Training Manual

Fishery Managemnt in M.P. Reservoirs including Enclosure Culture

Central Inland Fisheries Research Institute

(Indian Council of Agricultural Research)

Barrackpore, Kolkata-700120, West Bengal

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Edited by

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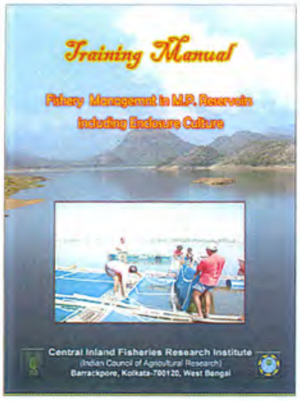

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Potentiality of enclosed fish farming in inland waters

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Introduction:

Inland open water fishery resources of India are recognized for variety as well as their rich production potential. It comprises 45,000 km of rivers; 1,26,334 km of canals; 2.7 million ha of estuaries; 0.24 million ha of floodplain wetlands; 0.19 million ha of lagoons and 3.15 million ha of reservoirs. The fish production obtained from all these resources is generally much less than their potential due to low priority given, till recent past, to inland open water fishery development in the country. Extensive floodplain wetlands in the form of ox-bow lakes (mauns, churs, jheels, beels-as they are locally called), especially in the states of Assam, West Bengal, Bihar and Eastern Uttar Pradesh , occupy important position in the inland fisheries of India because of their magnitude and their production potential. However the average fish production potential from Floodplain wetlands is not above 200 kg/ha/yr. This resource also provides ideal condition for pen culture operations, the technology for which has been developed, field tested and demonstrated by CIFRI. Reservoirs form the most important inland openwater fisheries resources in the country because of their sheer present day magnitude of 3.15 million ha which is expected to reach 6.0 million ha in next few decades. A production of 50-100kg/ha/yr can easily be obtained from large (>5000ha) and medium (>1000 to <5000 ha) reservoirs by adoption of the above said technology .The small reservoirs (<1000ha), having total hectarage of 1.48 million in our country, have the potential to yield 200 to 300 kg/ha/yr. With increasing demand on land for residential, agriculture, industries, etc. due to ever growing population, it is difficult to get land for construction of ponds for raising fish seed and fish in future, warranting exploration of other means for fish production. In this respect, rearing facilities such as cages and pens can provide low-cost alternatives to conventional land –based nurseries, since they do not involve land. Raising of fish seed and food fish in cages and pens is a specialised technique, which is gaining importance for exploitation of existing water bodies, especially reservoirs.

Suitable species for culture in cages and pens:

The desirable characteristics of the candidates for cage and pen culture are their capacity to grow fast, tolerance to withstand overcrowding, fast acceptance of supplemental feeds, high fish feed conversion ability , good quality flesh, resistance to diseases, high survival etc. Carps, catfish, snakehead and rainbow trouts have provided to be suitable candidates for cage culture in cages installed in fresh water bodies. Tilapias, milkfish, mullets and prawns are also cultured in cages and pens in fresh and brackish waters. The Indians and Chinese carps (*C. Catla,L. rohita,H. molotrix,C. idella and C. carpio)* satisfy the above desirable characteristics to a greater extent. The choice of species depends on the environmental conditions, market demand and availability of seeds.

Cage fish culture:

Cages are used for breeding, hatching of fertilized eggs, rearing of seed and growing of fish for table purpose.

Fish breeding in cages

Tilapia seed is produced in Philippines in fixed cages (3 x 3 x 1 m) fabricated out of fine mesh nylon netting. The cages are stocked with brood fish at densities of 4- 7 per sq. m. In the sex ratio, females dominate over males. After breeding, fry are collected once every fortnight and transferred to nursery cages for further growth (IDRC/SEAFDEC, 1979). In India, breeding hapas (2m x 1m x 1m to 3m x 2m x 2m) made up of velon screen material are used for induced breeding of Indian major carps in the conventional methods. Here, hypophysed brood fish are held in the breeding hapas (cages) fixed in rivers or ponds with running water facilities for breeding purpose. The injected fish breeds in this type of cages in about 6-8 hours after second injection. Thus, cages are used for breeding purpose. Further, the fertilized eggs are distributed to a battery of inner and outer hapas for hatching purpose. These hapas are also cages without top cover. Similarly, cages are used for breeding of common carp providing *Hydrilla* as substratum for attachment of adhesive eggs and subsequent hatching of embryos.

Spawn rearing in cages

Spawn and early fry of Indian major carps and exotic carps are reared in cages fabricated out of HDPE woven fabric with 40 mesh/inch during April-May to July-August and common carp and giant freshwater prawn during rest of the year. The biomass of the spawn and fry being less, high density can be resorted to in this process of rearing with high protein feed. In Japan, a stocking density of 15000 to 60000/ m3 is followed in case of grass and silver carps and they are fed with a mixture of egg yolk, soya bean cake, soya milk and soya flour. High survival of fish seed is obtained. In India, Natarajan, *et.al.* (1979) conducted carp *(C. catla, L. rohita, L. bata* and *c. mrigala)* spawn rearing experiments in floating nurseries (cages) fabricated out of 1/40" mesh nylon webbing suspended in lentic waters. Two such nurseries (3.5 sq.m. area each) were stocked @ 8500 hatchlings per sq.m. In addition to the natural food organisms available in the cages, extraneous feeding with a mixture of soya bean powder, groundnut oil cake and rice polish in the ratio of 1: 1: 1, having 32.9% protein was broadcast in the cages in powder form at 30% of the body weight. The feed was provided 4 times a day. After 15 days, the cages were changed. The hatchlings (7.8 mm) of one cage attained an average of 45.8 mm within a period of 28 days. Similarly, the hatchlings (6.5 mm) stocked in the second cage attained an average length of 30.2 mm in 21 days. The survival was estimated as 25%. In this experiment, the stocking density was much higher than that followed in ponds. Still, the growth rate of hatchlings was comparable.

Fry rearing in cages

Cages with higher mesh size are used for fry rearing and a stocking density ranging from 80 to 400/m^3 is followed in countries like Combodia, Vietnam and Indonesia depending upon the size of seed. In India, cages with 1-3 mm mesh size are used for rearing of fry . The stocking rate ranges from 700 to 2500 fry/sq.m. A mixture of soyabean powder, groundnut cake and rice polish in equal proportion is given as feed. The fry attain a size of 103.6 mm to 121.8 mm within a rearing period of 90 days. The stocking density of 300 to 700 fry/m2 has been followed in cage rearing at Getalsud reservoir . The seed were fed with powered mustard cake, groundnut cake and rice bran in the ratio of 3: 1: 1 at 30% of body weight in the beginning, but reduced gradually during rest of the rearing period. With progress in growth, the density is reduced in the subsequent stages of rearing. Thus, it is possible to develop floating seed production units. Kohli, (2003) conducted a series of cage fish culture experiments in three reservoirs viz., Walwan reservoir, Lonavala, Powai lake, Mumbai and Halali reservoir, Bhopal using HDPE cages of 3m x 3m x 3m with mesh size of 4-15 mm. The cages were floated using 200 l barrels and frame structures. Two meter water depth was maintained in the cages. *Tor putitora, T. khudree,* C. *catla, L. rohita* and C. *carpio* were the fish reared for raising fingerlings for stocking and fish for table purpose. Supplemental feed @ 2 -5% of biomass was provided. While mahseer fry took about five months for attaining more than 100 mm in length, catla, rohu and common carp attained this size in about 1.5 to 2 months period.

Raising of marketable fish

The fingerlings (> 100 mm) may be cultured in cages of knotted nylon nets of more than 10 mm mesh size for raising fish for table purpose. The stocking density depends on the carrying capacity of water, water exchange, species of fish and the quantity and quality of supplemental feed input. With high-tech system at saturated stocking and feeding on enriched formulated feeds, the production recorded in common carp is 35, 37.5 and 25 *kg/cu.m./month* in Japan, Germany and Netherlands. In culture of channel catfish in U.S.A., productions ranging from 20 to 35 kg/m^3/month are obtained. In Africa, yields of 7 *kg/m^3* /month in tilapia (0. *niloticus)* and 15 kg/m^3/month in trout (S. *gairdneri)* are obtained. Even in semi-intensive culture systems with low-cost adopted in developing countries in Asia, productions ranging from 1 to 4 kg/m^3/month of common carp from Indonesia and 9.4 *kg/m^2/month* of snakeheads from Vietnam have been reported. Natarajan installed two iron mesh (1/5") cages and stocked with fingerlings @ 300 per cage. The feed was provided in the form of balls kept in baskets hung inside the cages. The computed production worked out to 185 t/ha for cage 1 and 173 t/ha for cage 2. Culture of air-breathing fishes such as *Anabas, Heteropneustes, Clarias, Channa striatus* and C. *punctatus* in cages yielded a production of 0.3, 0.7, 1.0, 1.7, 1.5 and 1.3 *kg/m^3/month* (Dehadrai *et al.,* 1974; Murugesan and Kumariah, 1978). At higher stocking densities of 30-38 fingerlings per m^3 , Govind *et. al.* (1983) obtained a gross production of 1.52 to 2.2 kg */m^3/month* in common carp in a grow out period of six months when the fish attained a size of 325 to 350 g. The fish were fed with a mixture of powdered silk worm pupae (defatted), ground nut cake and rice bran in the ratio of 3 :3: 1 @ 10 to 20 % body weight of the stock.

Tilapia culture in cages at a stocking density of 100 to 200/m^3, with supplemental feed with a mixture of rice bran, ground nut cake and cattle feed pellets (1: 1: 1 ratio) at 3 to 5 % body weight of the stock resulted in a net production of 0.92 to 1.6 kg/m^3/month (Kumariah *et. al.* 1986). Catla stocked at a density of 13 / m^2 and fed with rice bran and ground nut cake (I: I) @ 5-10 % body weight attained an average size of 772 g in six months yielding a production of 1.41 kg/m^2/month. At higher density of 49 fingerlings of catla / m^2, Sukumaran *et. al.* (1986) obtained a production of 2.7 kg/m^2 /month (1.8 kg/m3/month). Here, the fish attained an average weight of 544 g in eight months with the conventional feed of ground nut cake and rice bran mixture (1 : 1 ratio) at 5 to 20% body weight of the stock. Kumariah *et al.* (1991) obtained a net production of 0.7 kg/m^3/month by stocking silver carp at 15 fish per m^3 and feeding them with a mixture of rice bran, ground nut cake and deoiled silk worm pupae (3.2:1 ratio) at 3 to 5% of the biomass. The fish attained an average of 472 g in 257 days from an initial weight of 61 g.

Pen culture

Fish culture in pens has a short history compared to cage culture. It has been experimented in Japan during early *1920s.* Pens are used for various purposes such as holding the fish temporarily for a short period before shifting to other places, raising fish for table purpose, short term rearing of fin-fish and shell-fishh, etc. in countries such as Philippines, Indonesia, Thailand, Malaysia, China and U.S.A. In India, pen culture has been experimented in an oxbow lake in Bihar (Banerjee and Pandey, 1978), Beels in Assam (Yadava *et al.,* 1983) and swampy tank at Bhavanisagar in Tamil Nadu (Abraham, 1980) for raising carp seed. Similarly, carp spawn produced in excess than the capacity of fish farm at Tungabhadra dam is cultured in pens erected in protected bay area of the reservoir since 1982 (Swaminathan and Singit, 1982). Pens assume importance as the material required for fabrication is cheaper, readily available in the market and even unskilled personnel can erect them without involving engineering skill. The pen structure can also be relocated at other suitable sites. The material may last for 3 to 4 years for raising several crops. Thus, pen culture can serve as one of the cheaper alternatives to costly land-based rearing space. Fish pen designing and construction is easy and simple when compared to that of cages. They are of various shapes (circular, semi-circular, square and rectangular). Rectangular shape will be convenient for harvesting, using drag net. The size of the pen can be from 10 m^2 to 5 ha area. However, smaller units can be easily managed. The height of the pen wall depends on the water level during the culture period. It will be convenient to have a depth ranging from 1 to 3 m.

Seed production in pens

Production of seed in pens is easier than in cages, as the pens are installed in the marginal area of the reservoir where of freshwater exist. The mesh size can be as large as possible for better water circulation, ensuring that brood fish do not escape. A water depth of 60 to 100 cm can be maintained in the pens meant for spawning. Brood fish consisting of gravid males and females are introduced into the pen for spawning and the eggs are collected for hatching elsewhere. Spawning of tilapia in pens is a regular practice in lakes in Philippines. By providing necessary materials for nest building or attachment of eggs, it is possible to breed fishes like common carp, gourami, catfishes, etc.

Raring of spawn

Split bamboo strips are woven into a mat with nylon twines and it is provided with fine meshed velon screen material and the pen is erected as described above. Spawn of desired fish is stocked in the pens and reared for raising fry and fingerlings. Unlike cage culture, all the management measures, which are followed in land-based nurseries, must be followed in pen culture also. The pens must be fertilized with organic or inorganic manure. Unwanted insects and enemies of fish spawn and fry must be eliminated. Supplementary feeding with balanced diet must be provided in feeding trays. Assessment of growth, survival and health conditions must be monitored regularly. Harvesting is done using seine net.

Raring of fry to fingerlings

The mesh size of the screen material for rearing fry to fingerlings may be slightly bigger (2 to 4 mm).

Raising of food fish in Pens: Poly-culture can be followed in pens to exploit all feeding niches therein. Species selection, composition and stocking rates will depend largely on the natural food supply, supplemental feeding, water depth and duration of water availability in the site. 5-10 fingerlings per sq. m may be followed for carps with supplemental feeding.

In Bihar a pen of 120 m^2 was stocked with catla, rohu and mrigal in the ratio of 7:12:16 per m^2. The fish were fed with a mixture of rice bran and mustard cake (2: 1 ratio) at 5-10 % body weight. They attained an average weight of 1100, 800 and 750 g from an initial weight of 166, 75 and 120 g respectively and yielded a computed production of 25t/ha/6 months .

Constraints in Pen and cage culture:

Cage and pen culture have their own limitations. Strong wind, wave action, water current, etc. may damage/dislocate the cages and pens. Clogging or fouling of cage and pen material may arrest the circulation of water, creating problems like depletion of D.O., accumulation of metabolites and left over feed. The cage and the fish therein can be easily poached. Failure of monsoon may affect pen culture activities especially when the structure is erected on the exposed marginal area. Harvesting of fingerlings and fish from the pen pose problem especially in circular, semi-circular and unshaped units. Sudden increase in water level may submerge the pen unit leading to escape of the stock.

The cage and pen culture experiment conducted in reservoirs in India and elsewhere has given encouraging results with high growth and survival. If the technologies are perfected in terms of material, fabrication, stocking rate, feed and feeding schedule, harvesting methods, they may serve as alternative means to land-based ponds for raising advanced fingerlings for stocking and to raise food fish for table purpose. Thus, these intensive farming system in the existing reservoirs may help to enhance fish production several folds. Further, these ventures can generate employment opportunities for rural people and also encourage ancillary industries of cage and pen fabrication.

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Fish production enhancement in reservoir and wetland through enclosure technique

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India being the meeting ground for three bio-geographic realms (Indo-Malayan, Eurasian Afro-tropical) is very reach in natural resources, including the wetlands, which support widevarieties of biodiversity. Wetlands in India are distributed widely, from arid cold desert Ladakh to warm arid zone of Rajasthan-Gujarat and from wet Manipur to Monsoonic central India, and wet humid zone of Southern peninsula. The country has an estimated wetland area of> 1.5 million ha (Sinha & Jha, 2008). Besides this, it also has 6740 km^2 of coastal wetlands of which nearly 80% is confined to Andaman & Nicobar Islands. Throughout the globe wetlands are perceived as highly precious ecosystems due to their multiple utility functions; have been the repositories of aquatic biodiversity. An estimated 40% of aquatic vertebrate fauna and more than twice the invertebrates and plants are supported by wetlands. These water bodies are also the excellent source of fodder & fuel, medicinal plants, tourism and navigation. Most of the functions associated with wetlands have significant economic and biological values, as such their wise use and conservation would be essential. In addition to these they are the lucrative source of fish and fisheries with high production potential (1000-2000 kg/ha), but pass through a critical phase of ecological succession and are in advanced stage of eutrophication. In recent years the yield from these systems has declined with an average fish productivity of 165 kg/ha/yr.

The wetlands in general and the floodplain wetlands in particular are shallow ecosystems, offering an ideal habitat for pursuing culture based fisheries or fisheries enhancement. It is rather easy to bring these water bodies under enhancement regime, wherein pen culture could be a viable economic activity, both for rasing stocking materials and table fish, especially in weed choked aquatic regime, which has been the hallmark of most of the wetlands in India, irrespective of their types and origin.

Wetland resources in India

The wetlands in India can be classified into three categories, based on the climate a geographical locations, such as (1) Himalayan wetlands, (2) Indo-Gangetic wetlands and (3) Coastal wetlands. In Himalayas many high altitude coldwater freshwater or saline wetlands are available such as Pangong, TsoMorari, Chantau, Chassul and Honlay (Ladakh, 4000 m above mean sea level). Most of these wetlands experience extreme environmental conditions, from cold desert condition in winter to high solar radiation during summer. In Kashmir valley many import wetlands are available like Dal, Anchar, Wulur, Haigam, Malgam and Kranchu, which posse unique biodiversity. In Himachal Pradesh (400-5000 m altitude) many important are available like Nako, Candar Natan, Chandertal, Surajtal, Rawalsar, Kajihar etc. In central and eastern Himalayas also wetlands spread over to many states like Sikkim, Assam, Arunachal Pradesh Nagaland and Manipur. The Loktak lake of Manipur with an area of 289 km2 is one of the largest wetlands of the region. Most of the high altitude Himalayan wetlands may not be attractive from fisheries angle barring Loktak lake of Manipur, but they are the unique reserves of precious biodiversity, as such need conservation. The floodplain lakes distributed under Ganga and Brahamputra river basins have been the excellent sources of fisheries, addressing livelihood concerns of millions of traditional resource poor fishers. These wetlands are locally known as beel (Assam & West Bengal), tal (Bihar & Uttar Pradesh), Pat (Manipur), Maun & Chaur (Bihar). The floodplain wetlands in Ganga and Brahamputra basin have an estimated area of > 2.32 lakh ha (Table I) of natural and perennial lakes. In addition to this, sizeable area is also available as seasonal wetlands, which could be handy for culture based fisheries development, including the pen culture, especially for raising quality stocking materials of desired size.

Table 1: Area of wetlands in the country

Total area under wetlands India	Area of flood plai n wetlands	Area of floodplain wetlands in different states (ha)
> 1.5 million ha	2.33 lakh ha	Assam = 1,00,000 Bihar = 40,000 West Bengal = 42,000 Uttar Pradesh = 30,000 NE States = 19,213

Source Vass, 1997, *Sinha & Jha, 1997*

General ecology of floodplain wetlands

Wetlands are productive ecosystems with greater efficiency of converting solar energy into organic carbon largely due to nutrient rich and substantial presence of autotrophs. The wetlands are, however, highly sensitive and fragile ecosystems representing the transition between aquatic and terrestrial characteristics. Data generated at CIFRI indicates that the bulk of the primary production is mainly through macrophytes (1000-5000 Cltn2/day) as compared to through phytoplankton chain (200-1500C/m2/day). Evidently, there exists a serious aberration from normal productive lakes as the energy fixed through macrophytic chain seldom get transferred to fish biomass in absence of effective fish grazers. The bulk of the energy fixed at the primary level, therefore, goes as waste without getting corresponding fish biomass. This has been a typical example of weed choked aquatic systems like floodplain wetlands, where the proliferation of phytoplankton is hampered invariably due to poor availability of major nutrients in the ambient water (N03-Tr-2.0; P04-Tr-0.05). The reason for such a condition could be attributed to the locking of nutrients in hydrophytic chain (from sediment to plants and back to the sediment).

The water quality of floodplain wetlands has been found conducive, by and large, for fisheries enhancement barring some isolated cases, which are either acidic in nature or receiving fair amount of external pollution load. But, wetlands throughout the globe are considered as stressed ecosystems on many counts. The fact remains that most of the lakes are in advanced stage of eutrophication as indicated from massive stands of macrophytes of all categories like floating submerged, emergent or marginal. The resultant impact is that they are being converter swamps at a very faster pace, leading to total loss of aquatic regime. Moreover, in the face of increasing encroachment for various purposes like human habitation or industrial expansion resource base is shrinking at an accelerated pace. Many prized wetlands like Dipper (As Kabartal (Bihar), Surhatal (Uttar Pradesh), Loktak (Manipur) etc. are the glaring example colossal resource loss, both due to natural ecological succession and increased human greed.

The biotic production of Indian wetlands indicates two major groups occupying the niches vengeance, such as (1) thick to very thick stands of macrophytes in the water phase (5-30 kg/m^2) and (2) dense growth of gastropods at the benthic niche. Incidentally, however, both of dominant biotic groups are not in the normal grazing chains meant for harvestable fish crop to effective fish grazers. Factually, unwanted proliferation of macrophytes remains to be the major problem in wetlands whereas the greater colonization of gastropods is the manifest, of this menace.

