow and multiply. But virulent obligate parasites do cause extermination of the host in no time; as a result both host and the parasite perish if the latter does not simultaneously find out another suitable host for its existence.

Parasitic afflictions of estuarine fishes recorded from

a) *Hooghly-Raimangal estuarine complex*

Various types of animal parasites have been recorded from the estuarine fishes collected from their natural abode as well as from estuarine wetlands. The following table (2) will give some idea about the parasitic afflictions of such fishes.

Dr Nikolsky (1963) has mentioned that most of the helminth parasites of the alimentary canal of fishes do not cause harm provided environmental conditions remain congenial; as such, digenetic trematodes and cestodes have not been incorporated in the above list.

Apart from the aforesaid parasitic afflictions of estuarine fishes carps of low-saline wetlands have been found to suffer from diseases like tail and fin-rot, dropsy, haemorrhagic septicemia, ulcer, branchiomyces etc. Causative organisms of most of these diseases are bacteria though dropsy can be associated with physiological disorder resulting in accumulation of water either in the body cavity and/or in scale pockets. Brachiomyces is associated with fungi. However, etiological agents of these diseases have not yet been identified upto species level.

b) ***Parasitic afflictions encountered from estuarine fishes grown in wetlands***

Not much of work has so far been done on the parasitic afflictions encountered from fishes grown in estuarine impoundments. However, some preliminary observations have been made and the data collected are furnished in Table 3.

Comparative studies on parasitic afflictions of estuarine finfishes

Estuarine fishes when collected from their natural abode they exhibit various types of parasitic afflictions, viz., protozoa, helminths and crustacea. But such fishes when collected from estuarine impoundments they are generally affected with different types of species. *Liza parsia* is seldom affected with *Trichodina* spp. in open waters where they are often parasitized with myxozoans but they are often parasitised by the ciliate parasite in close water bodies. Similarly *Mystus gulio*, collected from estuaries exhibit myxozoan infection but they become victim of acanthocephalid worms in estuarine impoundments. *Penaeus monodon* of open waters has been found to be infected with *Vibrio parahaemolyticus* but the bacterium can be seldom recorded from low-saline impoundments. However, the rate of parasitic affliction varies according to salinity of estuarine impoundments (Table 4).

Control measures

Animal parasites of fishes are, in general, the causes for chronic diseases which are associated with the weakness of the host, aggression of the parasite an environment is bad for the host but congenial for the parasite. As such, control measure of parasitic afflications in estuarine wetlands should be improved by means of managerial practices as well as prophylaxis.

Sanitation of the impoundment

Impoundments of estuarine wetlands are generally sun-dried during the months of December and January. This is an active measure towards sanitation; however, ploughing the bed and disinfecting the impoundment with quick lime (CaO) or slaked lime ($Ca(OH)_2$ solid form) may be of help to provide congenial environment to the fishes to be grown up therein.

Stocking density of fishes

Stocking density of fishes in a wetland impoundment would depend upon its productivity as supplementary feeding is never done in this type of system. However, mortality of *P. monodon* is found to be common in low-saline impoundments where density of the shell-fish is generally more than 0.4 million/ha. Mortality of this fish is found to be negligible in high-saline wetlands where the density never exceeds 0.1 m/ha.

Pre-stocking measure

In many wetlands adjacent to the stocking impoundment there are small water-bodies for growing the juveniles/fry to use them as stocking materials. Mortalities of fishes or outbreaks of fish diseases may be encountered there. This is a step towards quarantine measure. Moreover, such a practice is more welcome because treating the fish with appropriate medicine can be done in small body of water, which is quite economical as well. In general, 3% sodium chloride can be used as a dip treatment against epizoans excepting myxozoans. For bacterial diseases like tail and fin-rot, dropsy, ulcer etc. either sulpha-drugs or antibiotics can be used. Anyway, medication is the last resort for which an appropriate authority is to be consulted.