Reservoir resources in India

During the post-independent India, taming of rivers across the country has resulted into the creation of a large number of reservoirs with mammoth impounded waters. Presently country has > 3.1 million ha of reservoirs with nearly half the area falls under the category small reservoirs. The small reservoirs are the ideal ecosystems for fisheries enhancement culture-based fisheries development. The fact remains, however, that most of the reservoirs barring some small ones receiving effluents, are low productive waters.

Fisheries enhancement/Culture based fisheries

Fisheries enhancement or culture-based fisheries are also fish production at the interface aquaculture and capture fisheries. Evidently, these are the most extensive type of aquaculture or the most intensive way of managing a capture fishery, meaning thereby fisheries based on the recapture of farm-produced seed of fish. Reservoirs and wetlands are the major resource where fisheries enhancement tools can be applied for the production of animal protein, and can benefit the resource poor sections of the rural population, both in terms of poverty alleviationand combating the lingering problem of mal-nutrition.

Conceptually, however, one should be very clear on the definition of fisheries enhancement culture-based fisheries so as to distinguish these from other forms of aquatic resource management, where too stocking is involved.

Cage and pen culture and its history

There is some confusion concerning the terms 'cage culture' and 'pen culture' among the farmers. Both terms are often used interchangeably or in general termed as 'enclosure culture'. Both cage and pen culture are types of enclosure culture, and involve holding organisms car within an enclosed space whilst maintaining a free exchange of water. The two methods however, are distinct from one another. A cage is totally enclosed on all, or all but the top, sides by mesh or netting while in pen culture the bottom of the enclosure is formed by the lake bottom.

Current cage and pen culture methods

During the last 25 years, the practice of cage culture in inland waters has spread throughout the world to more than 35 countries in Europe, Asia, Africa and America, and more than 70 species of freshwater fish had been experimentally grown in cages. In all but a few areas, new materials such as nylon, plastic, polyethylene and steel mesh which although much more expensive have a much longer life-span and permit better water exchange, have superseded wood and bamboo. Most designs currently in use are of the floating type, and rely on a buoyant collar constructed either from locally available materials (e.g. wood, bamboo), or from steel or plastic pipe, and from which is suspended a synthetic fibre net. Styrofoam or oil drums are frequently used for supplementary flotation. Cages are usually floated in rafts, and either anchored to the lake/reservoir/river bottom, or alternatively connected to shore by a wooden walkway.
The origin of pen culture is more obscure, but believed to have begun in Asia, in the Inland Sea area of Japan in the early 1920s. It was adopted by the People's Republic of China in the early 1950s for rearing carps in freshwater lakes, and was introduced to Laguna de Bay and the San Pablo Lakes in the Philippines by the Bureau of Fisheries and Aquatic Resources (BFAR) and the Laguna Lake Development Authority (LLDA) between 1968 and 1970 in order to rear milkfish (*Chanos chanos*).

Advantage and disadvantages of cage and pen culture

Cages and pens have several advantages over other culture systems. Because of the use of a existing water body and it requires comparatively low capital outlay and a simple technology. These can also be used not only for producing high quality protein cheaply or to produce stocking materials for fisheries enhancement in wetlands and small reservoirs, but also can be practiced in eutrophication abetment through the production of phytophagus fish species. However, concern is growing about the environmental impact of these methods. Intensive culture is believed to accelerate eutrophication, and extensive cage and pen farming has had a record of high initial promise, followed by decreasing production.

Design and fabrication of cages and pens

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In order to increase productivity from open water fisheries resources of the country pen and cage culture were introduced in the country some decades ago for raising advanecd fingerlings. Induced breeding technique, though was standardized in the fifties of the previous century, country's open water resources mostly remained under stocked or stocked with improper sized small fry. Considering the cost of enormous number of advanced fingerlings required and difficulty in transporting such volume of seeds for stocking in reservoirs and wetlands the enclosure culture technique for in-situ production of stocking material would be the more appropriate. States like Assam, West Bengal and Bihar have adopted pen culture technique for raising seeds in wetlands. However, in Kerala, both pens and cages are used for fattening mud crab. Culture of pearl spot in a small scale has been practiced in peninsular state of Kerala.

In other countries like Philippines, culture of common carp, goby, tilapia and milkfish in net pens is very popular. In Japan, pen and cage culture of octopus and yellow tail are well-developed industries. Other countries in Asia and Eastern Europe are in various stages of development in these enclosure culture activities.

Undoubtedly, pen and cage systems, as used in the culture of finfishes, have attracted many developing countries. Therefore, it is a high time that a systematic packaging of the various technologies being adapted be prepared.

Design

Bamboo screen (mat)

Bamboo screen fencing is suitable in narrow and shallow waters of ox-bow lakes. The height of a pen wall depends on the maximum water level during the culture period. About 0.5 m of the pen wall should be above the maximum water level to prevent jumping out of fish. A portion of the pen wall should go into the bottom mud to keep the pen wall secured in position. Normally, the pen wall should be about 30 cm inside the bottom mud. Bamboo screen fencing is made with bamboo splits (10-15 mm width) interwoven with coconut coir (3 mm) or HDPE (high density polyethylene). Pen wall can be constructed in several pieces each piece having a frame work consisting of a few rows of horizontal struts, and two vertical struts along the two sides. Vertical bamboo bracers at intervals of 3-4 m or more should be provided depending on the bottom condition, water current, wind velocity etc.

HDPE net

Considering the durability and ease of handling HDPE nets can be utilized for constructing pen wall. For net pen wall the mesh size of netting should not be more than 10 mm. HDPE knotless webbing is best for net pen wall. If material of appropriate height is not available, sticking of two or more width of material will be required. HDPE rope of

4-5 mm and 3-4 mm thickness should be tied to the bottom and head line of the net respectively. Loops at an interval of 3-4 m in the foot rope is needed for tying with bamboo groove which is driven into the mud. This arrangement is made to ensure tucking of about 30 cm of the net into the mud. Steps for installation of the net pen is more or less similar to bamboo screen fencing.

Shape

The fishpen shape can be circular, polygonal or rectangular. The standardization work on the suitable shape of the pen module that best fits the culture of fish is being investigated. However, the circular shape is best appreciated because a circular configuration would be most suitable for any wind direction . While preparing a square shaped pen, care should taken so that its diagonal remain parallel to the prevalent/most dominant wind directions in the area. While considering the material requirement and cost if comparisons are made between a rectangle and a square, the latter has a shorter perimeter and therefore less expensive for the same structural framework and netting.

The fishpen module consists of two types of compartments: (1) the nursery compartment and (2) the growout compartment. The netting materials of the nursery compartments are of fine mesh which would prevent escape of small fry/fingerlings through the mesh. It would be a mistake if the pen culturist use wide mesh nets for the nursery units which will lead to loss of crop.The nets of the growout compartments are of wider meshes to contain the fingerlings after they have been released/shifted from the nursery compartment. However, the use of bigger mesh nets would allow easy entrance of other fish species from outside the pen which may compete for food and space.

Construction of pen

First of all, the perimeter of the fish pen is computed and the depth of water and mud is measured. Historical data of the water levels is also obtained from either the dam authority/cooperative society or from old folks residing in the vicinity of the waterbody who have first hand information on flood levels over the years.

Before assembling the nets, make sure that a working area measuring not less than 20 m by 50 m is available. It must be a relatively flat ground, and free of macrophytes, twigs, bushes and debris.

Once these are available, the enclosure dimensions are next computed.

Preparation of pen wall using split bamboo

Matured bamboos are split into small strips, 50-70 mm in thickness for knitting the screens. The screens are weaved using split bamboo strips tied by two-ply coir ropes or low/high density polyethylene twines. The distance between the two coir weavings is kept at 40-45 cm apart. To prevent movement of fish from and into the pens, a layer of commonly available polyethylene net (mesh size 1 mm) is stitched over the inner wall of the screens up to the level of the water column.

Preparation of pen wall using HDPE net

For net pen wall the mesh size of netting should not be more than 10 mm. HDPE knotless webbing is best for net pen wall. Preparation of pen wall starts with fixing of LDPE or HDPE ropes of 4-5 mm and 3-4 mm thickness to the bottom and head line of the net respectively. Loops at interval of 3-4 m in the foot rope are given for tying with bamboo groove which is driven into the mud. This arrangement is to ensure tucking of about 30 cm of the net into the mud. Steps for installation of the net pen are more or less similar to bamboo screen fencing.

Loops at an interval of 3-4 m in the foot rope are needed for tying with bamboo groove which is driven into the mud. This arrangement is made to ensure tucking of about 30 cm of the net into the mud. Steps for installation of the net pen is more or less similar to bamboo screen fencing

Depending upon resources, area and water availability, one of the following methods are adopted:

A. **Dry method**
   Generally in reservoir, this method is followed: During dry season, when water level is drastically reduced and vast area is available for pen construction
B. **Wet method**
   In case of shallow and perennial water body wet method as described below is followed.

Framework preparation and construction

Since there are many kinds of materials that can be used for pen framework, discussion will be limited to the use of bamboo as it is the most economical and readily available.

Prior to installation, the bamboo poles must be cleaned of sharp edges of the nodes to avoid damage to the net. They must also be slotted at the node diaphragm either by the use of chisel removing the diaphragm at the nodes from the outside. The size of the bamboo poles must not be less than 10 cm diameter at the trunk and 3 cm at the tip and 10–12 m long. It is not advisable to use young bamboo poles even if they meet the size specification as this will easily deteriorate in water.

The construction begins with fixing bamboo poles at the four corners of estimated pen area. The rest of the poles were pushed inside the bottom mud (up to the hard bottom layer) with an interval of 3 m for the bamboo screens. Thereafter, 1/4 longitudinal strip of a bamboo are tied to the poles horizontally below and above the water level at every 1.0 m longitudinal intervals to provide strength to the structures. The bamboo screens were placed along the long bamboo in such a way that no gaps were left at the lake bottom. Split (1/2) bamboos are tied to the outer surface of the screens.

The bamboo poles will be erected by means of an erection guide. A corner of the module shall first be located. A string shall be used to align the first set of poles. Using the erection guide, the 2nd, 3rd, 4th pole shall be driven into the mud. This must be followed by fastening the longitudinal and transverse horizontal stays to prevent misalignment. The next set of poles shall be erected by transferring the guide to the next position. This shall be done until the last pole on that side of the pen being worked on is completed. The bracings shall be installed after the third transfer of the guide to avoid overcrowding of workers in the same area.

Two teams will be employed. One team of three to four persons shall take care of the driving and the other team also of the same number shall take care of fastening the horizontal stays as well as the bracings.

When shallow mud strata are encountered, an improvised anchorage system to increase mud foothold of the bamboo pole may be used.

Design of cages

Cage design will depend upon the species to be reared, duration of culture and the nature of waterbody with consideration for depth, wave action, and water current. Cages are easy to construct. They can be of different shapes and sizes. The materials to be selected should be cheaper and readily available. Materials like nylon or polythene netting which is durable, strong and light-weight could be used for cage construction. The mesh size of the cage should be small enough to hold the smallest fish (fry) yet large enough to allow exchange of water. Water exchange which facilitate waste removal and intake of oxygenated water is very important aspect in selecting mesh size. The mesh size of commercially available nylon net in the local market which is cheaper in cost ranges from 1-1.5 mm. This net could be utilized in cage fabrication for fry to fingerling raising which require shorter period of rearing. Prolonged rearing in such net cages face the problem of bio-fouling, where jelly like animals or filamentous algae can attach to the cage wall and severely block the flow of water. For rearing fingerling to advanced fingerling or table-size fish a portion of the side or bottom of the net cage could be replaced with bigger (1-1.5 cm) mesh size net which would facilitate water exchange between inside and outside water. Total replacement with bigger mesh net could be a costly affair and hence partial replacement will reduce the burden of expenditure. A net cage of rectangular cage having dimension of 6 x 3 x 1.5 m found to be easily fabricated and managed. The net cages could be reinforced for longer lasting by using nylon ribbons in all the corners and joints. Rectangular split bamboo frame is to be tied with the cage, externally at the bottom of the cage for upright positioning inside water and half-bricks may also be tied at the corners, if needed. A cheaper quality net can be used as top cover of the cage to prevent predation from birds or snakes. Once the cage is ready, it can be hanged in water from a bamboo frame. Used metallic oil drum or PVC drum can be used for floating the whole structure of net cage and bamboo frame on the water surface in a pre-determined position.

Fabrication technique:

A battery of 8 cages covering an area totaling 144 m^2 may be considered as one unit. The description given below is pertaining to one unit of cages. The fabrication of floating net cages involves three components:

The construction of floating cage involves the following three components : –

a) ***The cage***: HDPE net (mesh size - 1mm) without knot may be used for the construction of a net cage. A suitable rectangular dimension of 6 x 3 x 1.5 m may be designed and fabricated with help of a tailor. Eight such cages having a total area of 144 m^2 can be fitted to a bamboo frame to make a battery.

b) ***The frame:*** Bamboo is the very common, locally available, cheap material for the construction of frame. To make a square shaped frame, first, a pair of bamboos (13 m long) is placed 15 cm apart laterally, subsequently, other three arms are made in the same manner. Following the same fashion, inside the square frame, a cross is made perpendicular to the arms, thus forming four equal sized squares within the main frame. Each small square is further divided equally by placing two pairs of bamboo giving rise to 8 equal sized rectangular shaped chambers for holding rectangular shaped net cages. The joints are tied together with the help of big iron peg. For monitoring the cages, 1 foot long split bamboos are fastened transversely at 1 foot interval on each arm for easy movement on the frame.

c) ***The float:*** Anything can be used as float. Considering the cost, durability and buoyancy, 220 l capacity, empty PVC drums (used solvent container) found to be suitable. A total of 12 such float, four in each arm, conveniently keeps the whole structure afloat. The floats are secured to the frame with the help of HDPE thread or galvanized iron wire.

Cage installation: The whole frame is constructed on land in the vicinity of water body. Latter the frame is gently dragged into the water and the floats are fastened. After anchoring the frame to a predetermined site the stitched net cages are tied with the frame and suspended in water. Half bricks are tied with the bottom margin of the net cages for perfect vertical suspension. A cover is placed on the top of the cage to prevent predation from bird.

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Case studies on cage culture of fishes in small reservoirs

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Reservoir fisheries development has attracted the interest of Govt. as well fishers community to augment fish production following different enhancement protocols. Accordingly, different kinds of resource enhancement and culture-based capture fishery approaches and techniques were tested and adopted in different types of such water bodies aiming at improving the income of the fishers and rural communities around the lakes. The fish yield often influenced by managerial factors coupled with innate ecological conditions of such water bodies as well as the ability of the fishers in harvesting the catches especially in weed choked reservoirs. In this context, as an enhancement tool, culture of fishes and prawns in net cages has drawn much attention in the recent past not only in Asia but also in the other parts of the world.

Cage culture began in Southeast Asia, though it is thought to be of comparatively recent origin. In India, practice of aquaculture in net-cages has not yet been widely spread neither in reservoir nor in floodplain wetlands, as it was in Philippines, China and Israel, primarily because the reservoirs are exploited through capture fishery system with the introduction of culture-based capture fisheries of late. In this regard, CIFRI has taken lead role in popularizing fish rearing in net cages in Inland waters especially in reservoirs as well as wetlands.

Advantage of cage rearing/culture of fishes over other conventional approach of aquaculture in inland water bodies is as follows:

- Technology is simple, can be adopted easily.
- Makes efficient use of water body with the greatest economy and helps in reducing the pressures on land usage.
- Utilizes proper use of the natural productivity of a water body.
- A well combination of varied types of culture within one water body indifferent to the treatments as well as harvest.
- Easy access to move and relocate, if necessary.
- Fish production can be intensified following high densities, optimum feeding resulting in accentuated growth rate with reduction in length of rearing period.
- Artificial feeding rate can be made optimal depending on growth rate.
- Predators as well as competitors could be controlled easily.
- Ease of daily routine checkup of stocks for better management with early detection of disease if any. Accordingly, need based preventive measures could be made without delay.
- Reduction in fish handling and mortalities.
- Harvesting of fish becomes easy and economical.
- Facilitation in storage and transport of live fishes.

- Involvement of low capital outlay.
- Cost effective production.

In spite of these, the limitations of cage culture mostly centered around environmental issues besides a few other disadvantages. Intensive culture applying maximum amount of feeds in cages develops eutrophication in the long run as was observed in Thailand, Malayasia with drastic reduction in dissolved oxygen, a high BOD_5 load and almost lethal concentrations of ammonia and total sulphides resulting in penultimate fish mortality. Amongst other limitations:

- Requires adequate water exchange through the cages to remove metabolites and rapid fouling of cage walls needs frequent cleaning which is less pronounced in reservoirs .
- Mostly dependence on artificial feeding if water body lacks available food niches.
- At times, probable interference from natural population can not be avoided with the entrance of small fishes in the cages and compete for food-requires vigil.
- In some occasions, natural fish population act as a potential source of disease or virulent micro-organisms with the likelihood of spreading diseases amongst the introduced species in the cages.
- Pouching or theft would be a probable menace in cage culture-if target is fry (10-15 mm) to fingerlings (80-100 mm) this could be avoided.
- Occasionally, hurricane/typhoon may create havoc with the damage/overturn of cages uplifting anchor systems- could be avoided through stronghold of anchor system which should be robust.

Case studies

Cage culture in Dahod reservoir, Raisen, Bhopal :

Dahod (23 ° N and 77 ° 29′30" E) reservoir, an irrigation impoundment in semi agro fertile land is situated in the center of India with an area of 459.94 ha at FRL. Dahod reservoir has been selected for all round development of fisheries in this reservoir and was studied from September 2006 to December 2008. Amongst limnological parameters, the water transparency was maximum in lentic zone in post monsoon 192 cm and minimum in lotic zone 40 cm, during the period of monsoon, dissolved oxygen in the reservoir ranged 3.8 to 12.0 ppm- maximum in lotic sector, whereas free carbon dioxide level was found to be varying between nil and 5.0 ppm. Due to only agricultural run-off in its catchment, reservoir is pollution free and all the parameters are in permissible limit; awaslkalinity ranged 30-88 ppm with an average 46.45 ppm, hardness ranged 28-48 ppm average 39.58 ppm, average GPP is 490 ($mgC/m^2/h$). Failure of monsoon in 2007 and 2008 was reflected in water quality parameters in this reservoir. Accordingly loading of nutrients with the run-off water was insignificant in this reservoir during second half of 2008, otherwise it was moderate. The fish production potential is 425 (kg/ha/y). The investigation indicates that the reservoir is in very good productive nature. The analysis of catch statistics in the light of limnological conditions suggests that whole scenario of fishery management needs ecosystem based exercise and proper sized fish seed stocking to augment fish production.

Availability of right fish seed at the right time is the main constraint in reservoir fishery development. To overcome this problem, attempts have been made to raise the fry to fingerling size in enclosures *in situ* and the reservoirs under investigations were stocked with the reared seed. The present fish production of Dahod is 40 kg/ha/y against targeted potential of 300 kg/ha/y. The management measures were taken with the objective to raise the production at least to 125 kg/ha in this reservoir. In Dahod, the fish yield was 30 kg/ha before CIFRI's intervention, which has been enhanced to 125 kg/ha during 2008-09.

For fishery enhancement in Dahod reservoir, in the first phase, one battery of eight cages each of 5 m x 3 m x 3 m size made up of netlon cages (1 mm mesh size) fitted on bamboo frames one above and one below floated on iron drums was installed in Dahod reservoir with the release of one lakh fish fry, 20-22 mm in size (Grass carp: common carp = 6 : 4) during mid April, 2007. Ten percent mortality occurred during transport of fish fries. The reared seed has been released in Dahod reservoir on 1st August, 2007 with the recovery of 45.82% fingerlings of Grass carp 70-96 mm/5.0-11.0 g and Common carp 85-112 mm/19-26 g.

In the second phase, two batteries of eight cages each (total sixteen cages) were installed and 36,000 nos. of IMC fry of 30-34 mm size (Rohu: Catla: Mrigal = 5: 2: 3) were released in three cages on 12 October, 2007. A recovery of 64.78% fingerlings could be achieved during mid March 2008 with fingerlings, Catla: 90-150 mm/19.24-31.58 g, Rohu: 88-160 mm/15.32-28.26 g and Mrigal: 82-130 mm/11.64-23.12 g. The other 13 cages were stocked with 1,40,000 nos. fish fries including Grass carp: 56,000 nos. and Common carp: 84,000 no. during mid December, 2007. The reared seeds have been released in Dahod on mid May, 2008 with a recovery of 80.97% fingerlings (Grass carp: 98-98 mm/3.42-9.89 g and Common carp: 72-110 mm/9.85-20.50 g.

The third phase of cage culture experiment (each cage size: 5m x 3m x 3m) was initiated on mid Aug, 2008 with the release of 2,00,000 fish fries (11-17 mm size) of IMC (Catla: Rohu : Mrigal = 10: 8.6:1.4) brought form Hoshangabad, M. P. Mortality occurred during transport including final acclimatization was Catla: 8,000 nos., Rohu: 3000 nos. and Mrigal: 1000 nos. and released in 16 cages. The reared fish seeds were fed with Rice polish (RP) : Mustard oil cake (MOC) : Agrimin (1 : 1 : 0.02) @ 4-5% body weight barring two cages where the seeds were fed with floating feed : Agrimin (1 : 0.01) at the mentioned rate. The reared fish fingerlings have been released in Dahod reservoir on mid Dec, 2008 with a recovery of 70% fingerlings size, Catla: 72-108 mm/6.06-23.50 g, Rohu: 68-124 mm/4.10-19.20 g and Mrigal: 62-110 mm/3.89-14.26 g (Table 1). The fingerlings fed with floating feed performed well. Abundance of zooplankton was significant (26.10%) inspite of low influx due to failure of monsoon in this reservoir getting reflected in to the growth of *Catla catla* in the cages.