Environmental monitoring

Wetlands of Hooghly-Raimangal estuarine complex receive sewage-water of Calcutta metropolis. Concentration of the same is more in transitional zone than other two zones, however, if care is taken towards the oxygen budget then safety of the stocked fishes can be ensured.

Fish-health monitoring

Proper check-up of fish health should be done during the growing period regularly. Examination of a small sample (60 fishes are enough for any large population) will be good to have an idea of the health condition of the population. This will help for further action. Before close, it can be safely concluded that a better management will ensure a better harvest.

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Table - 1 : Finfishes and shellfishes grown in estuarine impoundments

Shellfishes	Finfishes
Penaeus monodon	*Liza parsia*
P. indicus, P. merguensis	*Liza tade*
Macrobrachium rosenbergii	*Mugil cephalus*
Metapenaeus dobsonii	*Lates calcarifer*
M. dussumieri	*Chanos chanos*
M. brevicornis	*Etroplus suratensis*
M. monoceros	*Mystus gulio*
Macrobrachium rude	*Odontombliopus rubicundus* *Glossogobius giuris* *Megalop cyprinoides*

Table - 2 : Parasitic afflictions of estuarine fishes of Hooghly-Raimangal estuarine complex

Host	Parasite (Protozoa)	Habitat
Hilsa ilisha	*Ceratomyxa ilisha* *Zschokkella ilishae*	Gall bladder
Therapon jurboa	*Spheromyxa theroponi*	"
Lates calcarifer	*Leptotheca latesi* *Myxidium procerum*	" "
Odontombliopus rubicundus	*Ceratomyxa gobioidesi*	"
Glossogobius giuris	*Myxidium glossogobi*	"
Mystus gulio	*Leptotheca macronesi* *Parasite (Monogenetic trematode)*	"
Lates calcarifer	*Diplectanum latesi*	Gills
Eleutheronema tetradcactylum	*Diplectanum polynemus*	"
G. giuris	*Dectylogyrus gobii*	"
M. gulio	*Neomurraytrema tengra*	"
	Parasite (Acanthocephala)	
Mugil tade *Polynemus paradiseus*	*Neoechinorhynchus bangoni* *N. bangoni* *N. topseyi*	Alimentary canal " "
M. gulio	*Acanthosentis antespinus*	"
Hilsa ilisha	*A. indica*	"

Table-3: Parasitic infections in estuarine fishes of estuarine impoundments

HOST	Weight (gms) range	Total Nos. fishes examined	Nos. of fishes infected	Parasitic groups: Protozoan	Helminth	Crustacean	% of infections
L. parsia	20-60	155	56	Trichodina sp	-	Ergasilus sp	36.1
L. calcarifer	60-300	51	10	Trichodina sp	-	-	19.6
L. tade	100-200	65	-	-	-	-	-
E. tetradactylum	40-100	30	-	-	-	-	-
M. gulio	25-80	135	57	Trichodina sp	Neomurraytrema tengra	-	42.2
O. rubicundus	10-30	55	-	-	-	-	-
G. giuris	50-150	85	20	Trichodina sp	-	-	23.53
P. monodon	-	70	-	-	-	-	-

Table - 4 : Comparison of infection rates in cultured estuarine fishes

Habitat	Fish examined: No.	Species	Infection: No.	%
Low saline	235	5	88	37.4
Mid saline	145	5	35	24.1
High saline	266	7	20	7.5

METHODS OF STUDYING THE POPULATION DYNAMICS OF ESTUARINE FISHES

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The estuaries, as an ecosystem, undergo dynamic stresses mainly brought about by salinity changes and other physico-chemical factors, due to varying intensities of freshwater discharges in different seasons and tidal fluctuations throughout the year. The main estuarine regions in India constitute the deltaic estuaries of the rivers Godavari, Krishna, Cauvery, Narmada and Tapti, the Chilka and Pulicat lakes and the backwaters of Kerala including Vembanad lake. Considering the conditions prevalent in the Indian estuaries, it has been observed that marine forms predominate in the fish landings and the fluctuations in their catches are related to migratory patterns of species as well as the interaction of the various environmental factors.

In capture fisheries management, the study of the change of biomass at different time, space etc. i.e. dynamics of fish population is the paramount need of the hour to draw sustainable yields for years to come. Information on various inherent biological charactertics such as growth, recruitment, mortality, measurement of length, age determinant etc. is important for the evaluation of yield from fishery under varying biological and environmental factors. These basic parameters are also utilized for working out suitable population models for studing the dynamics of exploitation.

Estimation of parameters

Age-length distribution : Age-length distribution can be found if the stock is exploited fully through out its available stage covering its known life period. This could be achieved when well marked model growths are discernible from length frequency studies. Dissolution of multinormal distributions into uniformal ones through graphical methods has been pointed out by Harding (1949), Cassie (1954), Bhattacharya (1967) and others. These procedures, allot the numbers to each modal class representing different ages. Hard part studies such as studies on scales and otoliths also serve the purpose when the age marks (ring formation) could be identified.

Growth : Isometric and allometric :

Growth forms may be divided into two groups viz. isometric and allometric. it has been found that, within any stanza of a fish's life, weight varies as some power of length :

$$W = a\,L^b \quad \text{or} \quad \log_{10} W = a + b\,\log_{10} L$$

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where the weight (W) is proportional to a certain power (b) of the length (L). The value of 'b' is usually determined by plotting the logarithm of weight against the logarithm of length for a larger number of fish of various sizes, the slope of the fitted line being an estimate of b. The functional regression value b = 3 describes 'isometric growth' such as would characterize a fish having an unchanging body form and unchanging specific gravity. Many species seem to approach this "ideal" though weight is affected by time of year, stomach contents, spawning condition etc. On the other hand, some species have b - values characteristically greater or less than 3, a condition described as allometric growth.

Growth model :

The study of fish growth is central to fishery biology. Knowledge of how the fishes of a given stock grow is essential for most stock assessment purposes, since it is growth of individual fishes which provide from year to year the catch taken by a fishery. The available information on the growth of fishes is generally expressed by means of a single equation, such as the von Bertalanffy Growth model (VBG), the simplest version of which has the form :

$$Lt = L_{\alpha} \left(1-e^{-K(t-to)}\right) \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where L_{α} is the mean length the fish would reach if they were to grow to a very old age (indefinetely, in fact).

K is a growth coefficient

t_o is the "age" the fish would have had at length zero if they had always grown according to the equation (t_o generally has a negative value) and

L_t is the length at age t.

In case of allometric growth (ie, $b \neq 3$) we get in the usual notation

$$L_t = L_{\alpha} \left(1-e^{-Kd(t-to)}\right)^{1/d}, \text{ where } d = b-m$$

Under isometric condition (d = 1) solving (1) is well known using $L_{t+1} = L_{\alpha} (1 - e^{-K}) + L_t e^{-K}$ ....(2)

which is linear and e^{-K} and L_{α} are estimated using least square method. With the estimates of L_{α} and K obtained from (2) using

$\log_e (L_{\alpha} - L_t) = \log_e L_{\alpha} + Kt_o - Kt$ which is also linear, t_o is estimated.

Expressing in terms of weight, weight growth curve may be expressed as :

$$W_t = W_{\alpha} \left(1 - e^{-K(t-t_o)}\right)^3$$

In case of allometric growth it becomes

$$W_t = W_\alpha (1 - e^{-Kd(t - t_o)})\ n/d$$

Estimation of instantaneous rate of total mortality

Total deaths, which are equal to the decrease in the population numbers, can be written as proportional to the total mortality co-efficient Z

$$-dN = ZN_t\,dt \ldots\ldots\ldots\ldots\ldots\ldots\ (3)$$

Writing equation (3) in the form

$$\frac{1}{N}\,dN = -Zdt$$

and integrating we obtain

$$\log N_t = -Zt + \text{constant}$$
$$N_t = N_o e^{-Zt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (4)$$

Where N_o = numbers alive at time t = 0 and it is assumed that there is constant recruitment.