Table 1. Cage culture for fingerlings of IMC at Dahod (10 Aug-10 Dec, 2008)

	Length (mm)			Weight (g)		
Species	Initial	Final	Increment	Initial	Final	Increment
C. catla	13.50	90.00	76.50	0.10	14.78	14.68
L. rohita	13.50	96.00	82.50	0.06	11.65	11.59
C. mrigala	14.50	86.00	71.50	0.05	9.08	9.03

Cage culture in Pahuj reservoir, Jhansi, Uttar Pradesh:

Pahuj (25^0 29′ N and 78^0 32′ E) reservoir is a balancing reservoir supplying water to the Jhansi city as well as for irrigation purpose in semi agro fertile land, situated in the center of India with an area of 518 ha at FRL and total catchment area of 310.8 Km^2 with gross capacity of 18.25 M Cum. at FRL. Pahuj reservoir has been selected for all round development of fisheries in this reservoir and was studied from September 2006 to April, 2009. All limnological parameters were assessed. Secchi depth was maximum in lentic zone in post monsoon 376 cm and minimum in lotic zone 30 cm, during the period of monsoon. Dissolved oxygen ranged 5.9 to 12.4 ppm, maximum in lotic sector, whereas the free carbon dioxide level was found to be varying between nil and 9.0 ppm. Regular sewage incursion from Jhansi city was common phenomenon resulting in hue proliferation of macrophytes. Alkalinity ranged 98-176 ppm with an average 137.51 ppm, hardness ranged 87-174 ppm average 118.35 ppm, average GPP is 1000 ($mgC/m^2/h$). Though being a balancing reservoir getting replenished by up stream reservoirs, the reservoir receives very good run-off due to very good precipitation during monsoon in 2008 as was reflected in water quality parameters in this reservoir. Accordingly, loading of nutrients with the run-off water was very significant in this reservoir during second half of 2008, otherwise it was moderate. The targeted fish production potential is 300 kg/ha/y. The investigation indicates that the reservoir is in very good productive nature and much more productive than Dahod. The fishery management needs ecosystem based option with the stocking of proper sized fish seed to enhance fish production sustainably.

The present fish production of Pahuj is 105 kg/ha/y against targeted potential of 300 kg/ha/y. The management measures were taken with the objective to raise the production at least to 150 kg/ha in this reservoir. In Pahuj, the fish yield was 18 kg/ha before CIFRI's intervention.

In Pahuj, in the first phase, one battery of eight cages same as Dahod with the release of one lakh fish fry, 22-24 mm in size (Grass carp: Common carp = 75 : 25) during last week of October, 2007 was made. Only, one percent mortality occurred during transport of fish fries. The reared seeds faced cold waves with temperature lowered to 4-5 ^{0}C during end December, 2007 resulting in mortality of Grass carp: 20,000 nos. and Common carp: 1,000 nos. Initially, immediately after release of fries in cages, mortality of common carp occurred to an extent of 2,000 nos. while, grass carp did not encounter mortality. The reared fingerlings have been released in Pahuj reservoir on mid March, 2008 with a recovery of 63% nos. of fingerlings of Grass carp: 65-96 mm/3.89-11.87 g and Common carp: 74-115 mm/12.48-22.09 g.

In the second phase, 90,000 nos. fries (10-15 mm) of IMC (Catla: Rohu = 8 : 2) were stocked in one battery of eight cages same as above, brought from Konch Hatchery (Jalaun, U.P.) 110 km from Pahuj Dam, Jhansi on mid August, 2008. Transport mortality was negligible. A recovery of 86.6 % fingerlings (Catla: 80-180 mm/6.12-74.88 g and Rohu: 79-108 mm/4.95-13.39 g) was achieved (Table 2). The feed comprising the same as in case of Dahod with reduced quantity in the second month due to good natural productivity (Dissolved organic matter: 5.6 ppm) of this water body owing to local sewage incursion. Abundance of zooplankton was very significant (38.70%) inspite of low influx due to failure of monsoon in this reservoir getting reflected in to the growth of *Catla catla* in the cages.

Table 2. Cage culture for fingerlings of IMC at Pahuj (16 Aug-16 Oct, 2008)

	Length (mm)			Weight (g)		
Species	Initial	Final	Increment	Initial	Final	Increment
C. catla	13.00	105.00	92.00	0.11	28.75	28.64
L. rohita	12.00	95.00	83.00	0.06	11.80	11.74

Economics of cage production

The overall economics of cage production revealed that the cost of production of each fingerling comes around Re 0.36-0.40 whereas the market price of each fingerling is around Re 2.00 to 3.00 in India in its true sense. All total three crops per year – two IMCs and one exotics especially grass carp and common carp could be raised depending on the availability of food niches from cages installed. Only, the iron drums will be repainted after each cage harvest (one third of the drum surface remains under water), the bamboos serve for at least two to three years and after that 10-20% of the bamboos used are to be replaced there by reducing the cost of installation. The drum may be served for at least 5-6 years depending on the nature of maintenance after each cage harvest and even then the drums will be sold at three fourth of the price of initial procurement. The netlon cages will serve for two years and after that these would further be utilized for fish farm activities.

Therefore, it is cleared from the above studies that raising fingerlings from cages is profit worthy and if practiced in other Indian reservoirs, could solve the problem of stocking materials for which most of the reservoirs are starving. Thus the steady supply of fingerlings could be maintained following cage culture practices in Indian reservoirs.

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Feed formulation and feeding techniques in enclosure culture

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Introduction

Growth of fish may be defined as increase in muscle, fat and connective tissue. Biochemical and physiological functioning of body requires certain specific macromolecules like enzyme, lipid, carbohydrate, proteins etc and micronutrients like minerals and vitamins. These macromolecules and micronutrients are provided to fish either as natural food available from ecosystem or through feed formulated as per nutrient requirement of a particular fish species, their growth, maturity and reproductive stages. Supply of proper nutrition to fish is required for growth, better reproductive and immune performance. Fish feed can be compounded using available local feedstuff based on their energy and protein content which require assessment by fish trial for their digestibility and bioavailability.

Role of nutrients

Proper nutrition of fish requires balance feed containing various nutrients like proteins with essential amino acids, lipid, carbohydrate, vitamins and minerals etc. Their role in fish nutrition and example is described below:

i) Proteins mainly serve as source of essential amino acid for synthesis of body protein which may act as structural proteins (collagen, elastin etc.), carrier protein (haemoglobin, ceruloplasmin, apolipoprotein etc.), defense proteins (immunoglobulins, complement), enzymes (carbonic anhydrase, protease etc.) etc. Energy value of protein is 19 KJ/g. It mainly serves normal physiological function as well as immunity against diseases.

ii) *Lipid* is required in feed for providing energy for body maintenance and protein synthesis. This is the most efficient source of energy with energy value of 36 KJ/g. Lipid after digestion and absorption provide fatty acid which may be resynthesized inside body to lipid for storage as well as to form structural component of cell membrane. High quality sperm production depends on diet containing sufficient essential fatty acids. Lipid increases palatability of feed, reduces dust and stabilizes the pellet.

iii) *Carbohydrate* is easily utilizable source of energy with less efficiency as its energy value is 15 KJ/g. This is the cheapest source of energy.

iv) *Vitamins* act as cofactor or substrate in enzyme catalyzed metabolic reaction and is required in very small amount to body. Vitamin A is required for bloodstock development while vitamin E provide egg viability.

v) ***Minerals*** act as cofactor in enzyme catalyzed metabolic process and also provide material for major structural elements of fish like bone, fin etc. Phosphorus and manganese is required for spawning of broodstock.

Forms of food

Use of particular form of food depends on intensification of fish culture like semi-intensive, intensive or open, life cycle stages and consumer preferences etc. Fish food may be of following type:

i) Food organism available in natural ecosystem like beel, river,reservoir etc. is called ***natural food*** e.g. phytoplankton, zooplankton, periphyton, macrophyte, benthic flora and fauna etc.

ii) ***Live food*** is required for culture of most aquatic organism in their larval stages. These live organisms can be cultured in laboratory providing selective media for a particular class of organism.

iii) ***Forage materials*** which can be either introduced or made to grow in culture system. e. g. grasses and macrophytes.

iv) ***Compounded feed*** is mixture of a few ingredients to form powder, crumbles, pellet etc for easy application to culture system.

Fish feed formulation

Feed ingredients:

Fish feed contain energy source, protein source of animal and plant origin, vitamin, minerals, some additives, binder and antioxidants. Energy and protein can be available from locally available feedstuffs so that the feed can be prepared with lower cost.

A. Locally available feedstuffs (chief source of energy and proteins)

Grasses **are the source of energy mainly in form of carbohydrate. Grasses with high fibre content is suitable for herbivorous fishes.**

Cereals are rich in carbohydrate and can be used for balancing high protein of animal and plant origin. High starch present in cereals can act as natural binder. It is poor in essential amino acid like lysine and vitamins. Examples are rice, wheat, maize etc.

Root crops are rich and excellent source of energy in form of carbohydrate. It provides starch which act as natural binder in feed preparation .Example includes cassava and potato etc.

Fodder plants can replace fish meal in feed. Generally leaves and aerial parts are used as feed ingredients e.g. cassava and babul leaf etc.

Legumes are source of protein and minerals. Soybean meal can supplement fish meal due to content of essential amino acid and fatty acids. Example include soyabean, cowpea etc.

Oil-bearing seed contain higher protein (20-50%) but the proteins are deficient in some of essential amino acid like lysine and threonine. Examples include mustard, groundnut, sunflower etc.

Animal products balance essential amino acids and vitamin. Fish meal is the most suitable source. Example is fish meal, silk worm pupae meal, blood meal etc.

B. Feed additives

Feed additives are added in formulated feed for specific purpose and they are not source of protein or energy. Different type of feed additives is described below with their specific purpose of use, availability and example:

Feed additives	Specific purpose of use	Availability	Example
Vitamins and minerals	Supplement the deficiencies in ingredients of compounded feed	Individual or premixes of vitamins/ minerals	
Synthetic amino acids	Supplement lysine, threonine or methionine in compounded diet and act as chemoattractants.	Available in market	
Probiotics	Increase the feed conversion ratio	Available in capsule form	Live or freeze dried microbial or yeast culture
Binder	Improve palatability, enhance durability, preserve physical form during storage and preservation, increase water stability	Available in market	Carboxymethyl cellulose, hemicellulose, collagen, tapioca residues, wheat flour
Antioxidants	Prevent or delay spoilage by protecting lipid rancidification	Available in market	Natural: Vitamin E , Synthetic: Butylated hydroxy toluene (BHT), Butylated hydroxyl anisole (BHA), ethoxyquin
Carotenoids	Addition of colour to flesh and egg and used for high value culture species like salmon etc		Paprika, processing waste of shrimps and crabs, carotene, xanthophylls
Chemoattractants	Synthetic chemicals to elicit feeding response		Extracted compounds of muscles of mollusks and crustacean , free amino acids, low molecular weight peptides, nucleotides, organic bases etc
Preservatives	Control rate of deterioration by fungal attack		Sodium or potassium salt of propionic and benzoic acid

Basic consideration for fish feed formulation

- Nutrient requirement, feeding habit and specific stages of life of the species to be cultured. For increasing reservoir productivity, enclosure culture through cages involves fingerling rearing and table fish for which artificial feed.

- Availability and selection of local feedstuffs for protein and energy based on their nutritional content
- Balance of protein and energy to provide proper nutrients to fish
- Digestibility and nutrient availability
- Feed additives needed: binder, probiotics, attractants and antioxidants as per duration of storage and methods of feeding

Feed formulation (Pearson square method)

An empirical feed is to be formulated which will contain 26 % crude protein and 8 % lipid using the following feedstuff :

Feedstuff	*Protein (%)*	*Lipid (%)*
Fish meal	55.0	6.0
Groundnut cake/Mustard cake	34.5	13.7
Soybean meal	46.8	1.3
Rice bran/rice polish	13.3	2.4
Maize meal	9.8	4.5

Steps of feed formulation

Step 1: In any type of fish feed formulation , a suitable animal source of protein other than plant is to be included in order to provide all essential amino acids and to balance cereal protein. The most commonly used source is fish meal which is included normally @ 10 % of ration.

Actual protein included in diet from fish meal is 55.0 x 10% = 5.5 %
Rest of the protein i.e.: 26.0-5.5 = 20.5 % is to be met from other source forming 90 parts of feed

Step 2:

- 20.5 % in 90 parts of feed will be equivalent to 20.5 x 90% = 22.8 % in 100 parts forming energy and protein source of plant origin.
- Formulation of various diet using different combination of plant protein and energy source.

Diet a:

Protein level
Protein % | | Proportion of
Groundnut | | Ground nut
34.5 | Final protein | 9.5
| 22.8 |
Rice | | Rice
13.3 | | 11.7

- Actual amount of ingredient needed (100 parts)

$$\text{Groundnut} = \frac{9.5}{(9.5+11.7)} \times 100 = 44.8\ \%$$

$$\text{Rice bran} = \frac{11.7}{(9.5+11.7)} \times 100 = 55.2\ \%$$

For 90% it will be 44.8 x 0.9 =40.3 % for groundnut and 55.5 x 0.9 = 49.7% for rice bran respectively , thereby content of diet a will be :
Diet a = 10% fish meal + 40.3 % groundnut cake + 49.7% for rice bran. Similarly other three combinations calculated are as follows:
Diet b = 10% fish meal + 47.3 % groundnut cake + 42.6 % maize
Diet c = 10% fish meal + 25.5 % soybean + 64.5 % rice bran
Diet d = 10% fish meal + 31.6 % soybean + 58.4 % maize

Step 3: Lipid level will be calculated for all 4 diets as described above:
Diet a = Fish meal + groundnut cake + rice bran =8.06%
Diet b = Fish meal +groundnut cake + maize = 9.0%
Diet c = Fish meal + soybean + rice bran =2.48 %
Diet d = Fish meal + soybean + maize = 3.64

Step 4: The required lipid % in diet to be prepared was met by diet a. If not met, it could be reformulated by two- compound mixture

Step 5. Final formulation is as follows:
Fish meal 10% =10.00%
Rice bran = 49.7 %
Ground nut = 40.3 %
Vitamin-mineral mixture @ 1.5 and binder @ 4% is to be included in the formulated diet which may be taken into consideration during initial calculations.

Feeding method

Method is of two types as described below:

Non demand feeding involves predetermined feed at predetermined time interval. Suitable way of giving feed for initial life stages like spawn and fry is to broadcast feed powder over water surface whereas for grow-out fish to keep feed pellet or ball in earthen pot or tray 1-1.5 feet below water surface.

Demand feeding provides *ad libitum* feeding which is activated by fish stock. Feed is given in small sized gunny bag made of plastic in small amount in order to reduce wastage.

Ration size

Size of feed to be provided to fish stock will depend on the biomass present which can be calculated as follows: Biomass=average weight of fish x number. Ration size also depends on temperature of water and stages of life cycle of fish.

Feeding frequency

In ideal condition feed @ 5 % of biomass is to be fed daily in five times. But as it involves labour and cost, practically the same feed was fed twice daily preferably morning and afternoon at fixed time and place.

Feed development and feeding strategy for cage farming in reservoir

This two enhancement methods involves the rearing fish fry to either fingerling size or table size. The feed requirement will be as per their biomass and feeding frequency of the stages of fish. There may be several approaches which can be followed at various stages of feed formulation, feed preparation and feeding to reduce cost, better feed utilization and fish growth.

Approaches:

A. Prevention of feed wastage
- Feed processing (Cooking)
- Feeding strategy
  - Ration size
  - Feeding time
  - Feeding frequency

B. Increased consumption ------> Incorporation of attractants
C. Increased utilization ------> Incorporation of probiotics
D. Quality Improvement ------> Supplementation of amino acids
E. Stress mitigation in cages ------> Inclusion of antistressors

The strategy discussed above was tested in our experiment which gave promising results. Diet was formulated for fingerling production in cages using protein source (MOC & GOC), carbohydrate source (green gram waste, corn powder, rice bran) and lipid source (palmolein) fortified with vit.-min mix. yielded better result. *Catla catla* and *Labeo rohita* performed better with formulated compact feed in cages in Poka bundh, Bishnupur (W.B). Combined inclusion of attractant and probiotic, improved feed consumption, feed conversion and nutrient composition than used individually. Thrice feeding yielded better growth and feed conversion than fed once/twice (water temp. 27-28^{0}C.). Feeding scheduled during afternoon (1500-1900 hrs), maximized feed consumption in *L. rohita* fingerlings.

Standardization of feed formulation for cages

Feed stuff/Inclusion	Feed I (Control)	Feed II (Diet I + PA)	Feed III (Diet II +Antox)
Soybean oil cake	M	P	P
Mustard oil cake	N	K	L
Deoiled rice bran	O	Q	Q
Fish meal	A	A	A
Vitamin premix	B	B	B
Mineral mixture	C	C	C
AQUACE	D	D	D
Vegetable oil	E	E	E
Probiotics (dry yeast)	-	X	X
Attractant	-	Y	Y
ANTOX	-	-	Z

Nutritional requirement of fish at various point of life along with feeding method, rate and form of feed

Stages of life	Nutritional requirement	Forms of feed	Feeding rate and method	Remarks
Starter (Fry or larvae when endogenous source exhausted)	Nutritionally complete, easily digestible, appropriate particle size	Powder, flakes	10% of biomass Broadcasting	Excessive mortality rate
Fry (Unmetamorphosed young stage)	Higher level of protein and energy on a mass basis	Powder, flakes	10% of biomass Broadcasting	
Fingerling (Metamorphosis to 10-20 gm weight)	Less protein than fry and starter	Crumbles and pellet	5 % of biomass, Given in earthen pot or tray in form of ball	
Grow-out fish (Table to larger fish)	Energy and protein requirement uniform	Pellet, ball	2-5 % biomass	
Broodstock	Higher level of protein, and low level of fat, Essential vitamins and minerals for reproduction	Pellet, ball	2-5 % biomass	Quality of offspring
Improved product quality	Product requirement			Value addition

Feed quality assessment

Feed ingredients denotes the energy and protein content in feed but their digestibility, absorbability and bioavailability can only determine its real contribution to fish nutrition Therefore it is very much essential to undergo fish trials of formulated fish feed for their suitability of feeding.

Methods of quality assessment

1. Energy value:

i. Bioavailability can be determined by digestible energy (DE) of carbohydrate, lipid and protein.

DE= IE-FE (IE: intake energy, FE: Fecal energy)

ii. Metabolizable energy means the energy available to fish for growth and metabolism

ME=IE- (FE+UE+ZE) where UE=Urinary energy and ZE = gill excretion energy

iii. Retained energy (RE) denotes the energy retained in whole carcass of fish as well value of feed for providing energy for growth

RE= ME-HI (HI= Heat increment/energy of metabolism)

iv. Feed Conversion Ratio (FCR) $= \dfrac{\text{Mass of feed consumed (dry)}}{\text{Increase in mass of fish product (wet)}}$

2. Nutritional value of protein can measure the effectiveness of particular protein source in supplying the fish requirements.

i. Protein efficiency ratio (PER) $= \dfrac{\text{g wet weight gain of fish}}{\text{g crude protein fed}}$

ii. Net protein utilization (NPU) $= \dfrac{\text{Protein gain in fish}}{\text{Protein intake through feed}} \times 100$

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Water and sediment quality management in cage and pen farming of fishes

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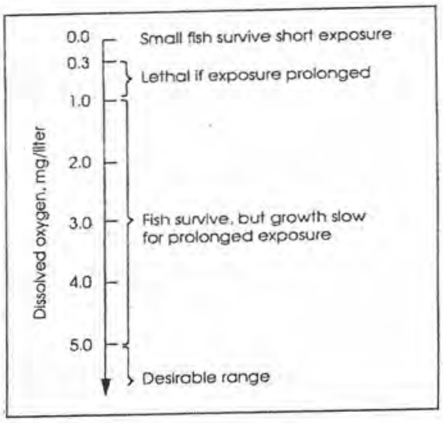
Problems are frequently faced when small water bodies are used for enclosure culture. Those problems usually centre around water quality deterioration, low oxygen, ammonia or nitrite build-up, and excessive algal blooms. These problems may also occur in the relatively larger water bodies but are not as common. Adequate depth of about 6 feet or greater is important for keeping the fish wastes away from the enclosure, maintaining adequate circulation through the cage, and for reducing the chances of weed encroachment around the enclosure. Very deep water bodies are more likely to experience low dissolved oxygen problems in the summer. The characteristics of the watershed of a water body can be critical for successful enclosure culture. Washings from the watershed may cause water quality problems. Wastes can over fertilize the water leading to severe algal blooms, water quality deterioration, and eventually disaster. This is particularly true of small water bodies of less than 5 acre. High amount of organic matter wash into the water body can result in oxygen depletions due to rapid bacterial decomposition of the detritus. Water bodies that have chronic problems such as severe weed infestations, surface scum, fish kills, stunted wild fish populations, and severe water level changes during the summer are not good candidates for enclosure culture. These problems must be brought under control first. It may be necessary to treat chemically for weeds or to stock grass carp, remove wild fish, and/or renovate it.