Equation (4) is among the most basic equation of fish population dynamics. From this, expressions for the annual rates can be obtained. From (4), we have $N_2 = e^{-Z}N_1$ and hence

$$S = \text{survival rate} = \frac{N_2}{N_1} = e^{-Z}$$

$$A = \text{annual death rate} = 1 - e^{-Z}$$

An advantage of instantaneous rates is that they can be added or substracted. Thus we have

$$Z = M + F$$

where M is the instantaneous rate of natural mortality and F the instantaneous rate of fishing morality. Of the total deaths, proportions of F/Z, M/Z will be due to fishing and natural mortality respectively, so that

$$\text{Annual rate of exploitation} = u = \frac{F}{Z}(1 - e^{-Z})$$

$$\text{and rate of natural deaths} = \frac{M}{Z}(1 - e^{-Z})$$

There are several methods of estimating Z :

1. $Z = \log_e \dfrac{N\ (n + 1)}{N\ (n + 2)}$

where N(n + 1) is the number (or percentage) of fishes of relative age n+1 and N (n + 2) the number (or percentage) of fishes of relative age n + 2

2. Z can also be estimated from the mean length in the catch by means of the equation :

$$Z = \frac{K(L_{\alpha} - \bar{L})}{(\bar{L} - L_c)} \quad \text{(Gulland, 1982)}$$

where L and K refer to equation (1), $\bar{L}$ is the mean length in the catch of all fish L_c (Beverton & Halt, 1957) and L_c is the mean length at first capture.

3. Catch Curve : From equation (4), we have

$$\log_e N_t = \log_e N_o - Zt. \quad \text{......................... (5)}$$

As indicated by Ricker (1975) the right limb in the graph obtained from (5) may be considered for estimation of Z.

4. Z can be estimated by comparing the abundance of the same year classes over successive fishing seasons. But as availability changes as well as changes of fishing intensity may affect such comparisons, the following slightly modified formula may be used for the estimation of Z :

$$Z = -\log_e \frac{(N_0 + N_1 + N_2)\,x}{(N_1 + N_2 + N_3)\,x+1}$$

where N_i = the relative abundance of the ith year-class and the suffix x and x+1 denote the two consecutive fishing seasons for which comparisons are to be made.

Stock Assessment :

For a given fishery resource there is, however a largest average catch or yield that can be continuously taken from a stock under existing environmental conditions so that the stock remains unaffected. The ultimate objective of management programme is to assess this max. yield or what is termed the max. sustainable yield (MSY). In general there are three models to assess exploited fish stocks.

The first is based on Beverton and Holt (1957) yield per recruit model. Since this assumes the knowledge of the estimate of vital parameters such as Z and F, this model comes under micro-analytical model. The model takes into account recruitment, mortality, age, growth and other factors affecting a stock. The model is based on two major assumptions namely the stock is in a steady (or equalibrium) state. In other words, recruitment, growth and mortality are constant. Secondly, the yield is directly related to the recruitment. The yield-per-recruit is estimated from the equation :

$$Y/R = F \exp\left(-M(t_c - t_r)\right) W_{\alpha} \sum_{0}^{3} Un \exp[-nK(t_c - t_o)].\{Z + nk\}$$

Where M and F are the instananeous rates of natural and fishing mortalities respectively Z, the total mortality (F + M), W_α the asymtotic weight, t_c, the mean age at first capture, t_r the mean age of arrival on the fishing ground and k, the growth parameter. In the model it may be noted that stock assessment becomes species-specific or it is applicable to the stocks having more or less the same, Z,F,M and W_α.

The second model is based on catch and effort only (Schaeffer 1953); hence called macro-analytical model. The following approximate method followed by Banerjee (1973), Pauly (1983) may be used for the aeeseement of maximum yield from the currently exploited stocks. If fishing affects the stock, then the following relation is expected to hold good : $Y/f = a - bf$, where Y/f = catch per unit effort, F = fishing intensity, and a and b are constants.

The corresponding yield equation is given by

$$Y = af - bf^2$$

This is somewhat simplied form to Schaeffer's (1953) approach. Differentiating the yield equation and putting

$$\frac{dy}{df} = 0$$

we get an estimate of maximum sustainable yield $y_{max} = \frac{a^2}{4b}$ corresponding to the fishing intensity f = a/2b. This model may be used for groups of fishes exploited by same type of gear. In case of more than one type of gears if there is no problem of estimation of effective effort, then in this case also this model can be used. Hence this model is gear or effort specific.

In tropics multispecies exploited by multigears is ubiquitous. Estimation of effective effort may not be that easy. In that case a third model, called relative response model (Alagaraja, 1984) may be useful. The model depends on successive catches to predict the maximum catch that the fishery can sustain. There are three assumptions for success of this model. These are (1) Stocks existing in a particular area are exploited by various types of gear that are not species specific. This implies that the effect of fishing a mixture of stocks by these gears is proportional to the relative abundance of stocks in the mixture. (2) The fishing is increased over a period of time till the optimum level is achieved (3) When the effort is increased the catches also increase till a maximum lavel is reached, but the rate of increase increases first then decreases and finally reaches to nil. In the progressive fisheries where multispecies are exploited by multigears and where evaluation of effective effort poses problems particularly in tropical fisheries, this model is useful. The model is

$$C_t - C_{t-1} = f\ (C_t - 1)$$

A simple version of the above is a linear relationship between the successive catches, namely

$$C_{t+1} = a + bC_t \text{ .... } (6)$$

In the progressive fishery the level of maximum catch can be predicted and suitable management measures could be suggested in advance to get sustainable yield from the fishery. (6) is the same form of the well known equation in von Bertalanffy's growth model.

$$\text{Hence, } C_{t+1} = C_{max} (1 - e^{-k}) + C_t e^{-k}$$
$$\text{and } C_{max} = a / (1 - b)$$

Various other models have been developed by different scientists. They differ from one another depending upon the assumptions made regarding the parameters.

Continuous survey of resources is very useful for efficient management of a fishery resource. Collection of basic data - catch, fishing effort, size and age structure of the catches extended over a long period - is necessary. After the necessary aforesaid data have been collected they have to be processed and analysed to furnish information on the current status of the resources. In practice, if the analysis show that the predicted outcome agrees with the observed outcome the model or the hypothesis stands, otherwise the model is no longer valid and has to be revised. A continuing resources survey is thus quality control in industrial production. A quality control chart permits a close watch on the processing behaviour of an industrial production and warns the industry when the processing is out of control. Likewise a continous resources survey over several attributes year after year helps in keeping a careful watch regarding the effect of fishing on a fishable stock.

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CERTAIN ISSUES IN ECONOMICS OF PRODUCTION AND MARKETING OF INLAND FISH

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With the increase in population and income, demand for fish and fish products has been increasing while at the same time population growth causes some adverse effects on ecological conditions which, in turn,have negative effects on fish production, both inland and marine. Together these factors create demand and supply imbalances which are generally reflected in ever firming fish prices. Therefore,issues relating to allocative and marketing efficiency arise necessitating an indepth analysis.

Production and resources.

Agricultural production depends upon the natural growth and reproduction of plants and animals, but farmers take control of these processes and stimulate them to yield food and other commodities for human consumption. For this activity of production farmers need a supply of productive resources such as land, seed, breeding stock, human skill and effort, tools and machines. These productive resources, also known as factors of production, are usually grouped into four main categories : (1) natural resources, (2) labour,(3) capital and management, (4) management.