Water quality management is a key for successful fish culture. Most periods of poor growth, disease and parasite outbreaks, and fish kills can be traced to water quality problems. Water quality management is undoubtedly one of the most difficult problems faced by the fish farmers. These problems are even more difficult to predict and to manage.

Oxygen : In natural waters, dissolved oxygen is very important chemical factor as regulator of metabolic process and as indicator of water condition. A series of oxygen determination along with knowledge of turbidity and colour of water could provide more information about the nature of water than any other chemical parameters (Hutchinson, 1957). During plankton bloom, wide fluctuations in DO is observed. Rain water influx reduces DO during monsoon months. Good productive water should have DO >5 mg/l. The direct effects of DO are presented in figure 1.

Fig. 1 Effect of dissolved oxygen concentration on warmwater fish



Oxygen stress is the most frequently encountered water quality problem in enclosure culture of fish. The concentration and availability of dissolved oxygen (DO) are critical to the health and survival of enclosed fish.

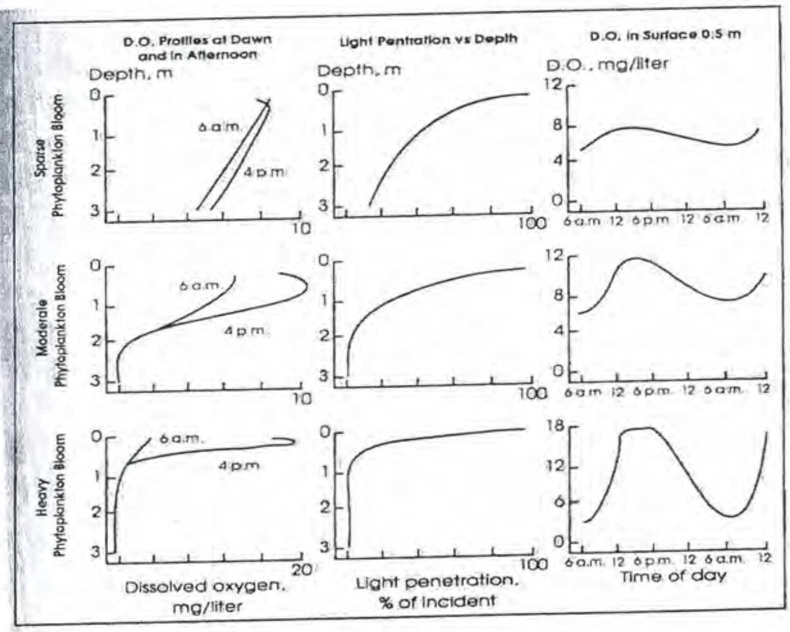
Critical dissolved oxygen levels vary depending on species being reared and interactions of DO with other water quality parameters; e.g., carbon dioxide, ammonia, and nitrite. In general, warm water species such as catfish and tilapia need a dissolved oxygen concentration of 4 mg/l DO (or ppm) or greater to maintain good health and feed conversion. Healthy warm water fish can tolerate 1 mg/l DO for short periods of time but will die if exposure is prolonged. Prolonged exposure to 1.5 mg/l DO causes tissue damage, and any prolonged exposure to low dissolved oxygen levels will halt growth and increase the incidence of secondary diseases, apparently by reducing the fishes' ability to resist infection. Many parasites, diseases, and chemical agents can damage the gill filaments affecting oxygen transport across the gills. This can cause the fish to behave like low dissolved oxygen conditions even though the cause is a disease problem.

The concentration of dissolved oxygen in any body of water varies over time and is affected by physical, biological, and chemical factors. Physical controllers of dissolved oxygen are temperature, atmospheric pressure, and salinity. The solubility of gases in water decreases with increase in salinity and temperature. The salt ions remain hydrated in solution and water does not behave free. Thus, as salt content increases, free water content decreases and solubility is also lowered. Temperature is an important physical controller of dissolved oxygen. As water temperature increases 10°F the amount of oxygen that will dissolve in water decreases by approximately 10 percent. The physical transfer of oxygen between the atmosphere and water occurs across the water surface when dissolved oxygen concentrations are above or below saturation. The rate of this transfer is regulated by turbulence across the water surface.

In small water bodies biological processes are more important in regulating DO. Biological factors that affect dissolved oxygen are plant photosynthesis (both phytoplanktonic and macrophytic) and plant and animal respiration (fish, invertebrates, bacteria, etc.). Most of the oxygen in aquaculture systems is produced by plant photosynthesis during sunlight hours. Planktonic algae (phytoplankton) usually produce the bulk of this oxygen. High densities of aquatic macrophytes (rooted underwater plants) usually reduce phytoplankton growth and water circulation and, therefore, can cause dissolved oxygen problems in enclosed production systems.

Plant and animal respiration are the most important oxygen reducing processes in aquaculture systems. Fish must compete with all other living organisms for the ponds' available dissolved oxygen. This is particularly acute at night when plants in the system are also consuming oxygen through the process of respiration. In most aquaculture systems night time phytoplankton respiration is the major consumer of oxygen. Respiration rates are temperature driven in cold-blooded animals (i.e., fish) and plants, increasing oxygen consumption with rising temperatures. Total plant and fish biomass is also usually greatest during warm weather and high light intensity conditions. For all of these reasons, summer nights, with high water temperatures and respiration and low wind turbulence, bring most oxygen problems. Phytoplankton – DO – light penetration interrelationship is presented in figure 2.

Fig. 2 Phytoplankton – dissolved oxygen – light penetration interrelationship



In cage culture situations, low dissolved oxygen is particularly acute because the fish are crowded into such small areas. Most fish kills, disease outbreaks, and poor growth in cage situations are directly or indirectly due to low dissolved oxygen.

Turnovers and plankton die-offs are two other situations in which dissolved oxygen levels may fall below critical levels. Turnovers occur during cold rains, heavy winds, and prolonged cold spells in summer. These conditions cause the upper oxygenated layer of water to mix with the cold oxygen- depleted layer of water on the bottom of the system. The mixing of the two layers reduces the total dissolved oxygen in the whole system to critical levels due to both dilution and chemical reduction. Turnovers are particularly common in deep ponds with large watersheds.

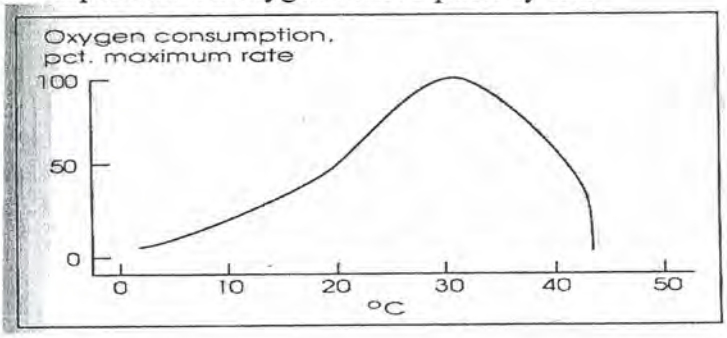
Plankton die-offs can occur as a natural consequence of algal population dynamics due to seasonal changes in temperature, pH, light intensity, nutrients, diseases, parasites, toxins, or other factors which are not clearly understood. Plankton die-offs can also occur as a consequence of nighttime low dissolved oxygen. In this case, the density and biomass of the plankton become so great that a critical dissolved oxygen concentration is reached in the aquatic system due to night time respiration demands. The plankton dies from lack of oxygen along with the fish.

Dissolved oxygen management is one of the most critical management techniques that must be learned by a fish farmer. It includes both biological and mechanical manipulation. Biological manipulation can include fertilization and submerged aquatic plant control to maintain a healthy phytoplankton bloom. Mechanical manipulation through aeration may help maintain adequate dissolved oxygen concentrations and may save fish during chronic low DOs, turnovers, and plankton die-offs.

Gas super saturation of water can be a problem in aquaculture. It may lead to gas bubble trauma with bubbles in blood, tissue (head, mouth, fins) and protrusion of eyes. Oxygen saturation by 300 % may also cause fish death. Plankton bloom due to eutrophication may cause such situation.

Temperature : Water temperature is related to solar radiation and air temperatures. Water temperature closely follows air temperature. Temperature is the single most important physical factor controlling the life of a cold-blooded animal. Temperature is critical in growth, reproduction and sometimes survival. Fish and crustaceans are poikilothermic or cold-blooded. Water temperature changes daily and seasonally, so the body temperature of fish and crustaceans changes frequently. The rates of biochemical processes are temperature dependent. Within the temperature range that normally occurs in the natural habitat of a particular species, the rate of biochemical processes is related to temperature by vant Hoff's law, which states that a 10°C increase in temperature roughly doubles reaction rate. The relationship between temperature and a typical biochemical reaction, oxygen consumption (figure 3), is : (1) oxygen consumption increases with temperature at roughly the rate predicated by vant Hoff's law until a maximum value is achieved, (2) the peak oxygen consumption rate is maintained over a small temperature range, (3) oxygen consumption decreases relatively rapidly as temperature continues to increase, and (4) a lethal temperature is finally reached. It is pointed out that many species suitable for aquaculture will survive and reproduce over a wide temperature range, but the temperature range for maximum growth is narrower. For example, a species might tolerate temperatures of 5 to 36°C but the range for maximum growth might be from 25 to 30°C.

Fig. 3 Effect of temperature on oxygen consumption by fish

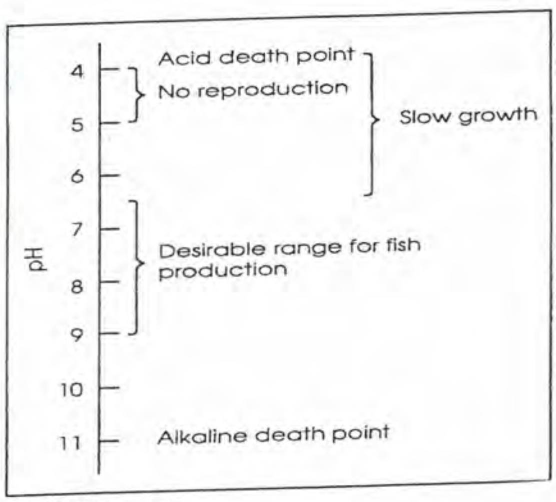


In aquaculture, it is seldom economical to cool or heat large volumes of water. Therefore, species which exhibit maximum growth rates at prevailing water temperatures usually are selected for a particular location. Tropical and subtropical species does not grow well when water temperatures fall below about 26 or 28°C and that water temperatures below 10 or 15°C may kill them. Warm water species which are native to temperate climates grow best at temperatures between 20 and 28°C, but they can survive at temperatures near O°C. Coldwater species grow best at temperatures below 20°C, and they may die when temperatures exceed 25°C. Some workers use the term cool water for species that grow well between 10 and 20°C and use the term coldwater for species that grow best below l0°C. Each species of fish has an optimum temperature range for growth, as well as upper and lower lethal temperatures. Below the optimum temperature feed consumption and feed conversion decline until a temperature is reached at which growth ceases and feed consumption is limited to a maintenance ration. Below this temperature is a lower lethal temperature at which death occurs. Above the optimum temperature feed consumption increases while feed conversion declines.

Animals are sometimes transferred quickly between waters of different temperatures. If temperature difference exceeds 3 or 4°C, sudden changes in metabolism may cause thermal shock and even death. Therefore, animals should be tempered by gradually changing temperature during transfer. A temperature change of 0.2°C/min usually can be tolerated provided the total change in temperature does not exceed a few degrees.

pH : pH is a measure of the relative acidity of the water. The pH in a water body fluctuates daily due to uptake and release of CO_2 during photosynthesis and respiration. The pH is lowest at or near dawn and highest at mid-afternoon. The desirable range of early morning pH for fish production is from 6.5 to 9. The acid death point is a pH of approximately 4 and the alkaline death point is approximately pH 11 (Figure 4). When the pH is outside the desirable range, fish growth is slowed, reproduction reduced, and susceptibility to disease increased.

Fig. 4 Effect of pH on warmwater fish



Gill tissue is the primary target organ of acid stress. When fishes are exposed to low pH, the amount of mucus on gill surfaces increases. Excess mucus interferes with the exchange of respiratory gases and ions across the gill. Therefore, failure in blood acid-base balance resulting in respiratory stress and decreasing blood concentrations of sodium chloride which cause osmotic disturbance are the dominant physiologic symptoms of acid stress. At low pH, aluminum ion concentration increases in water, and many times, toxic effects of aluminum may occur in addition to pH effects. The gills of fish also are highly sensitive to alkaline solutions. The water reaction is very important since it controls availability of all nutrient elements. In Indian reservoirs, acidic water reaction is seldom recorded, although acidic sediment has been observed in some reservoirs of Karnataka, North East regions, etc,. The allochthonus source of basic cations from catchment washings actually maintains water pH and resists from getting acidic. Normally, during monsoon, due to dissolution of CO_2 and organic acids, low pH values are observed.

Ponds with acidic bottom muds and soft water usually are not productive fish ponds. Lime can be added to these ponds to increase the pH and alkalinity (total concentration of bases). Limed ponds have fewer pH, dissolved oxygen, and other related problems. A total alkalinity of 20 mg/l is considered the minimum concentration for a system used in fish production.

Turbidity: Turbidity determines light penetration in water. Suspended particles, organic materials, and the planktons (floating or suspended microscopic plants and animals) of the aquatic system determine turbidity. Suspended soil may reduce photosynthesis and, therefore, oxygen production. Water body which always have a moderate amount of suspended clay (i.e., muddy) may actually prevent wild fluctuations in oxygen levels. Large quantities of suspended soil particles washed into a system during heavy rains, however, may cause irritation and clogging of the gills which can lead to secondary diseases. In general, high concentrations of suspended soil are not desirable.

Since photosynthesis can occur only to the depth of light penetration into the aquatic system, plankton turbidity is a measure or index of a healthy phytoplankton bloom (green colour) in the system. A healthy bloom will produce oxygen, reduce undesirable macrophytic plant growth, and reduce fish stress because of reduced visibility. Reduced visibility in enclosed culture reduces stress on the fish caused by reactions to seeing people and possibly other animals in close proximity.

A healthy phytoplankton bloom (green water) is one with a Secchi disc visibility of 40 to 60 cm. Clear aquatic systems with a visibility above 60 cm indicate a need for additional fertilization and possible liming. Visibility of less than 30 cm indicates a plankton bloom which is too dense and may cause low dissolved oxygen problems. Visibility of less than 15 cm is critical. Low visibilities due to intense plankton blooms are usually associated with high feeding levels and may necessitate aeration and a reduction in the daily feed ration.

Ammonia and Nitrite : In water nitrogen remains as free gas (N_2), ammonia (NH_3), ammonium (NH_4^+), nitrate (NO_3^-), nitrite (NO_2^-) and organic nitrogen. Free NH_3, NH_4^+ and NO_2^- are very toxic to fish at more than permissible level. NH_3 becomes problematic at high pH or low DO. Dissolved inorganic N of 0.2-0.5 mg/l is considered favourable for fish production. Generally, phytoplanktons utilise NO_3^- and NH_4^+ form and some zooplankton can utilise particulate organic nitrogen. In productive culture system the nitrate content may go up to 2.5 ppm. Ammonia is the primary nitrogenous waste produced by fish from protein digestion. Any nitrogenous waste from manure runoff into the water body, inorganic fertilizer, plant decomposition, and/or uneaten feed is transformed into ammonia by bacteria in the aquatic system. Bacteria of the genus *Nitrosomonas* convert ammonia into nitrite. Sublethal levels of ammonia are known to cause gill and tissue damage, poor growth, and increased susceptibility to disease. Nitrite at sublethal levels reduces oxygen transport into the fish, resulting in poor feed conversion, reduced growth, and increased susceptibility to disease. Nitrate ion is highly soluble. Due to its negative charge, it is not retained by clay colloids and is lost by leaching, denitrification, etc., if not utilised by biotic sector. NO_2^- is toxic to fish since it forms methemoglobin, also called brown blood disease. In brackish water, Ca^{+2} & Cl^- reduce toxicity of nitrite. In Indian reservoirs, inorganic N content is very low except premonsoon and monsoon months. During premonsoon the content increases due to faster decomposition of bottom organic load. The run off from fertile catchment increase its content during monsoon.

At stocking densities normally recommended for enclosure culture, neither ammonia or nitrite toxicity problems should be encountered. In ponds where higher density enclosure culture is attempted, where livestock manure can wash into the water body during rains, or where a plankton die-off has occurred, the level of ammonia (and later nitrite) may pose problems.

Phosphorus : Phosphorus is a key metabolic nutrient and the supply of this element often regulates the productivity of natural waters. In fact, most natural waters respond to additions of phosphorus with greater plant production. Experience with pond fertilization also suggests that additions of phosphate fertilizers will increase fish production in most systems. Therefore, information on the dynamics of native and added phosphorus in ponds is important to aquaculturists. All aquatic organism take P as phosphate while some algae also utilize particulate organic matter as source of P. Concentrations of phosphorus in water are quite low; dissolved orthophosphate concentrations are usually not greater than 5 to 20 ppb and seldom exceed 100 ppb even in highly eutrophic waters, and the concentration of total phosphorus seldom exceeds 1000 ppb. Indian reservoirs are also characterized by very low level of phosphate and it does not exceed 100 ppb. The reservoirs of Rajasthan, however, have high level of phosphate (traces – 930 ppb), received from rain washings of catchments. Lack of phosphorus in water does not seem to be indicative of low productivity particularly in reservoirs free from pollution because of their rapid turn over and quick recycling e.g., 95 % of the P is taken up by plankton within 20 minute while some algae can convert inorganic phosphate into more insoluble organic state within one minute. Some plants can absorb more phosphorus than they need for growth and store it - possibly for later use. The absorption of phosphorus or other nutrients in excess of the amount required for growth has been demonstrated in phytoplankton and is termed luxury consumption.

In cage culture, the sediments normally play lesser role. In case of pen culture, since the bottom floor is included in the production process, sediment phase becomes very important. Normally feeds are supplemented in cage or pen cultures. If in pen cultures systems, feeds are not supplemented, sediment phase will play very important role in determining the fertility status of the culture system. The exchange of water of the pen area with its surroundings will also modulate the importance of sediment. In the production systems where the water exchange is minimum, the role of sediment is maximum.

The overstocking and overfeeding of the fish in cages in Lake Taal of Philippines have resulted in fish kills due to heavy organic loading that has caused dissolved oxygen depletion with water quality deterioration and lake overturns. De la Vega (2002) recorded 2.6 kg of wasted feed per cage per day which amounted to 2,500 mt of wasted feed with a value of US$800,000 from 8,000 cages. The uncontrolled proliferation of milkfish cages/pens in Bolinao, Pangasinan, reduced the water current speed by 40-60 percent in the bay and caused the drop in dissolved oxygen values below the optimum level of 5 mg/l during neap tides with the high organic loading from fish wastes and excess feeds (Jacinto, 2006). Consequently, massive fish kills occurred with losses estimated to be over US$12 million.

Under Indian context, cage culture in fresh water reservoirs are in practice to get the desired stocking materials. In such situation, no water quality problem is anticipated. Unutilized feed materials will in fact, enhance growth of the reservoir fish population.

The sediment parameters commonly considered important are :

Redox Condition : With respect to redox reaction, the sediment maintains a relatively oxidized layer at the soil water interface. Thickness of the layer depends upon oxygen content of neighboring water phase. Below the oxidised layer is reduced phase. In highly reduced condition availability of Fe^{2+}, Mn^{2+} increases greatly. Phosphorus (P) availability also increases. Under extreme reduced condition H_2S, CH_4 and organic acids are produced, some of them exert toxic effect.

pH : Under reduced environment the sediment pH has a tendency to shift towards neutrality due to formation of ferrous and manganous hydroxide in acid soils and bicarbonate ions in alkaline soils. Availability of P is greatly reduced in alkaline soil due to formation of calcium phosphate and in acid soil due to reaction with Al and Fe compounds. If the base saturation of soil is low and organic matter content is high, the latter on decomposition produces different fatty acid and humic acid which makes the soil more acidic. Such sediment type with very low pH reduces productivity. This type of situation is mostly found in high rainfall areas. In the red and laterite zones the sediment pH is normally acidic due to the dominance of Fe and Al compounds.

Sediment pH range and potential fish productivity may be grouped as :

pH range	**pH value**	**Natural productivity**
Highly acidic	<5.5	low
Moderately acidic	5.5 – 6.5	average

Near neutral	6.5 – 7.5	high
Moderately alkaline	7.5 – 8.5	average
Highly alkaline	> 8.5	low

Between the moderately acidic and moderately alkaline conditions, relatively more productivity is expected from the moderately alkaline sediment systems.

Specific conductivity : With increase in the concentration of CO_2 and intense reduced condition, specific conductivity also increases due to solubilisation of $CaCO_3$ and formation of more soluble $Fe^{2+}$and Mn^{2+} compounds. A very low value of specific conductivity (about 50 $\mu S\ cm^{-1}$) indicates lower level of salts and nutrients and is normally less productive. With increase in salt content of sediment, the specific conductivity value increases proportionately.