The pricing of these factors of production in an economy results in various theories of rent, wages, interest and profits. Further, we may distinguish factor inputs between those resources which provide input flow - a flow of services for a single production period only i.e. the resource is completely eaten up within the production period and those resources whch provide an input (service) flow over several periods or years. The former are called current or monoperiod resources - for example feed; the latter are denoted as durable or polyperiod resources - for example capital goods or machinery or farm building. It is the durable or polyperiod nature of resources that gives birth to important concepts of fixed costs, depreciation and variable costs.

Production function - Bio-economic relationship.

Aquaculture : Output from an aquaculture production system is a function of variable and fixed inputs applied in production process. By examining progressively complex representation of this relationship, it is possible to establish the link

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between (or differences) biological and economic considerations of aquacultural producers. The relationship between input and output is commonly referred to as production function, and most of the text books on production economics are replete with methods of determining this physical input-output relationship and thereafter adding an economic component, and interpreting producer behaviour based on the results.

Let us begin with the simple unconstrained case (no capital constraint) of one output and a single variable input. This can be illustrated in a two dimensional diagram (Fig.1) where output (e.g.,fish) is dependent on the quantity of input X_1 (e.g. feed) used. All other inputs are have been held constant.

Additional quantities of feed are applied, total physical product (TPP) as shown in production response curve first increases at an increasing rate, then increases at decreasing rate (diminishing returns) and finally with excessive feeding, actually declines. This single variable input case can also be expressed mathematically as $Y=(X_1)$ with X_2 .... Xn constant where Y = output, X_1 = variable input; and X_2----- Xn are fixed inputs. When all inputs are varied proportionately then returns to scale are obtained.

Decision making environment in capture fisheries-risk and uncertainty

Management : As compared to site-based aqua-enterprizes greater uncertainty surrounds the production function of the fishing unit. Unlike his counterparts in culture fisheries action of an individual fisherman or group of fishermen may have more than one outcomes. Some risks are foreseable and they may qualify for insurance coverage but variartions in catch due to a number of uncontrollable variable and meterological factors may intercept the task of establishing meaningful physical relationship between input and output. This is the reason that most of the studies in economics of fishing boats in our country have exclusively relied on cost-return analysis showing marginal returns grearter than marginal costs. Relevant parameters in riverine environment such as patterns of breeding, recruitment and growth are beyond the purview of fishermen and this factor is largely responsible for imprecision in input - output relationship. Therefore, there is a need to dilute efficiency goals in capture fishery management. James A. Crutchfield (1970) has aptly remarked "Conventional procedures for estimating potential net economic yield assume that all factors of production excluded from the fishery, or forced to leave it, are employable elsewhere in the economy. Unfortunately, however the economic, social and political isolation of fisherman makes them particularly immobile and the opportunity cost (i.e. income foregone) of employing them in the fishery may approach zero. Consequently, political expediency and dictates of common humanity frequently require that employment in a fishery be larger than efficiency considerations alone would dictate......it may even be that efficiency criteria are satisfied if excessive labour inputs to fishery are less costly than alternative ways of providing minimum acceptable living standards".

Marketing subsystems

Four major approaches are widely known (1) functional approach, (2) institutional approach (3) organisational approach and (4) price efficiency approach. The functional approach examines the important marketing functions of exchange (buying and selling), physical handling, storage, transportation and processing) and facilitation standardisation,financing, risk bearing and market intelligence. The institutional approach studies various agencies and intermediaries that perform the market process. Both of these approaches are essentially descriptive.The organisational approach attempts to link the structure of the market (concentration ratio, barriers to entry, product differentiation)to the conduct of intermediaries (price determination and competition) and performance of the subsystem (profit margins, technical efficiency,progressiveness). Finally, the price efficiency approach examines the role of price mechanism and its allocative functions in terms of space, time and form.