Nitrogen : It is basically present in soil in the organic form, gets mineralized to NH_4^+& NO_3^- and becomes available to different organism. Under reduced condition, transformation of organic N is hindered beyond NH_4^+ stage. Water bodies with moderate to high production potential have available N 25-75 mg/ 100g soil. Available N <25 mg/ 100g are generally indicative of poor production.

Phosphorus (P) : Available phosphorus is normally poor in Indian water bodies and it is the limiting input in many cases. But in the pen culture systems high levels of the element may be accumulated in the sediment from the added inputs leading to eutrophication. Phosphorus undergoes various types of transformations and fixation in soil due to reaction with Ca, Al & Fe compounds depending upon soil pH. However, in aquatic system, under anaerobic condition, a congenial environment is developed to increase solubility of P through following mechanisms -

a) Solubilistion of calcium phosphate due to accumulated carbonic acid in presence of decomposing organic matter.

b) Reduction of insoluble ferric phosphate.

c) Hydrolysis of ferric and aluminum phosphate.

d) Release of occluded phosphate by reduction of hydrated ferric oxide coating.

e) Replacement of P from ferric and aluminum phosphate by organic anions.

f) Anion exchange (PO_4^{3-}) between clay and organic matter.

In general, sediment available phosphorus (as P_2O_5) content and potential fish productivity may be grouped as :

< 3 mg/100g	poor
3 – 6 mg/100g	average
> 6 mg/100g	productive

A regular correlation is generally noticed between the sediment available phosphorus content and fish production. In the highly variable natural systems, when most of the sediment quality parameters show wide variability with productivity, available phosphorus gives good correlation with aquatic production.

In sediment, phosphorus is present in the free, calcium bound, aluminium bound and organic forms. Normally the available form of the nutrient is present in low levels (< 1%). In sediment having acidic pH, the aluminium bound form dominates over calcium bound form. In alkaline environment, the reverse condition prevails. These forms contribute up to about 15% of total P. The organic bound form normally predominates over all the forms and may contribute about 70% of the total P. In the organic rich sediments (organic carbon 4-5%) the organic fraction may go as high as 95% of the total content. The total P content may greatly vary in the range of 500 – 4500 mg/100g.

Soil organic matter : It is the source of food for benthic feeding fish and invertebrates. Also, is the storehouse of different element. It also serves as the substrate on which microbes develop. In case of culture systems, sediment organic carbon content and potential fish productivity may be grouped as :

< 0.5 %	low
0.5 – 1.5 %	average
1.5 – 2.5 %	high
> 2.5 %	low

In case of culture systems having organic carbon content of > 2.5 %, the problem of oxygen deficiency may be commonly encountered. Sediment pH is also acidic causing unavailability of P and other basic nutrient elements and leads to lower fish production. Liming of such water bodies greatly improve its productivity by bringing the nutrient elements into its available form.

C/N ratio : The ratio of between organic carbon and total nitrogen is a good indicator of productivity. Water bodies may be grouped having C/N ratio ranges and productivity as :

<5	poor
5-10	moderately productive
10-15	optimum
>15	less favourable (than 10-15 range)

In sediments having lower C/N ratio the availability of the energy source becomes limiting causing reduction in the microbial activity leading to lower productivity.

Calcium content : Exchangeable form of the element controls sediment health but generally no correlation is noticed between exchangeable form of Ca and fish production.

Primary particles : The proportion of sand, silt and clay actually determine majority of the sediment attributes. The water holding capacity and seepage losses are also determined by the composition of the primary particles. The clay fractions are actually the store house of nutrients. But too much of clay may retain the nutrients strongly and thus, may not remain available. The mechanical support of sediment to the constructed pen structures is also determined by the ratio of primary particles.

Among the water and sediment quality attributes, the sediment condition may serve as a reliable index of aquatic productivity when the water quality parameters fail to explain the differences in productivity.

To understand the impact of pen culture on sediment properties, a case study is discussed here - Impacts of milkfish (*Chanos chanos*) aquaculture on carbon and nutrient fluxes in the Bolinao area, Philippines. Cultivation of milkfish in the Bolinao takes place both by use of net cages and fish pens, where the water column and the seafloor are enclosed by nets supported by bamboo sticks. Fish pens are shallow, rendering the coupling between benthic and pelagic processes and is thus much more direct compared to net cage farming. The fish pens are often installed in reef lagoons or in shallow straits with tidal currents, which allow exchange of water and keep the farms well flushed.

In the present study, four fish pens were selected, on the basis of their production stage, from juveniles to consumable stages of milkfish (Table 1). The size of the fish pens varied between 1404 and 2886 m^2 with a stocking density between 10000 and 20000 juveniles. The age of the fish ranged from 1 week to 4–9 months, and the weight from a few grams to consumable size (600 g). The fish pens were named according to the type of feed used. All farms used dry pellets as feed with Frymesh and Starter accounting for about 7% of the total input, and Grower and Finisher for 48% and 45%, respectively (Table 2). The organic carbon, nitrogen and phosphorus content of the fish feed varied between 40–46% dry weight (DW) particulate organic carbon (POC), 4.3–5.5% DW particulate organic nitrogen (PON) and 0.78–1.78% DW total phosphorus. The water depth varied between 0.5–2 m along the study sites.

Table 1. Description of the studied fish pens

Fish pen	Size of fish pen (m^2)	Stocking (no. of juveniles)	Age of fish at sampling
Frymesh	1404	10000	1 week
Starter	2886	20000	1 month
Grower	1680	15000	3–4 months
Finisher	2520	15000	4 months (some 9)

Table 2. Input data of the various fish feeds used in the milkfish pens during one crop production (5 months) and the elemental composition of the farmed fish

Type of fish food	Input (kg m^{-2} crop^{-1})	Carbon concentration (% DW)	Nitrogen concentration (% DW)	Phosphorus concentration (% DW)
Frymesh	0.21	40.2	4.31	0.78
Starter	0.26	45.2	5.38	1.78
Grower	3.13	45.6	5.51	1.38
Finisher	2.98	44.3	4.92	1.10
Total input	6.58	–	–	–
Composition of fish (%/g fish)	-	19.3[a]	4.42[b]	0.68[c]

The sedimentation rates were recorded to be very high inside the fish pens at all sites (Table 3), and generally increased with the input of fish feed. The low water depth resulted in a rapid and large sedimentation of waste products. The POC and PON content of the sedimenting material increased with the input of fish feed. The POC, PON and Total P concentrations in the settling material were determined to be much lower than that found in the feed pellets. The sedimentation rate decreased along transects conducted up to 100 m. The organic enrichment of the sediments was high compared to that observed in net cages. The settling particles were mixture of uneaten feed, feces, resuspended sediment, phytoplanktonic detritus and external sources. High concentrations of chlorophyll-a were found inside the fish pens suggesting that phytoplanktonic detritus contributed to the settling material.

Table 3. Sedimentation rates and elemental composition of the organic matter in various stages of crop production inside and along transects from the fish pens

Fish pen and distance	Sedimentation rate (g DW m^{-2} d^{-1})	Carbon concentration (% DW)	Nitrogen concentration (% DW)	Phosphorus concentration (% DW)	C:N (molar)	C:P (molar)
Frymesh						
Inside	292 ± 18	1.48	0.12	0.043	14.4	9.0
15 m	273 ± 39	4.19	0.44	0.026	11.0	42.1
50 m	192 ± 17	3.72	0.26	0.016	16.7	61.3
Starter						
Inside	242 ± 19	6.28	0.35	0.027	20.9	17.9
15 m	72 ± 36	6.28	0.35	–	19.4	–
100 m	54 ± 54	1.80	0.12	0.027	17.5	45.3
Grower						
Inside	339 ± 46	5.41	0.37	0.073	17.1	19.2
25 m	253 ± 39	6.46	0.43	0.086	17.4	19.5
50 m	180 ± 13	2.52	0.17	0.026	17.3	28.2
Finisher						
Inside	493 ± 12	10.95	0.39	0.575	32.8	4.9
15 m	44 ± 44	2.40	0.16	0.025	17.0	24.2
100 m	41 ± 41	2.76	0.17	0.009	18.9	83.0

The sediments were enriched in organic matter in the upper surface layer inside the fish pens compared to the sediments outside. The sediment POC and PON concentrations were enhanced inside the fish pens by up to 4 fold for POC and a factor of 9 for PON. The sediment total P concentration was very high in the sediments at the Finisher fish pen, 3–4 times higher than the concentrations at the sediment surface on the other fish pens.

The sediment oxygen utilization (SOU) and the CO_2 production was high at all the fish pens (Fig. 5) and increased with the input of fish feed. The SOU and CO_2 production were 2–10 times higher than found in the surrounding sediments in the fish pens stocking >3 month old fish, and the oxygen uptake rate of >250 mmol m^{-2} d^{-1} measured at the Finisher fish pen. Inside the fish pens release of ammonium was noticed in majority of the cases. Gas bubbles were observed in the sediments at the Finisher fish pen, and the sulfate concentration was depleted in the surface layers, and it is thus likely that the organic matter was mineralized through methane production concurrent with sulfate reduction in this sediment.

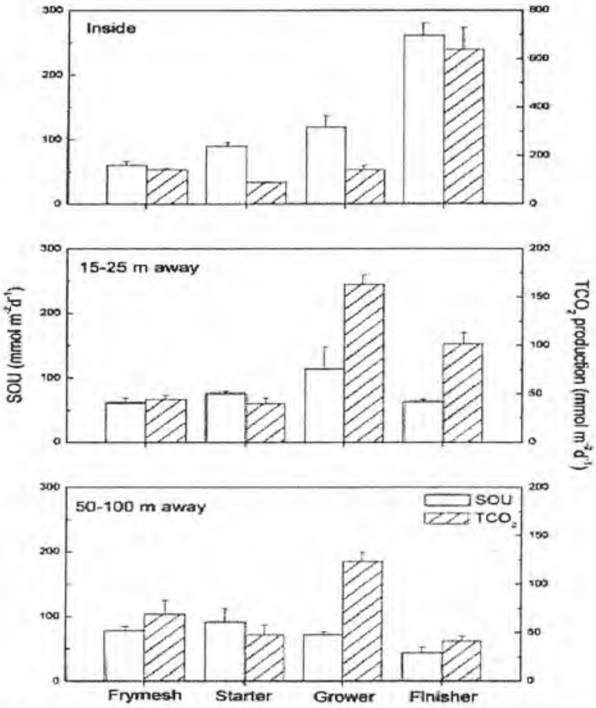


Fig. 5. SOU and TCO_2 production at the four fish pens and along transects measured

Such farms are generally abandoned after each crop production for a period of 1–2 months to re-establish the sediment conditions. By that time the wide C:P ratios are lowered down by way of decomposition of the labile organic matter.

The rapid organic matter mineralization at the Grower and Finisher fish pens resulted in a significant efflux of ammonium and phosphate. The release at the Finisher fish pen was about twice as high as that found under net cages in temperate waters, which is exceptional when considering the oligotrophic conditions in the studied area. The high ammonium and phosphate efflux was reflected in the water column inside the fish pen with higher nutrient concentrations and high chlorophyll-a concentrations suggesting that the pelagic primary production was stimulated.

The generated results were expressed in the form of mass balance for carbon, nitrogen and phosphorus (Fig. 6). The sediment accumulation was very high for phosphorus in the fish pens probably due to the large binding capacity of phosphorus in carbonate rich sediments compared to temperate sediments. The sediment accumulation was similar to salmon production for carbon and nitrogen in the order of 10–25% of the total input. The results obtained suggest that fish pen culture leads to even greater impacts on benthic carbon and nutrient cycling than those of suspended cage culture.

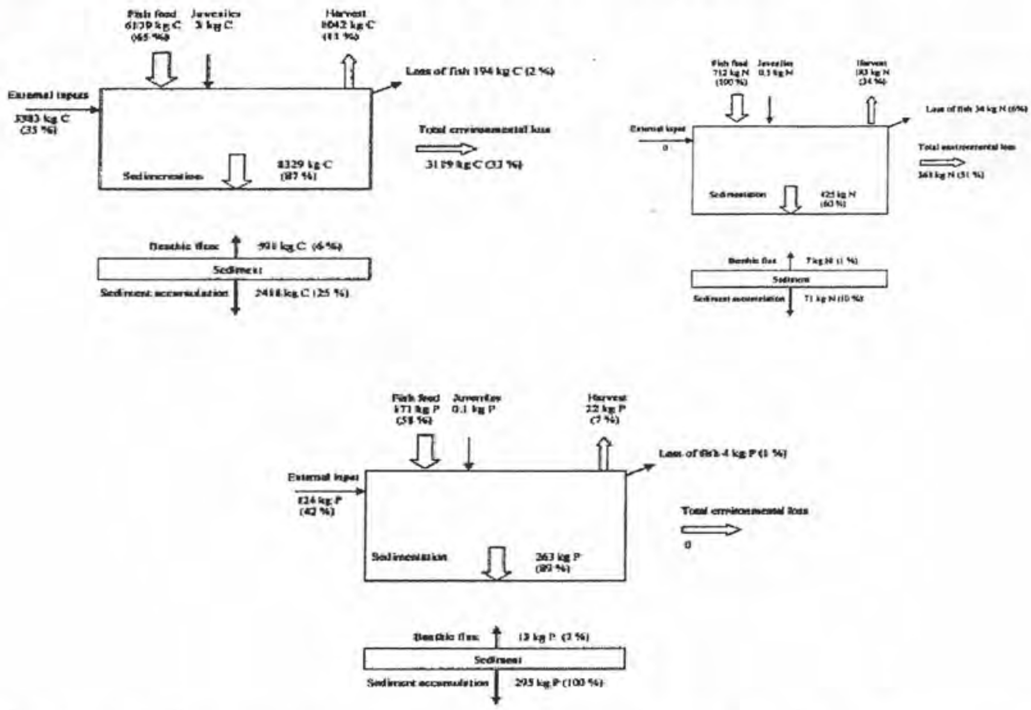


Fig. 6. Carbon, nitrogen and phosphorus mass balance in the fish pen for one crop production (5 months).

The soil quality management include the practices which will keep the sediment in a healthy condition and therefore, the productivity of the system is maintained. Such activity include liming and some of the practices as mentioned in the case study.

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Common health risks management of inland open water fishes

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The inland fisheries resources of India are noted as much for their heterogeneity in composition as for as their opulent productive potential. India is endowed with a vast expanse of open inland waters in the form of rivers, canals, estuaries, lagoons, reservoirs, lakes, ponds, tanks etc.

Although the vast and varied inland fishery resources of India have a rich production potential, this potential has not been achieved. The production potential of the major river in India, the Ganga, in its lower reaches, is estimated at 198.3 kg/ha/yr, whereas the actual fish yield is 30.0 kg/ha/yr, and thus, only 15.2% of the potential is harvested. At the present level of management, the yield from the Indian reservoirs, on average, is about 30 kg/ha, whereas a production of 50-100 kg/ha can be easily achieved from large and medium reservoirs, while the small reservoirs have the potential to yield 100-300 kg/ha. The floodplain wetlands, commonly called beels in India, have a rather poor yield, 100-300 kg/ha, against a production potential of 1,000-1,800 kg/ha/yr through scientific management. The present average productivity from aquaculture ponds and tanks is 1,830 kg/ha/yr against a much larger potential. These are the aquatic resources where future enhancement techniques like pen and cage culture are to be adopted. Thus it is relevant to understand the present environmental status of these ecosystems.

1. Status of aquatic environment as habitat for fish

With the outlook for fisheries shifting from increasing yield to increasing profitability the approach for fisheries development is to ensure sustainability and reduce environmental impacts. Thus knowledge of the relative state of any water-body is essential in relation to fish health status.

Rivers— Rapid urbanization, industrialization, and intensification of agriculture have all affected the rivers in different ways in India. Most Indian rivers, at present, are highly regulated. Human settlements, deforestation, mining and other activities have degraded the river catchments and increased sediment loads of all rivers. Also, during the past few decades, rivers have received increasingly large discharges of industrial effluents, fertilizers and pesticides from agricultural practices and domestic wastes (CPCB 1996). All this affected riverine biota.

Sewage pollution is the major source of water quality deterioration of our rivers. It results in deoxygenation, high BOD load, rapid eutrophication and accumulation of heavy metals in the environment. Sharp fall in dissolved oxygen in water puts the biotic communities under severe stress. Domestic and municipal effluents are estimated to constitute 75% of India's wastewater by volume .The enormity of sewage pollution is reflected in the river Ganga in which more than 70% of the total pollutional load is contributed by the sewage.Municipal sewage is very often accompanied by trade waste

synthetic detergents, heavy metals and (MBAS) from small scale industries sprawling around thickly urban areas.
Industrial wastes is the second most important pollutant in the rivers.3 million small-scale industrial units (SSIUs) about 35.30% of them are of polluting nature. Large water polluting industrial units discharging effluents into the rivers and lakes, only 29% have adequate effluent treatment plants. 229 class 1 cities in India generate about 16662.5 MLD of waste water whereas the capacity to treat only 4037 exists. 345 Class 11 towns generate about 1650 MLD of waste water whereas capacity to treat only 61.5 MLD exists.

Flood Plain wetlands: The floodplain wetlands (beels and bheries), the second-most important inland resource in India, located in the states of West Bengal and Assam, are mostly in various stages of eutrophication, the majority of them are choked with submerged or floating vegetation and having sub-optimal water quality (. This has affected the general fish health condition, and most fishes are stressed and have retarded growth. The water quality of typical wetland *Beel* of theGanga- Brahmaputra floodplains ,Das 1999 show that the dissolved oxygen (DO) level is reduced to nearly 3.5 mg/L around 10 PM at night, and remains below this level for nearly eight hours, causing stress to resident fish. Moreover, un-ionised ammonia levels are in the range of 0.05-0.25 mg/L, which also act as a stress factor. As a result, the normal health of the fishes are affected. The sewage fed bheries of West Bengal where fishes are reared in approximately 4,000 ha of water area, the ecological conditions limit fish production. The water quality is sub optimal creating stressful condition for the fishes (Das *et al.*, 1994).

Reservoirs: Industrial development and urbanization in the catchment of reservoirs has caused eco-degradation. Degradation due to domestic water resulting in fish mortality has been reported in Musi, Byramangala and Hussain Sagar. Industrial waters have also in many cases degraded the system resulting in fish kills. Several workers have reported water quality deterioration in reservoirs due to effluents viz. by heavy metals in Tungabhadra reservoir, by effluents from Kanoria chemical plants containing high chlorine in Rihand reservoir by coal washery effluents in Panchet Dam by paper mill effluents into Hirakud Dam by effluents from coffee curing plant in Harangi reservoir; by effluent from synthetic fibre company in Bhavanisagar reservoir. Thermal power plants have also contributed in some cases in deteriorating the habitat status of reservoir by releasing hot water (40-45°C) and fly ash in Rihand reservoir .
There are various reports of fish mortality from different river systems of our country (Table-1).

Table 1. Fish kill reports from Indian rivers

Place	Year	Cause	Source
River Gomti, Lucknow	1983, 1984, 1986	Distillery waste	Joshi, 1994.
River Chahar, Alwage	1974	Pesticide	Joshi, 1994.
River Tungabhadra,	1984 1994	Poly fiber, royan effluents	Murthy, 1984.

Harihar			
River Ganga, Monghyr, Bihar	1968	Oil refinery effluents	Sunderesan *et al.* 1983
River Adyar, Madras	1981-82	Tannery effluents	Joshi, 1994.
River Gomti, Tripura	1988	Epizootic ulcerative syndrome EUS	Das and Das, 1993.
River Shella, Meghalaya	1988	EUS	Das and Das, 1993.
River Churni, West Bengal	1993 1997	Sugar mill effluents	Ghosh & Konar, 1993. Konar, 1997.
River Yamuna, Haryana	1999	Sudden increase in turbidity due to sugar factory discharge	Anon, 1999.
River Bhavani Tamil Nadu	1999	Untreated effluent of South India Viscose	Bhavani River Protection Council
River Burhi Gandak, Bihar	2000	Effluent from sugar mill	Alam *et al.* 2001.
River Sutlej	2001	Probably effluents of NFL and Punjab Alkalis and Chemicals Ltd.	The Tribune, Chandigarh. 24th November, 2001.
River Gomti Lucknow	2003	Effluent from sugar mill, paper mill, Sugar mill and distilleries, upstream of Sitapur and Lakhimpur-Kheri	India-ej News,13th July.2003
River Gedilam Tamil Nadu.	2005	Sugar mill effluents of Nellikuppam,	The Hindu, 11th May 2005
River Brahmaputra	2007	Chlorine in Waste water	CIFRI report,2007

Assessment of the impact of specific fish health problems has been constrained by the inadequate baseline data on the production figures for different fishes species caught from inland waters. This is precisely the reason which limits evaluation of production losses in India due to disease and other causes. It should be borne in mind that fish mortality is not the only determinant for evaluating the effect of fish diseases. Even stress and morbidity, which leads to weight loss and poor growth in surviving fish population contribute substantial losses to the fishers.

Biological requirements of fish

Fish are poikilothermal aquatic animals. To survive they need continuous acclimation with the environmental changes which occur due to alterations in the water quality and because of other anthropogenic factors. Knowledge of the environmental requirements is essential to maintain good growth and health of fishes.

Temperature : Fishes are often subjected to the hazards of rapid temperature changes in tropical waters either due to daily variations in water t emperature in shallow waters or thermocline in deeper water bodies, due to thermal effluents or simply due to stocking of fishes into warmer receiving waters. These temperature changes though sublethal, can place a stress of considerable magnitude on the homeostatic mechanism of fishes. Both defense mechanism and susceptibility to disease of a fish is dependent on temperature. Solubility of oxygen in water is also dependent on temperature. Higher the temperature lesser is the solubility of dissolved gases. But reverse is true for the pollutants (heavy metals, pesticides and crude oils).

Light : Normal orientation, movement, colouring, feeding and other physiological activities like breeding, gonad maturation are dependent on light. Sudden spot lighting sometimes causes fishes to panic, they attempt escape and a greater shadow can be fatal. Excess of light stops photosynthetic action and may cause sunburns of fishes.

Dissolved gases : Dissolved oxygen (DO) and nitrogen are of great importance for fishes. Concentration of oxygen in air in 260 mg/l but it is scarce for fishes in water (0 to 14 mg/l). Nitrogen is biologically inert. Depletion of oxygen in water will result in asphyxia in fishes. However, supersaturation of both these gases in water may cause gas embolism. In acid water, carrying capacity of haemoglobin is reduced. The minimum amount of dissolved oxygen required for good growth of fish is 5 mg/l. CO_2 is very soluble in water but its minimum presence in water is due to its less availability in air (0.04%). For healthy growth of fish 3 mg/l or less of free CO_2 is permissible in water bodies. High CO_2 concentrations are almost always accompanied by low DO concentrations.

pH : The recommended pH range for optimum growth of fish is between 6.5 to 9.0. Fish and other vertebrates have an average blood pH of 7.4. A desirable range for conducive water pH would be close to that of fish blood (*i.e.* 7.0 to 8.0).

Alkalinity : A total alkalinity of 20 mg/l or more is necessary for good productivity and for good growth of fish the ambient water should have more than 180 mg/l. Bicarbonate of water is dependent upon pH and temperature.

Ammonia : Ammonia in water is extremely toxic and even relatively low levels pose a threat to fish health. It is known that NH_4^+ is harmless to fish but NH_3 is toxic. Fish continually excrete metabolic ammonia directly into the surrounding water via gills where it gets diluted in natural waters but not so in confined waters.

Hydrogen sulfide : It is produced by chemical reduction of organic matter in water body that accumulates and forms a thick layer of organic deposit at the bottom. The bottom soil turns black and a rotten egg smell is discharged. The maximum acceptable level of undissociated hydrogen sulfide is 0.002 mg/l.

Suspended solids : These are solid particles (> 0.45 μm) arising from natural weathering of rocks, land erosion or wastes associated with certain industries like coal mining, sound and gravel extraction. It affects the gill tissues of the fishes depending on the nature of the solid.

Environmental stress and related fish diseases

Stress

Is an abnormal physiological condition of fish body functions resulting when its adaptive physiological responses to a single or cumulative stress factor are extended to or approaching the fish limit of tolerance for that stress factor.

Health

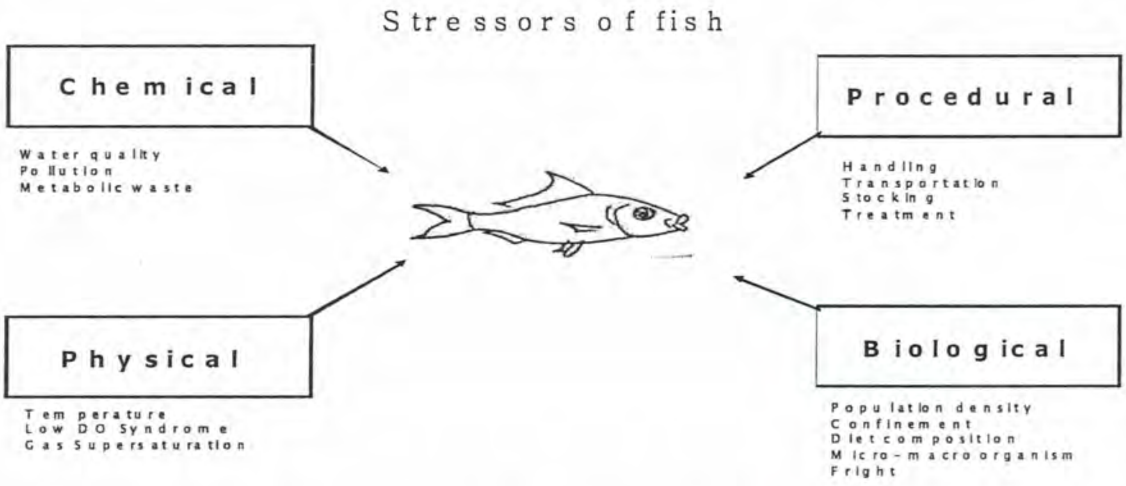
Is the normal physiological condition of fish body functions at a given time,. It is free of physiological abnormalities caused by stress or disease.

Disease

Is an abnormal physiological condition of fish body functions impaired by stress, inherent weakness of disease? It is obvious that stress health and disease parameters are interrelated. Stress of fish will proportionately affect fish health and may lead to infectious disease of fish health and may lead to infectious disease of fish, especially if compounded by two or more stressors. Disease will then further impair fish health. The interrelationship react in back and forth direction as indicated by solid and dashed arrowed.

Stressors of fish

The stressors which elicit morphological, biochemical, physiological and community response in fish fall into four categories as depicted.



A fundamental management objective in either culture or capture fishery is to avoid and minimize stress on fish. This requires an understanding of stressors and their effects on fish and an ability to recognize fish that are under stress.

What happens when the fishes are stressed?

The term stress or stressor or stress factor is defined as a force or challenge in response to which there is a compensatory physiological change in fish. Thus an environmental or biological stress is of significance if it requires a compensating response by a fish, population or ecosystem. It considers the stress response in terms of primary, secondary and tertiary changes that involves succeeding higher level of biological organization.

i) Primary response :Following perception of a stressful stimulus by the central nervous system the stress hormone *viz.* cortisol and epinephrine are synthesized and released into the blood stream.

ii) Secondary response :Changes in the blood and tissue chemistry and the haematology occur such as elevated blood sugar level and reduced clotting time. Diuresis begins followed by blood electrolyte losses and osmoregulatory dysfunction. Tissues changes include depletion of liver glycogen and interrenal vitamin C, hypertrophy of interrenal body.

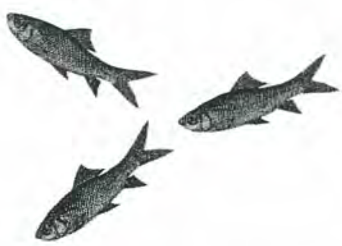
iii) Tertiary response :Manifest in reduction of growth, resistance to diseases, reproductive success and survival. There may be decrease in recruitment to succeeding life stages, as a result population decline occurs.

Stages of stress in fish

NORMAL

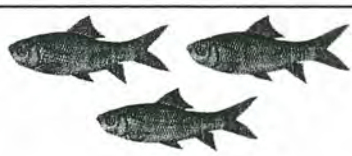
Healthy; alert; normal activity, body color, social (schooling) activity

ESCAPE



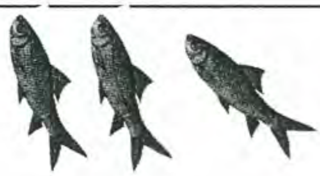
Healthy; alert; increased activity and body movement; slight increase in opercular (respiration) movement; possible slight body color change (usually darker); schooling fish remain together

ADAPT



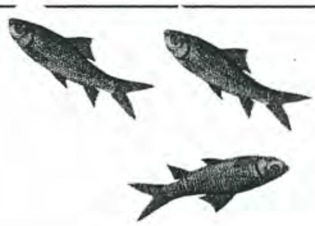
Healthy; alert; usually swimming higher than normal in water; increased opercular movement; schooling fish remain together

FATIGUE



Lethargic but sufficiently alert to avoid dip- no: capture; reduced activity and movement; usually gasping at or near surface; color change distinct (usually much darker); schooling fish separate 10 individuals

EXHAUSTION



Hanging listlessly, usually disoriented (commonly upside-down) at surface: little or 110 response to avoid dip-net capture

Stressors and their physiological impact in fishes:

A fundamental management objective of all fish rearing practices is to avoid and minimize stress on fish. This requires an understanding of stressors and their effects on fish and an ability to recognize fish that are under stress.

Aquatic stressors impact on fish health

Fish health management is basically dependent on a balanced interaction of three varibles viz., environment, host (fish) and pathogens. A shift in the balance in the form of deterioration of the water quality will lead to stress in fish altering their physiological competence and making it susceptible to pathogens in the environment.Thus the success of fish and fish populations in acclimating to alterations in the aquatic environment depends to a large extent on the ability of individuals to affect and maintain successful compensating responses.

Knowledge of the tolerance limits for acclimation to the single or cumulative effects of such biotic and abiotic stress factors forms an important part of the database for species habitat relationship needed for effective fishery resource management (Wedemeyer *et al.*, 1984).Keeping this aspect in view the succeeding pages will elaborate on the various laboratory and field investigations conducted to demonstrate firstly how many of the environmental factors influence the health status of fish through alteration of physiological competence of fish and secondly the use of some of this bioindicators at the primary, secondary and tertiary levels of biological organization for assessing fish and aquatic ecosystem health.

Development of clinical profiles for diagnosis

Clinical profile of healthy normal fishes and those subjected to stressors low DO ,high or low temperature, pH ,high unionised ammonia ,phenol, heavy metals and its combination, determined and can serve as guideline for clinical pathological reference by health workers.

Haematological profile of normal fish

In order to diagnose the stressed condition of fish information on the normal blood levels of fish is essential for a fish health worker to differentiate between the normal and stressed condition of fish. Das *et. al.* (2002 and 2003) established the normal range of haematological values for the stress sensitive parameters in *L. rohita* and *R. rita* under specific range of water quality conditions regarded as optimum for fishes. It is suggested that the range of values can serve as a guide for carps and catfishes for stress diagnosis.

Temperature --Fishes are often subjected to the hazards of rapid temperature changes in tropical waters either due to daily variations in water temperature in shallow waters or thermocline in deeper water bodies, due to thermal effluents or simply due to stocking of fishes into warmer receiving water. These effects often become additive or synergistic with those of other adverse stimuli (*eg.* low water *p*H, algae, oxygen shortage). Thesesublethal temperature changes can place a stress of considerable magnitude on the homeostatic mechanism of fishes.

High temperature : Experiments conducted by Das et.al, 2002 on juveniles of fish *L.rohita* and *R.rita* subjected to a rapid (5 min) sublethal temperature increase from 28 to 35 °C showed significant increase in cortisol and decrease in interrenal ascorbic acid. Hypercholesterolemia, hyperglycemia and hyperlactemia were also evident accompanied by increased blood haemoglobin and haematocrit and stable protein levels. Compensatory responses were initiated within 72 hr in both the fishes. *R.rita* recovered more quickly indicating it to be more resistant to the heat stress than *L.rohita.* Hence fishes subjected to sublethal temperature stress should be given a metabolic recovery period of 72 hr prior to further stress being applied.

Low temperature : The physiological effect of cold shock on *Labeo rohita* was studied in the laboratory by Dutta etal,2002. The low temperature shock at 5°C was given to juveniles of the fish for 5 min. and subsequently transferred to aquarium water of 28°C for recovery.A significant decrease occurred in anterior kidney ascorbic acid level. There was a rise in plasma cortisol within 20 min after the shock. Plasma chloride levels decreased significantly but subsequently recovered. Plasma glucose level increased due to glycogenolysis in muscle and liver. Plasma lactic acid level increased and persisted upto 24 hrs of recovery.

In another study(NPCC/CIFRI annual report) conducted to assess the impact of low temperature on fish, *L. rohita* juveniles were subjected to gradual lowering of the ambient temperature from 28°C to 13°C (critical temperature for *L. rohita*). The result indicated significant rise in plasma cortisol with hyperglycemia. There has been a cessation of feeding and sudden burst of activity followed by a state of total cessation of activity. But death did not occur as the fishes recovered when placed in warmer waters after thirty minutes.

pH -- In aquatic ecosystem, the pH of water is one of the most important water quality parameter influencing the health of fishes. Most natural waters have pH ranging from 6.5 to 9.0. In water bodies having pH less than 6.5 or more than 9.0, the stress exerted on the resident fishes affects reproduction and growth over a period of time.Experiments were conducted by Acharya et. al 2005, in *Labeo rohita* fingerlings exposed to sublethal acidic pH of 5.5 and alkaline pH of 9.0 for a duration of 30 days to make a comparative assessment of the physiological changes occurring in the fishes.

Fingerlings of *Labeo rohita* exposed to sublethal acidic pH of 5.5 and alkaline pH of 9.0 for 30 days exhibited changes in various physiological parameters. At pH 5.5 fishes from 7 day onwards elevated levels of haemoglobin, haematocrit, plasma cortisol, glucose, cholesterol, protein and lactic acid with reduced levels of plasma chloride, hepatosomatic index, RNA/DNA ratio of muscle and condition factor were recorded. No indication of metabolic recovery was observed at the acidic pH. Fishes exposed to pH 9.0 also showed similar changes in the various parameters only after 21days of exposure. Ultrastructural alterations of gills in fish at acidic pH were rugose lamellar surface, destruction of normal secondary lamellae, release of blood cells, increased mucous production and loss of microridged patterns on the epithelial cells of filaments. At pH 9.0 fusion of secondary lamellae occurred. The extent of alterations in blood parameters with the ultrastructural changes in gills of the exposed fish was greater at pH 5.5 than at pH 9.0. These results suggest that the fish are under greater physiological stress at the acidic pH.

Unionised ammonia ; Ammonia (NH_3) has long been recognized as one of the principal fish toxicants encountered in intensive culture systems. Two major sources of NH_3 are from fish excretion and decomposition of nitrogenous organic compounds in fish rearing water bodies. The accumulation of toxic metabolites, mainly ammonia, is one of the important factors limiting stocking densities in ponds.

Effects of ammonia toxicity in some blood and tissue parameters of *L. rohita* fingerlings subjected to sublethal level of unionized ammonia (UIA-0.132mg/l) for 30 days were studied (Acharya et al, 2005) . The 96h LC_{50} was found to be 0.512mg/l of UIA for the fishes.
Fingerlings of Labeo rohita subjected to sublethal unionized ammonia (0.132mg/l) for 30 days exhibited significant changes. Increase in haemoglobin, haematocrit, plasma cortisol , plasma glucose, plasma cholesterol and plasma lactic acid levels whereas, decrease in plasma chloride, liver and muscle glycogen , hepatosomatic index and DNA/RNA ratio of muscles with stable plasma protein was observed. Metabolic recovery was not observed within 30 days of exposure.

Nitrite : High nitrite levels in water may develop as a result of an imbalance between the bacterial nitrification and denitrification processes of ammonia. One prime toxic action of nitrite is that it oxidizes haemoglobin to methemoglobin. As nitrite raises the fraction of methemoglobin in the blood, it reduces the total oxygen carrying capacity of the blood.

Study conducted by Acharya et al, 2005 to evaluate the changes in various blood parameters of the fish *Labeo rohita* exposed to sublethal levels of nitrite (0.02mg/l, 0.1mg/l and 0.4mg/l) for 2,24,48, and 96 h.indicated that the time of exposure at individual concentrations did not show any significant differences in haemoglobin, cortisol,chloride and lactic acid. Haematocrit showed significant reduction with increasing concentration of nitrite irrespective of duration of exposure. Fishes exposed to 0.4 mg/l nitrite showed significantly high levels of glucose beyond 2hr. The mean erythrocytic fragility of fishes exposed to the3 concentrations of nitrite for 3 exposure periods showed significantly higher sensitivity to osmotic stress. The results suggest decrease in haematocit and cell wall strength of erythrocytes creating stress to fish.
Water quality impact in culture ponds : The impact of optimum and detrimental water quality on the stress sensitive physiological parameter of fish *L. rohita* were assessed in two fish culture ponds of West Bengal (Dutta et al ,2005) . S1 a 1ha static fresh water pond with optimum water quality where *Labeo rohita* was cultured with *Catla catla,* and *Cirrhinus mrigala* at a combined stocking density of 6000/hectare and species ratio 3:4:3. Organic cowdung was the main fertilizer and the fishes fed on natural feed. S2 the second pond was a 10ha sewage fed wetland (bheri) where *Labeo rohita* was cultured with *Catla catla, Cirrhinus mrigala* and *Tilapia mossambica* at a stocking density of 6000/hectare with a stocking ratio of 3:3:3:1.The main fertilizer and food for fishes in the culture area was Kolkata municipal sewage water.
The investigation was conducted for 12 months. The water quality parameters were assessed in relation to the impact on the stress sensitive physiological parameters of fish Labeo rohita. Optimum levels of transparency, dissolved oxygen, unionised ammonia, alkalinity and hardness in S1 reflected in minimum variation of the physiological parameters of L. rohita but suboptimal levels of DO (nil-18.0mg/l) and CO_2 (nil-16.0mg/l) observed diurnally and unionised ammonia (0.11-0.42mg/l) found throughout the experimental period in S2, resulted in significant variation in plasma cortisol(90.0-377.0ng/ml), cholesterol(89.6-285.0mg/dl) and condition factor (0.7-1.3) in L. rohita. The results are of significance for fish aquatic habitat management.

Cultural practices as stressor

Fishes are frequently subjected to the stress of cultural practices adopted by farmers like handling, crowding, transportation or a combination of all the three procedures. These effects often become additive or synergistic with those of other stimuli (*e.g.* low unionized ammonia and dissolved oxygen) and can place a stress of considerable magnitude on the homeostatic mechanism of fishes. This may be the possible reason for the seasonal post stocking mortality of fishes. The severity of stress and the period needed for their recovery are not very clear in fishes.

Study conducted on these aspects by Dutta *et. al.* (2002) on *L. rohita* revealed that the fishes subjected to crowding, handling and transportation stress in hundis for 1 hr are also subjected to additional stress of perceptible water quality changes. It was observed that there is a gradual depletion of dissolved oxygen from initial 6.8 mg/l to 1.8 mg/l, UIA from nil to 0.1 mg/l and CO_2 from 2.0 to 6.6 mg/l. Thus a hypoxic condition is created along with toxicity produced by rise in unionized ammonia levels. These stressors have significantly altered as depicted in Table- 2.

Some of the blood and tissue parameters *viz.* plasma, cortisol, glucose, lactic acid and liver glycogen, haemoglobin and haematocrit were elevated compared to normal values. However, it is also observed that the fishes recovered after 48 hr post stress period. It indicates that the cultural procedures frequently adopted by the farmers significantly stress the fishes resulting in post stocking mortality. For proper fish health management fishes subjected to such stressors should not be further stressed with 48 hr for their metabolic recovery. It is apparent that the homeostatic mechanisms of fish are continually being impacted by the normal demands of the aquatic habitat itself. Coupled with it may be the effects of aquatic pollutants and in many cases fish cultural practices like handling, crowding and transportation. Although fishes very often do survive stressors for limited periods because of their homeostatic capabilities marginal conditions should not be created in the aquatic environment. Knowledge generated on the physiological capabilities of fish should be used to set priorities and tolerance limits that will protect fish and aquatic ecosystem health.

Biological stressors

Various microorganisms (bacteria, fungus) protozoans as well as macro organisms (ectoparasites) are major stressors of fish as well as being pathogenic to fish, often as a result of stress. Urceolariid ciliates (Trichodina sp. Tripartialla Sp.) can serve as a good indicator of stress in fish .An average number of these trichodinids above 20 in 0.05 ml of gill mucus is indicative of stress and sub optimal water quality (Das et. al.1997).

Parasitic diseases

A parasite is an animal which spends part or all of its life living at the expense of another animal, known as the host. There are thousands of fish parasites but few are cause diseases of significance. In open waters many freshwater fishes are infected by parasites but very few reports of them causing serious damage to fish populations are documented. However, in culture facilities may of these parasites cause serious outbreak of disease. Parasites range in form the microscopic to those which can easily visible. These are broadly divided into the Protozoans and Metazoans.

Ichthyophthiriasis

The white spot disease or ichthyophthiriasis is a common disease of freshwater carps affected fishes exhibit minute white nodular spots on the skin, fins and gills and are restless. The causative is *Ichthyophirius multifilis.* The infective stage in the host is the migratory thereon which infests fish slim or gills. Here it grows as trophont (adult parasitic) and on reaching 1 mm size escapes from the host move slowly with characteristic horeshoc shaped macronucleus and encyst (tormont) on a convenient substrate. The tormont break to release the infective thereouts which remain infective for four days. The control of this infection is concentrated on the life stages outside dermal tissue of host. This can be controlled by hourly bath treatment for 7 days in 2%-5% NaCl solution. Pond treatment advocated is application of 15-25 mg/l formalin.

Trichodiniasis

Various life stages of Indian major carps and catfishes and most of the freshwater fishes are affected by the parasites. Affected fishes exhibit pale coloured gills with a creamish coating due to excessive mucus secretion and mild hyperplasia. The causative agent is urecolarii ciliats of the genus *Trichodina, Triparticella* and *Trichodinella.* These are beautiful looking with shape varying from a flat disc to a bell shaped one. It attaches to the fish gills by means of the adhesive disc constituted by skeletal elements. It reproduces by binary fission. The presence of these ciliats indicate deteriorating water quality thus the treatment methods adopted are (i) water quality improvement (ii) diminishing stocking density of fish (iii) bath treatment of fishes with 2-3% NaCl or 50 mg/l $KhnO_4$ (iv) pond treatment with 5 mg/l $KMnO_4$ or 25 mg/l formalin.