Market demand

Market potential can be assessed from the market demand, its size and growth. Factors determining market demand are population,income, prices expenditure elasticity and dietary habits or consumer preferences. The price of close substitutes such as red meats, eggs, etc. do affect the prices of fish and products. Market demand can be estimated in five ways; the comparison between demand in different areas, market trends, statistical analysis, consumer surveys, and direct market experiments. All these modes of estimation are beset with serious limitations.

Market infrastructure and price support

This is an area calling for government support in terms of investment as it is beyond the ability of small scale fish producers. Public investment should create a huge network of externalities which could be appropriated by fishery sector. Producers are only price takers and single producer cannot have a perceptible effect on aggregate supplies. His cost of production is irrelevant in the short-run as price is determined by aggregate supply and demand. In the event of saging market or glut buying support becomes necessary. Wherever feasible and necessary, market regulation is also essential so as to check unfair trade practices.

Further, appropriate market intervention can be made by fishery cooperatives/ corporations but their performance has been listless so far.

PROJECT APPPRAISAL OF AQUATIC PRODUCTION SYSTEMS

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Introduction

Generally, any country has various types of resources such as land, water, capital and labour. Development projects including fisheries or aquaculture often provide goods and services that satisfy human needs. Economics being the science of alternation, aims at striking a balance between unlimited ends and scarce resources. In furtherence of this project analysis is made so as to assess the contribution of a specific project.

A project may be defined as an investment activity in which financial resources are allocated to create capital assets that produce benefits over an extended period of time.

A project cycle is a sequence that a project is planned and carried out. It may be divided into identification, preparation and analysis, appraisal, implementation and evaluation.

Objectives of project appraisal

"We undertake economic analysis of agricultural projects to compare costs with benefits and determine which among alternative projects have an acceptable return" (Gittinger, 1982).

It is significant to note that the quotation did not say `the best return' but `acceptable.' The best applies only one, accceptable leaves a room for more than one. A decision on `the best` comes after decision on acceptable and requires other decisions on the selection and relative value given to different criteria (i.e. project objective). We undertake project appraisal to assist countries, organisations and individuals to make investment (money, materials, time) decisions prior to, during and even after the project is implemented/ completed.

Project objectives

Each participant in a project has many objectives. A farmer may wish to avoid risk. For private business firms or government corporation, a major objective is to maximise net income, yet both have significant objective other than simply making the highest profit - A society as a whole will have as a major objective increased

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national income, but it clearly will have many significant objectives. In project analysis, the objectives of the analysis provide the standard against which costs and benefits are defined.

Fishery development projects

The selection of specific aquaculture or reservoir fisheries development project is generally a product of past performance during plan periods. In fact, reviewing the performance of fishery sector resources and available infrastructural base need to be judged so as to plan realistically new projects. Subsequently, different projects are defined as potential alternatives to meet public and/or private development objectives. Individual projects are to be harmonised with national objective of increased growth with justice.

Project appraisal techniques - Investment criteria

Within the broad framework of national plans project analysis tries to identify and value the costs and benefits that will arise with the proposed project and then compare them with the situation as it would be without project.The difference is the incremental net benefit arising from the project investment .This approach is not the same as comparing the situation "before" and "after" the project. The before-and-after comparion fails to account for changes in production that would occur without project and thus leads to an erroneous statement of the benefit attributable to the project investment.

Three different criteria (measures of project worth) for estimating a project's efficacy (effective ability) are commonly applied. Each depends on the principle of discounting. These criteria are : Net present value (N.P.V.), Internal rate of return (IRR) and benefit-cost ratio.

a) ***Net Present Value (NPV)***

This is most straight forward discounted cash flow measure of project worth.

It is the discounted benefits minus the discounted costs of the project. It is computed by finding the difference between the present vaule of the benefit stream less the present value of the cost stream.

The mathematical formula for the net present value (N.P.V.)is as follows :

$$NPV = \sum_{t=1}^{n} \frac{Bt - Ct}{(1+i)\, t}$$

Where Bt = benefit in year t;
Ct = Costs in year t; t = 1,2,........n;
n = number of years; and
i = interest (discount rate).