Myxo sporeans disease (white spots on gills or scales)

Indian major carps gills are infected with white to creamish cysts ranging from 1-4 mm or more. In heavy infection the cysts assume a cauliflower shape blocking the entire gill surface of the host. The respiratory surface of gill is blocked with excessive mucus secretion hyperplasia and asphyxiation. Affected fests are tellioușe-incepted spores of *Myxobolus bengalensis, M. catlac, M. hosadurgensis* and *Thelohancellus eatlac.* Besides the gills scales and body surfaces are also heavily infected with the cepts in *C. mrigala* and *L. rohita.* Affected fishes are tetlargic with loose perforated scales and ulcerations. The causative agents are the encysted spores of *Myxobelus mrigalae M. sphericum* and *M. rohitac*. The infective stage of the myxosporeans is the mature spore which is ingested by the fish from the water body On entering the fish the infective sporoplasma of the spore comes out as a small amacloula and penetrate the gut wall. This amoeba reaches the infected tissue possibly through blood stream where it becomes a tropliozoit and increases in size to form a cyst. Here the mature spores develop. The life cycle of myxosporeans offer them a high degree of protection against most control measures. Life cycle stages which are vulnerable to control measures, occur within the tissues of the host and are not easy to reach. The spore though exposed outside is very resistant to chemicals. Thus the control measures are limited to prophylactic measures like (i) control spores from entering fish ponds (ii) segregation of age groups as fry and juveniles are more susceptible. Therapeutic measures done are disinfections of pond after dewatering with CaO and drying for a month.

Dactylogyrosis and Gyrodactylosis

This disease affects fry, fingerlings and adults of the cultured. Indian major carps causing extensive losses. In dactylogyrosis the colour of the gills fade and there is excessive mucus secretion. In gyrodactylosis there is a fading of the normal body colour, dropping of scales and excessive mucus secretion. In general there is growth reduction and morbidity in affected fishes for both the diseases. Adults of these monogeneans attach to the host by a characteristic attachment organ called haptor, which produces damage to the attaching site. These monogeneans have a direct life cycle involving a single host. *Dactylogyrus* P is oviparous laying eggs as which liberate free-swimming larvae. These larvae on locating a new host become attached and metamorphose into a mature worm. *Gyrodactyhus* sp. is viviparous and liberates young worms which attach to a new host. The parasites can control by therapeutics *viz.* (i) bath treatment with 1-5% NaCl for 10-15 min. or 100 mg/l formalin with aeration (ii) pond treatment with 25 mg/l formalin or 2-5 mg/l $KMnO_4$.

Argulosis

Indian major carps are mostly affected by the parasites. The affected fishes are restless with erratic swimming behavior and loss of appetite. Attachment site of parasites show sign of ulceration growth retardation and occasionally mortality occur. The causative agent is the branchiran parasite *Argulosis foliaceus, A. bengalensis* and A. siamensis in Indian fishes. The adult parasite is oval, flat and transparent to whitish with two conspicuous black spots. It is visible moving freely on the surface of the host fish and is distinguishable into cephalothoraxes, thorax and abdomen. It matures inhabiting the host fish. After copulation the female leaves the host and lays sticky eggs on the submerged vegetation, rocks, sticks etc. The nauplius and other developmental stages, which are free living are parasitic to fish. The minimum period required for completion of the life cycle of Argulus sp. varies between three to six weeks. Argulosis are initiated when parasitised fishes enter unaffected water areas. Argulosis controlled by (i) bath treatment with NaCl @ 3-5%, (ii) pond treatment with $KmnO_4$ @ 5 mg/l, (iii) mechanical removal of *Argulosis* sp. sticky eggs by hanging bamboo mats or corrugated sheet in the water area and its removal and drying in the sun after a week.

Ergasilosis

The disease occurs in Indian major carps and exotic carps. Infestation occurs in gills, buccal cairty operculum, and gills. The parasitic copepods look like white bodies less than 2 mm long. Surfacing, lethargy and restlessness occur in affected fish. Infection increases with size of the fish causing damage to gill tissue and retardation in growth. The causative agent is species of *Ergasilus*. The adult female is parasitic and lodges firmly in the gills by second antenna modified into hooks. The parasites are controlled by pond treatment with Potassium permanganate # 5 mg/l or bath treatment of affected fish with 2-3% sodium chloride.

Lerneosis

The disease is prevalent in Indian major carps. Heavily infected fishes become moribund with erratic movement and emaciation. Attachment areas on host exhibit sloughing off and ulceration. The causative agents are *Lernaca chockoensis*, *L. bengalensis* and other species of *Lernaca.* The adult female of this parasitic copepod, anchor to the fish by cephalic processes of the modified head. The parasites are controlled by the same treatment of Ergasilosis.

Saprolegniasis

Eggs, fry and fingerlings of cultured Indian and exotic carps are affected. Infection is characterized by presence of a cotton wool like growth on fish or fish eggs. Fishes become lethargic and listless forming mycotic granuloma in acute cases. The causative agent is *Saprolegnia parasitica* characterized by filamentoas non-septate hyphae. The myclelial branolis profusely and intertivine to produce the white tuft. The chemicals treatment used to control this infection are (i) Bath treatment with Sodium chloride @ 3-5% or Malachite green @ 1-2 mg/l for half an hour for fingerlings and adult and flashed with 2 mg/l Malachite green the affected eggs for 5 days.

Branchiomyosis

Fry, fingerlings and adult of Indian major carps and exotic carps are affected by the disease. Diseased fishes gills lose their normal red colour and turn yellowish brown with gradual degeneration. The gill rot is caused by the pathogenic fungus *Branchiomyces demgrans* and *B. sanguinis.* Deteriorating water quality acts as a pre-disposing factor for proliferation of the parasite. The control measures advocated are (i) proper maintenance of quality and hygienic of the water bodies (ii) bath treatment of affected fishes with 3-5% Sodium chloride (iii) Lining with CaO @ 50 kg/ha.

Dropsy

The disease affects juveniles and adults of *Catla catla*, *L. rohita* and *S. mrigala*. Infected fishes exhibit accumulation of water in the body cavity and in scale pockets with loose scales. The abdomen is distended with mild ulceration. The causative agent is species of *Aeromonas.* The disease is controlled by (i) maintaining hygienic condition of the water body (ii) Application of bleaching powder 1 mg/l or 5 mg/l Potassium permanganate.

Columnaris disease

Indian major carps and exotic carps are affected by the disease. Initial stages exhibit grayish patches overhead and dorsal sides later on red ulcerations appear with erosion in the distal gill filaments. The causative agent is the bacteria *Flexibacter columnaris.* The disease is controlled by (i) improving the water quality (ii) Dip treatment in 500 mg/l Potassium permanganate (iii) Pond treatment with 5 mg/l Potassium permanganate.

Haemorrhagic septicaemia

The disease affects Indian major carps and catfishes. Infected fishes show external lesions and ulcerations. The epidermal as well as the scales are lost and lesions become prominent. In advanced cases large cutaneous haemorrhages occur. The causative agents are species of the genus *Aeromonas* and *Pseudomonas* which cause ulcers on fish populations stressed by high stocking density and bad water quality. The control measures advocated are (i) improving water quality (ii) pond treatment with Potassium permanganate @ 5 mg/l or Bleaching powder @ 1 mg/l (iii) Hourly bath in 8-10 mg/l chloromycetin on three consecutive days.

Eye disease of *Catla catla*

Advanced fingerlings and adults of *C. catla* are affected by the disease. The eyes look reddish due to vascularization and later on become opaque. The eyeball gets putrefied leadin got death of fish. The remedial measures advocated are (i) Maintaining high dissolved oxygen and hygienic condition of the pond (ii) Pond treatment with 5 mg/l Potassium permanganate.

Epizootic ulcerative syndrome

The disease affects both wild and cultured fishes. Affected fishes exhibit abnormal swimming behavior. Initial symptoms appear as red spits on the body causing localized ulcerations. These spread to become bigger ulcers with sloughing of scales. Gradually the ulcers become deep with a peripheral black melanistic ring. In advanced stage ulcers can be seen in all parts of the body of the fish. Uniformly fishes in advanced stage of infection have necrotising ulcerative lesions typically leading to granuloma formations. It is suspected that a biological infectious agent is the primary cause of EUS. Some abiotic factors act as predisposing factors for EUS outbreak like water areas with low alkalinity and hardness – a characteristic of acidic low calcium, soils. The suspected biological agents are viral, bacterial, fungal and other animal parasites as evidenced by investigations conducted throughout the world. But recent pathological and epizootiological evidence indicated that EUS is a seasonal epizootic condition of freshwater and estuarine fishes of complex infectious aetiology, characterized by presence of invasive *Aphanomhyces* sp. infection leading to mycotic granulomatosis. The remedial measures for the disease are confined to small manageable fish rearing water areas. The chemicals used for containing the disease are *viz.*

i) **Lime :** A dose range of 100-600 kg/ha has been found effective. In water areas having alkalinity below 20 mg/l the higher doses of lime is applied and in water areas with alkalinity greater than 40 mg/l lower dose of lime (CaO) is applied.

ii) **Lime and bleaching powder :**

Prophylactic : Application of CaO @ 50 kg/ha and after one week bleaching powder @ 0.5 mg/l is disease prone water areas.

Therapeutic : Application of CaO @ 100 kg/ha, depending upon the pH and after one week bleaching powder application @ 1 mg/l when initial symptoms of EUS appear.

iii) **CIFAX :** A drug formulated by CIFA when applied @ 1 litre per hectare meter of water area on EUS affected fishes is reported to cure the diseased fishes.

Gas bubble disease

Small fry and fingerlings of *C. mrigala* and *L. rohita* are affected by the disease. The young fishes slow erratic movement and gradually die exhibiting a whirling movement. The abdomen is swollen. The balance of the fish is lost due to accumulation of large gas bubbles in the intestine. The disease normally occurs in water areas where load of organic fertilizers is high at the pond bottom. In the anaerobic condition existing at the bottom of such water areas the fertilizer or manure undergo decomposition releasing gases in the form of bubbles. The fingerlings fry to ingest them mistaking it for planktonic food and accumulate in the intestine disturbing the fishes balance. The diseased condition can b e avoided by (i) stopping application of unfermented fertilizers and (ii) addition of freshwater to the water areas.

Gill disease

It is caused by a variety of water borne irritants. There are suspended matters of

$< 0.45\ \mu$ m size arising up out of coal washings, cement or dust arising out of various factory discharges. Besides these particulate irritants other chemical irritants of the gills are ammonia, nitrite or fluctuating pH, low D.O. with any combination of high CO_2 and decreased pH also cause problems.

The early signs of this gill disease in fish respire heavily with greater opercular movement. Fish tend with use one pectoral fin only with excessive mucus secretion. In advanced cases fish cannot fully close the opercular because of gill swelling due to hyperplasia.

The condition can be checked by proper water quality management.

Algal disease

Some organisms co-existing with the fish as components of the same environment might become harmful or lethal fry, fingerlings and adult of Indian major carps, exotic carps and other catfishes are very affected. Surfacing of fish occur with erratic movement. There is clogging of the gills by the algae causing respiratory distress and mortality in some case. The causative agent is the bloom condition of blue green algae. Microcystis and *Anabaena* sp. It is often encountered in eutrophic water areas. The pea soup coloured bloom of algae may occur due to excessive use of fertilizer and feed. Overcrowding of algae causes its mass mortality. The dead and decomposing cells release enough breakdown products or toxins harmful for fish. The bloom condition can be controlled by (i) copper sulfate application @ 0.5 mg/l (ii) sprinkling cow dung @ 200 kg/ha over surface of water or covering it with water hyacinth thereby blocking sunlight.

Nutritional diseases

Normal health of the fish is a manifestation of proper feed availability in the water body. Nutritional diseases are difficult to specify since a pathological condition cannot always be attributed to nutritional inadequacies. Some of the disease conditions are as follows :

Starvation

A starved condition of fish in a water body can result from (a) complete deprivation of food (b) inadequate supply of feed (c) not acceptability of feed. The symptoms of starvation are enlarged head and very slender body, darker colour, retarded growth, emaciated bodies, soft flesh and pale gills. These fishes harbour higher parasitic load than normal fish. The starved condition can be avoided by providing nutritionally balanced diet. This requires an understanding of the nutritional components causing deficiencies in fishes. These are *viz.*

Proteins : Proteins are essential for maintenance, growth, reproduction and repletion of depleted tissues for energy metabolism. Ten amino acids constitute the most important component in the nutritional value of proteins.

Carbohydrates : Compared to higher vertebrates dietary carbohydrates are less metabolized by fishes. Excess of carbohydrates in diet of cyprinid fishes very often lead to excessive glycogen deposition in liver with consequent degeneration of hepatic tissue.

Lipids : The fat component of the diet must provide sufficiency of essential fatty acids as well as calories energy. Fishes appear to synthesize most of the required fatty acids except the linoleic or the linolenic seris, which is essential for normal growth.

Vitamins in fishes are of two classes *viz.* (i) fat soluble vitamins which are vitamins A, D, E and k all essential of healthy growth of fish (ii) water soluble vitamins which are Thiamin, riboflavin, pyridoxine, pantothenic acid, biotin folic acid, cyano cobalamin, choline and ascorbic acid.

Indicators of health condition of fish stock

Escape reflex **:** External agitation such as quick motion, stamping on the bank, sound etc. cause health fishes to quickly submerge under water. Sick fish do not react and can be caught easily.

Defensive reflex **:** A healthy fish caught from water toss about quite violently when placed on ground and calm down after a while. Sick fish are sluggish in water as well as out of it.

Tail reflex **:** When the fish is held by the head and posterior portion in free it keeps the posterior fin in a horizontal position or even slightly obliquely upward while the caudal fin is always stretched in a fan shape.

Management guidelines to avoid fish health problems

1. Select good fish stock. Fish with poor genetic composition or in poor health and physical condition will grow slowly, convert feed poorly and general production performance will always be lower than for fish of select quality. Guidelines for choosing good stock include:

    - Choose proper species for culture environment
    - Use only selectively bred stock
    - Use only fish in good general condition and free of disease

. Handle fish with special care when collecting, holding, transporting, stocking and sampling. Improper handling of fish is one of the most serious and common stressors that cause poor fish production, disease and death. Guidelines for proper handling include:

2. Identify and minimize individually all chemical, physical and biological stressors for each handling situation. Be especially conscious to avoid the most common stressors. For example:

- Never remove fish from water unless absolutely necessary
- Do not hold fish out of water longer than absolutely necessary
- Do not stack layers of fish out of water in nets and containers (e.g. baskets)
- Do not hold fish at high densities in closed water containers (e.g. tubs and tanks) without proper aeration and water quality control
- Do not change water temperature around fish by more than 4°C at one time and by 2°C/hour over long periods of time
- Do not measure and weigh individual fish unless there is some specific need for that information and the fish are expendable

Treatment Of Diseased Fish

Disease epizootics in caged fish do occur, though in well managed cages/ponds it is restricted These epizootics usually correct themselves if the fish are in a relatively stress free environment and receiving good nutrition. However, sometimes chemotherapeutic treatment may be necessary. The treatments may be necessary in holding and handling facilities before stocking, in ponds, but not in large reservoirs and lakes where cages arc suspended, and directly in cages.

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Protocol for diagnosis and treatment of some common fish diseases

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Myxozoan Parasites:

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

Test Samples: Fish with white spots in gills.

Collection, fixation and staining.

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

Procedure: (Fresh preparation Lugols' iodine preparation)

For contact smear the different organs are smeared on a clean glass slide with a drop of 0.5% normal saline solution. The smear is covered with a cover slip, paraffin sealed and examined under microscope.

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

Results:

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

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

Procedure (Staining)

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

Urcealariid ciliate viz; Trichodina sp and Tripartiella sp. Are frequently found in the gills of fishes. Their identification in fresh smear from gills is easy as they move about freely. But for species identification they are to be stained permanently by Klein's' Silver Impregnation technique.

Collection, Fixation and staining.

Test Sample; a fish with pale cream coloured gills.

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

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

Examination of fish for bacterial pathogens

Test Sample: diseased fish with lesions suspected to be affected with bacterial disease.

Procedure:

- Scrap the gills or skin and transfer the scrapings to a microscopic slide or a small portion of the tissue is macerated and put on a slide in a thin uniform smear.
- These are examined under microscope.

Isolation of Bacteria for Culture:

This step is normally taken for sampling the fish/prawn at the disease outbreak site.

Test Sample: diseased fish with lesions on body suspected to be affected by bacterial disease.

Procedure.

- All the instruments and hands of the examiner are washed with 70% alcohol.
- The lesion is cleaned with 70% alcohol.
- A sharp scalpel is heated, cooled and an incision is made deep in the wound.
- The bacterial plating loop is heated red hot on a spirit lam/Bunsen flame, cooled and inserted 2-3 mm inside the incised tissue.
- The nutrient agar plate is opened near the flame, the loop containing sample is spread on one portion of the plate and the plate closed.
- Again the loop is heated red hot and cooled.
- The plate is opened and the inoculated sample spread over it in 3 streaks. The plate is closed.
- The process of heating and cooling is repeated and finally the streak brought into a single line.

- The streak plate is then sealed with paraffin for transportation to the laboratory.
- The plate is then placed in the incubator at 37°C for further development of the bacterial colony

Examination of fish for fungal pathogen:

Collection, Staining and Identification

Test Sample: A fish with lesions and fungus having a cotton wool appearance near lesions.

Procedure

- A portion of affected tissue is teased out and smeared on a slide
- A drop of Lactophenol or cotton blue is put on the smear and a cover slip is pressed on it.
- The sides of the cover slip are sealed with paraffin
- Observe under a microscope.

Results

Non septate hyphae and zoosporangia stain blue………..*Saprolegnia sp*

Examination of fish for Helminth parasites:.

Procedure: (Collection)

Monogenetic trematodes like Dactylogyrus sp infect gills. They are carefully teased out under the dissecting microscope and placed in a watch glass containing normal saline. Digenetic trematodes and cestodes may be infesting various organs of the body. They are also similarly removed and placed in normal saline.

Procedure (Fixation)

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

Procedure (Preservation)

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

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

Procedure: Staining (Trematode and cestode)

Semichon's Carmine Method.

- Take the preserved specimens in a watch glass
- Wash thoroughly in 70% alcohol
- Place in diluted semichon's carmine for 3-5 minutes or more according to the thickness of the specimens.
- Destain in acid alcohol and wash thoroughly in 70% alcohol.
- Dehydrate through 90% and absolute alcohol grades.
- Mount in Canada balsam.

Procedure: Staining (Acanthocephalan and Nematodes)
Lactophenol Method

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

Examination of fish for Crustacean parasites:
Parasitic copepods and Branchiurans
Preservation

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

Procedure: (Fresh Preparation)

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

Procedure(Staining)

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

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EIA of cage and pen culture on inland waters

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The introduction of pen culture in inland waters changes both biotic and abiotic components of the environment. An enclosure is an open fish rearing system than the land based ponds, raceways or tanks and there is greater interaction between the penned fish and the out side environment. By contrast, enclosures use existing environments to grow fish. Pens thus can be considered as a subcomponents of the aquatic ecosystems in which they are sited, since the enclosure and the surrounding environment are intimately related i.e. changes occurring in the water body will have an effect on the enclosure environment and vice versa. There is little opportunity to treat wastes emanating from pens.

The environmental impact of pen culture in inland waters is as follows:

Disease

The occurrence of disease outbreaks in fish farming is usually associated with bad husbandry as the disease causing organisms cause problems when the fishes become stressed due to inadequate dietary or environmental condition. The introduction of large number of fishes in enclosures has a dramatic effect on disease agents. Diseases from outside the enclosure site can easily be introduced by transportation of fry/fingerlings from other areas with out proper precautions being taken. It has been reported that the parasites present in the wild fishes reach abnormal level due to increase densities of fish and changes in environment subsequent to the introduction of pens in inland waters.

The role of increased nutrient levels often associated with intensive pen culture in promoting proliferation of parasites. Eutrophic conditions may also favour increased production of intermediary hosts like crustaceans. In intensive pen culture system, fishes may expose to high levels of free ammonia and succumb to parasitic epizootics.

Predation

Pen farming fishes act as magnet to a wide variety of fish eating vertebrates. They are predatory fishes, reptiles, birds and mammals. Many of these species move into an area where pen farm has already been established, attracted by large numbers of readily detected fishes and also by the heaps of fish feed kept on the site. There has been very little evaluation of the impact of these predators either on the environment or on the enclosed fish. However, 0.5% of all the penned fish generally shows evidence of bird damage, which could lead to secondary bacterial or fungal infection.

Damaged to nets by unsuccessful predators such as birds, turtles, monitor lizards and rats have been reported from several pen farming areas. Predation of wild fish may increase through the attraction of predators to the enclosure site. Another serious problem is the impact of the immigrant predator population on disease causing organisms transfer to the pen farmed fishes. It is experienced that both birds and mammals play important role in the life cycle of many endoparasitic fish diseases.