An appropriate discount rate has to be used to calculate the net present value. For financial analysis, the discount or cut-off rate is usually the marginal cost of money to the firm. This is the rate at which the enterprise is able to borrow money. The decision criterion for the net present value measure of project worth is to accept all independent projects with a zero or greater net present value when discounted at the opportunity cost of the capital.

II) *Internal Rate of Return (IRR)*

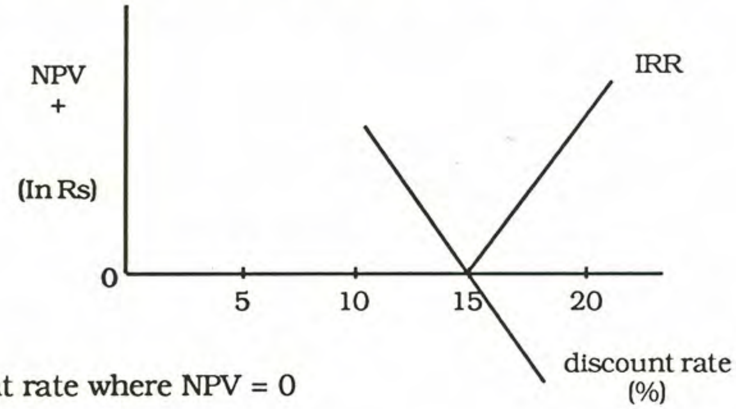
The discount rate that will equate the present value of the benefit stream to the present value of the cost stream is known as internal rate of return. It is the discount rate that makes the net present value of the project to zero. It is the maximum interest rate that a project could pay for the resources used if the project is to recover its investment and operating cost.

IRR can be presented in a mathematical statement

$$\sum_{t=1}^{n} \frac{Bt - Ct}{(1+i)\ t} = 0$$

Where Bt = benefit in year t; Ct = Cost in year t; t = 1,2.....n; n = number of years; and i = interest (discount rate)

The relationship between NPV and IRR is illustrated in the graph below :



IRR is the discount rate where NPV = 0

The decision criterion used for selection of projects using IRR is to accept all independent projects having IRR equal to or greater than the opportunity cost of capital.

III) *Benefit Cost -Ratio :*

This is the ratio of the discounted benefits to the discounted costs.

$$\text{Benefit Cost Ratio} = \frac{\sum_{t=1}^{n} \frac{Bt}{(1+i)^t}}{\sum_{t=1}^{n} \frac{Ct}{(1+i)^t}}$$

Choices of projects with capital constraint

Consider three alternative projects A1, A2 and A3 –

with discounted costs and benefits as shown below :

Alternative Projects	Costs (C)	Discounted benefits (B)	NPV (B–C)	B/C
A1	100	200	100	2.0
A2	50	110	60	2.2
A3	50	120	70	2.4

NPV ranks A1 first

Benefit cost ratio ranks A3 first with capital constraint of rupees 100 and using NPV as criterion, will do project A1 the net benefit = Rs. 100. With capital constraint of Rs 100 and using benefit cost ratio will do A3 first and then A2, we get Rs 130 net benefit. Therefore, when there is a capital constraint, the benefit cost ratio is the more appropriate criterion. In case of mutually exclusive projects,a project with higher IRR often finds favour.

Financial Vs economic analysis

Project costs and benefits expressed in market prices may not reflect the real value to the society. Market prices do not necessarily indicate relative abundance or scarcity of various factor inputs. Economic costs as distinct from financial costs represents the value of goods and services in alternative uses to the society. Generally this excercise is done with the help of shadow prices or accounting prices. Higher valuation may be added to the scarce resources such as foreign exchange or lower valuation to labour in a developing economy. In financial analysis taxes are usually treated as cost and subsidies as a return though it is a cost born by the community. These project appraisal techniques are in the nature of broad indicators.