Impact of pen culture

Intensive culture of fishes in pens has largely restricted at present in lakes and reservoirs in temperate regions. This type of fish production system has resulted in high levels of waste production per unit of live weight, compared to other live stock such as chicken, swine or cattle. Irrespective of differences in methodology, species cultured and site of culture, most studies have recorded an increase in suspended solids and nutrients and decrease in dissolved oxygen level in and around the enclosure farming water.

Changes in flora and fauna of inland waters associated with enclosure culture are evidenced from carp culture on stream biota. A change in fish communities at intensive pen culture sites are inevitable because of release of nutrients and loss of feeds to the environment. Wild fish have been observed in comparatively high densities in the immediate vicinity of fish pens. The feeding response of the enclosed fishes act as a signal to the wild fishes that food is available.

Growth rate, abundance and survival of fish have been noted in lakes and reservoirs in many countries where intensive pen culture is practiced. It may be due to availability of feed and raise in nutrient level in the water body due to pen culture operations. On the other hand, instances of decrease in natural fish population have also been recorded from lakes where intensive pen fish farming is practiced. All water bodies have characteristic fish communities which are dependent upon the trophic state and changes in the trophic state will cause fish community change. Effect of water quality changes on the growth and survival of the pen farmed fishes have been reported from various sites of the world. The off flavour in pen cultured fishes is associated blue green algae due to development of eutrophic condition in intensive pen farming inland waters.

Commercial extensive culture of fishes in pen enclosure is restricted to tropical and subtropical countries, where fishes are grown without supplementary feeding. The exploitation of inland waters for extensive pen fish farming have shown highly successful fish crop in the first and second year but gradually decreases in the subsequent years. At that stage the fish farmers become highly dependent on supplementary feeding to fishes and in course of time the water quality get detoriated.

Conclusion

- Pen culture causes friction among the local beneficiaries as limited number of people can participate in this programme due to its large size and cost involvement in operation.
- Interactions between the inner and outer environment of pen enclosure occur with little restriction, so changes in one part of the ecosystem affect the other.
- Pen culture effects water flow, current, sediment transport, space and aesthetics.
- From the user point of view, it would be better to restrict to pen culture in particular areas and therefore in such multi-use water bodies there must be a compromise between the parties.

- Pen culture are the effects of enclosing large number of fish on local fauna-predatory birds, mammals, wild fish, parasites and other disease organisms.
- The method of culture has the greatest effect on environment, since it directly affect nutrient concentrations, oxygen level and toxic metabolites.
- Disease causing organisms thrive well in eutrophic conditions and changes in water quality affect the amenity value of water for drinking purposes, recreation and fish production purposes.
- In a multi use water body the impact of pen culture on environment must be quantified in water quality terms.

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Impact of pen culture on fish production enhancement in floodplain wetlands of Assam

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The fish production is determined by the nature and extent of fisheries resources. These resources are Rivers, reservoirs, wetlands, other open waters, ponds and tanks. These resources are quite different from each others. The levels of fish production from these resources are dependent on the nature of the resources and production technology followed. India has extensive floodplain wetlands, defined as low lying areas bordering large rivers, which are seasonally inundated by the spillover from the main river channel. Floodplain wetlands are important fishery resources and contribute significantly to the Indian Inland fisheries. These wetlands are integral component of the Ganga and Brahamputra river basins, covering an area of more than two lakh hectares (Table 1).

Table 1. Distribution of Floodplain wetlands in India

State	River Basin	Local name	Area (ha.)
Arunachal Pradesh	Kameng, Subansiri, Dibang, Lohit, Dihing & Tirap	Beel	2,500
Assam	Brahamputra & Barak	Beel	1,00,815
Bihar	Gandak & Koshi	Maun, Chaur & Dhar	40,000
Manipur	Iral, Imphal & Thoubal	Pat	16,500
Meghalaya	Someshwari & Jinjiram	Beel	213
Tripura	Gumti	Beel	500
West Bengal	Hooghly, Ichhamati, bhagirathi, Churni, Kalindi, Dharub, Dharala, Pagla, Jalangi, Behula, Torsa & Mahananda	Beel Charha & Baor	42,500
Total			203,028

Source: Updated from CIFRI 2000

Floodplain wetlands are a 'halfway house' between a flowing river and a pond. They are among the world's most productive ecosystems and have been providing tremendous economic benefits to mankind (Tiner 1984).

The state of Assam is endowed with copious aquatic wealth in the form of beels, swamps, ponds and rivers. With the total area of nearly 3.74 lakh ha, the total fisheries resources of Assam is highest in the country (Table 2). There are about 1392 listed beels in Assam of which 423 are registered and remaining 969 are unregistered and under the control of both government (505) and private ownership (464). These beels are distributed over the valleys of Brahamputra (about 92000 ha) in the northern and central Assam and Barak valley (about 8000 ha) in southern Assam. The beels are considered to be one of the most productive ecosystems owing to their characteristic interaction s between land and water system. The floodplain wetlands, the prime fishery resources in Assam, are highly productive ecosystems (Dey, 1981; Choudhury, 1998; CIFRI 2000) providing livelihood support to a large section of the population next only to agriculture.

Table 2: Fisheries Resources of Assam

Resources	*Number*	*Water Spread Area (ha)*
Rivers	48	**205000 (4820 Km)**
Beels/ Oxbow lakes	Registered 423 Unregistered 969 Total 1392	**60215** **40600** **100,815**
Forest fisheries	33	**5017**
Derelict water bodies/ Swamps	9852	**30124**
Reservoir fisheries	1	**1713**
Ponds/Tanks	208121	**31232**
Total	**219447**	**373901**

Source: Department of Fisheries, Govt. of Assam

Culture based fisheries through Pen culture

Culture based fisheries are recognized as an important means of increasing the fish food supplies, particularly in rural areas in developing countries in Asia and South America (Thayaparan 1982, Lorenzen et.al. 1998, Welcomme and Bartley 1998; DeSilva 2003; Sugunan and Katiha 2004). Culture based fisheries also have the added advantage over traditional form of aquaculture in that it is less resource intensive and is therefore more attractive to government of developing countries and support (DeSilva 2003; Felsing et.al. 2003). Enhancement of fish productivity through culture based fishery development in beel ecosystem has great promises in Assam. Generally, the food niches of the beels remain either unutilized or underutilized. This situation provides an opportunity for harboring larger fish stock than what is naturally available. The beels in Assam are best suitable for culture based fishery development. They are productive in nature, rich in nutrients like organic carbon, available nitrogen and phosphorus besides having favourable thermal and oxygen level (Sugunan, 1997). Raising desirable stocking material through pen culture in beels offers a lucrative option to meet the growing demand for quality fish seed (Vass, 1990). The fingerlings raised in pens have shown higher rate of survivability, better growth and are also found to be fairly resistant to diseases, being raised within the same ecological condition and having been already acclimatized (Gireesha *et. al.*, 2003).

Since the beels are highly rich in nutrients with warm water regime and bright sunshine, these can be considered as highly productive ecosystem. Unfortunately however the phenomenon of auto stocking, which was prevalent earlier, has received a serious beating in recent years owing to changed land use pattern making the connecting channel between the beels and rivers, non functional. Because of this development, there has been an alarming decline in natural fishery of beels. In the backdrop of such a scenario, external stocking of economically important and fast growing species has become inevitable for optimum utilization of diverse niches and for securing sustainable fish production from these water bodies. The average productivity of floodplain wetlands of Assam was only 172 kg ha^{-1} yr^{-1}, though the research of CIFRI indicates that the productivity potential of these beels is in the range of 1000 to 1500 kg ha^{-1} yr^{-1}. This gap of productivity requires culture based fisheries in beels of Assam.

CIFRI effort:

The Pen culture technology developed by CIFRI has been found to be an effective tool for getting quality seed of right size critical for fish yield enhancement in open waters. Introduction of pen culture in beels has an added advantage of being low cost technology with reasonably high returns. Besides pen culture operations can be pursued towards the shallow marginal area of the wetland, as such do not interfere with the fishery of the main wetland. CIFRI, Barrackpore in 2002-03 introduced this technology in eleven selected wetland of Assam under the National Agricultural technology Project (NATP Jai Vigyan mission mode Project on Household Food and Nutritional security in Hilly, Backward and tribal areas) to solve the quality seed problems and popularize culture based fisheries among the beel fishers of Assam. The technology included weed clearance in the pen area, Pen construction and erection, preparation of pens for stocking of spawn and fry, feeding, monitoring and harvesting of fingerlings. Three Indian major carps were taken as candidate species for this programme.

After the completion of this demonstration, culture based fisheries was adopted in other beels also through the seed stocking either in pen culture or pond or direct stocking of more than 10 cm size of stunted finger/ yearlings available from the adjoin hatcheries.

The objective of the present success story is to assess the role of stock enhancement in increasing the productivity of the studied wetlands and to assess economics of beel fisheries management together with the benefit to the fishermen. This study covers period up to the year 2006-07.

Description of the study Area

Three floodplain wetlands situated in Central Assam under the Brahamputra valley were selected. These beels are perennial in nature and under the management of lease holder mostly fishermen. The property and water regimes of the selected wetlands under study are mentioned in table 3. The ownership of the beels was with Assam Fisheries Development Corporation (AFDC). The fishing right of the beels were leased out to the highest bidder (they should be from fisheries community or a fishermen cooperative society under the Assam Fisheries Act 1953) after competitive bidding for a stipulated period of time (not less than five years) by the government. The lease value per year was in the range of Rs. 51000 (Damal) to 575000 (Haribhanga) based on the total water area. The variation in the lease value may be due to the productivity of the beel and the competitive bidding for management control of the beel.

Table 3: Property and Water Regimes of Selected Floodplain Wetlands under study

Beel	District	Avg Size	Owner ship	Lease		Fishing regime	Water regime	Type of beel
				Rent	Period			
Haribhanga	Nagaon	130	AFDC	5,75,000	7	Private	Perennial	Closed
Damal	Morigaon	20	AFDC	51,000	7	Private	Perennial	Closed
Puthimari	Barpeta	60	AFDC	54,000	5	Private	Perennial	closed

Success Stories:

Haribhanga Beel

Haribhanga Beel is located in Nagaon district at 26:31:15° latitude and 92:48:33° longitude with an average effective water area of 125 ha. The maximum, minimum and average depth of water in the beel is 4.24 m, 3.03 m and 3.64 m respectively. This beel can be classified as closed, medium and shallow beel based on riverine connection, size and depth respectively. The ownership of the Haribhanga wetland was with Assam Fisheries Development Corporation (AFDC). The fishing right of the beels were leased out to the lessee for seven year on the rent of 5.75 lakh per year from 2002-2003 to 2008-2009 by the government. Fisheries from Haribhanga beel supports livelihood of the lessee family as well as of other sixty four fishers families.

Haribhanga beel was one of the eleven beels where pen culture technology was demonstrated for stock enhancement measures. The three Indian major carp species were taken as candidate species in this demonstration. The details of results of this demonstration for the year 2002 and 2003 are given as under in Table 4.

Table 4. Pen Culture Demonstration and Economics in Haribhanga Beel

Year	Pen area (m^2)	Stocking		Harvesting		Pro. Kg/ha	Total capital Cost	Capital cost (1Crop)	Recurring cost (1 crop)	Total cost (1Crop)	Gross Income (1 crop)	BC ratio
		L (cm)	W (g)	L (cm)	W (g)							
2002	2000	4.8	1.3	16.6	56.6	2210	14750	4573	11766	16339	30940	1.89
2003	2500	4.7	1.2	16.6	67.9	1450	15623	4843	8768	13611	27375	2.01

After harvest the catch was released in the beel for stock enhancement. The resultant increase in the productivity of beel can be seen through increase in production. This demonstration has provided him an opportunity for increasing the production of beel through stock enhancement using pen culture.

Different Options

The demonstration on pen culture has provided ample opportunity to the lessee for raising the productivity of beel through stock enhancement measures. He set a target of 500 kg/hectare and achieved it in 2004. But stock enhancement and other measures like controlling weed infestation as suggested by scientists from CIFRI required a lot of investment. Though the income from beel after 2004 has risen significantly but an capital investment of Rs. 10 lakhs was required immediately towards boundry cover, weed clearance, stock enhancement etc.

Pen culture by fisher

A pen of 5000 m^2 has been installed in the beel. 8 to 10 cm size of carry-over seeds of three Indian major carp and three exotic carps like grass carp, silver carp and common carp purchased from the fish seed farm and released during the year. The pen culture information is given in table 5.

Table 5. Fish species stocked and harvested in pen culture in 2006-07

Fish Species	Number stocked	Stocking Length (cm)	Stocking weight (gm)	Number harvested	Harvested Length (cm)	Harvested Weight (gm)	Production (Kg)
Rohu	10000	8	5	9000	17	50	450
Catla	2000	8	5	1800	18	100	180
Mrigal	2000	8	5	1800	17	50	90
G carp	2000	12	7	1800	28	200	360
S carp	10000	12	7	9000	25	100	900
C carp	10000	12	7	9000	28	300	2700

Figure 1. Stocking and harvesting length of different species

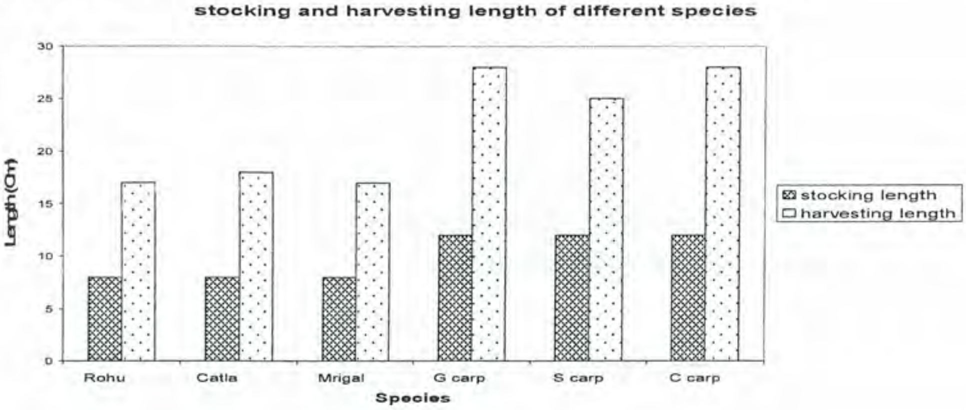
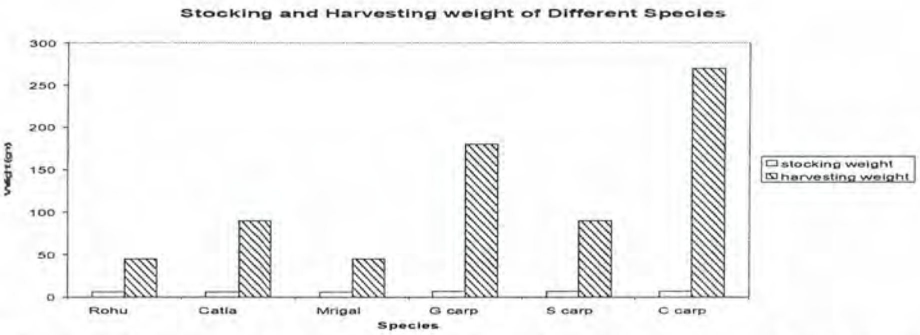


Figure 2. Stocking and harvesting weight of different species



The above figure shows that the growth of exotic carp in pen enclosure was higher than the growth of Indian major carp. The other reason for selecting these three carps under the pen culture was the farm gate price of this species which is nearly Rs. 55/kg. The harvest of two cycle of pen culture operation was released for further stocking of beels.

Help from Financial institution

In 2005 he came in contact of NABARD and through it got a credit of Rs. 10 lakhs from Assam Grameen Vikash Bank, Kuwaritol Branch (refinancing of NABARD). Certain condition of better efficiency in fisheries was laid by NABARD like purchase of motorized boat and he fulfilled it.

Innovative ideas

Some of the innovative ideas used by the lessee of Haribhange beel after the credit from the Assam Grameen vikash Bank.

Protection from poaching

Poaching especially from other side of the beel was a perennial problem in Haribhanga resulting in loss of up to 10% of production. For controlling this menace he conceived an idea of covering the total boundary of other side of the beel with bamboo screens and from an expense of Rs. 4 lakhs in 2006.

Weed Clearance

Macrophyte infestation was always a big problem in beels of Assam and one of the big factor in reducing efficiency in beel fisheries. It also makes some of the area inaccessible for fishing operation. In 2003-2004, Scientists from CIFRI suggested him to do time to time weed clearing to realize better productivity from the beel. The weed clearing of whole beel was carried out in 2006 with an investment of Rs. 1.5 lakhs and till 2008-09 Haribhanga was almost more than 90% free from weeds. This is a significant achievement because in 2005-06 and 2006-07, there was no flood in Assam and as a result most of the beels have become more weed infested.

Motorized boats

For increasing the efficiency of fisheries operation a motor operated boat was purchased and now used in the fishing operation. This is the first time in Assam, a motorized boat come to exist in beels.

Katal fishing on a large scale

Brush park fisheries locally known as katal is very popular in Assam and is used as a fish aggregating device in Assam wetlands. The motive is to entice the fishes in accumulated mass of bushes, weeds and tree branches for a period of 2-3 months, where they form their abode and finally caught unaware by enclosing the area (Yadava et. al. 1981). Five to six katals was erected with a circumference of 300-500 meter area was a regular feature since last several years. This year the lessee has erected 5 katals with the same size as last year alongwith a Katal of the size of more than 1500 meter in length. This requires a big capital expenditure and cost him Rs. 1.5 lakhs.

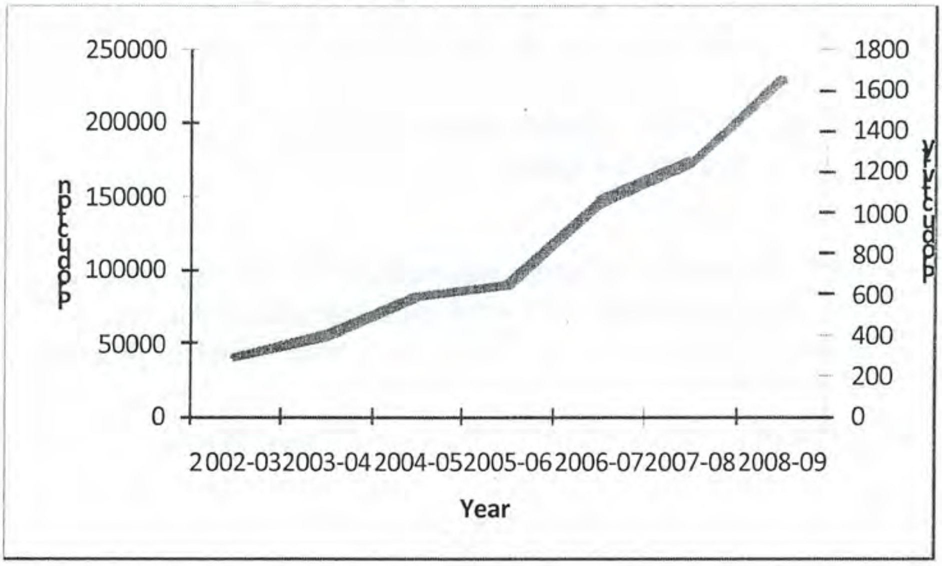
Production and productivity of the beel

The total production in 2006-07 was 131250 kg of fish with a productivity of about 1050 kg/ha. Apart from the production of stocked fishes other fish species caught were Bighead, *L. calbasu, L.Gonius, L. bata, C. reba, N. chitala, C. punctatus, C. gachua, Chanda sp., C. batrachus, H. fossilis, Colisa spp, C. striatus, C. marulius, A. mola, D. aquipinnatus, G. giuris, M. armatus, M. puncalus, A. testudineous, N. notopterus, Puntius Spp., Xenetodon cancilla, M. tengra, Wallago attu*, etc. The production of Indian major carps, exotic carps and other fishes was 80500, 40750 and 10000 kg respectively. The production of the beel had increased to 156250 and 206250 in 2007-08 and 2008-09 respectively.

Annual trend of Production and Productivity

Annual trend of production and productivity indicates a paradigm shift in the fish catch in Haribhanga wetland. The fish production of this beel was increased significantly from 37000 kg in 2002-03 to 206250kg in 2008-09. The productivity was also increased from 296 kg ha^{-1} yr^{-1} in 2002-03 to 1650 kg ha^{-1} yr^{-1} (figure 3).

Figure 3: Annual trend of production and productivity in Haribhanga Beel



Damal beel

The Damal Beel is located in Bhurbandha block of Morigaon district at N $26^0 12'61.9''$ latitude and E $092^0 20'60.0''$ longitude with an average effective water area of 20 ha. The beel is typical oxbow lake. This beel is under the control of Assam Fisheries Development Corporation (AFDC) and present lease is from 2004-05 for seven years.

Stock enhancement measures

The pen culture technology was disseminated here and used in 2005-06. Pen was erected on an area of 3500 m^2. The species composition used in Damal was Rohu, Catla, Grass carp, Silver carp and Common carp. The species ratio was approximately 30:10:10:20:30. The growth of exotic carp was found better than IMC after 3 month growth period. The species composition and the growth were given in table no. 6.

Table 6. Fish species stocked and harvested in pen culture in Damal beel

Fish Species	Number stocked	Stocking Length (cm)	Stocking weight (gm)	Number harvested	Harvested Length (cm)	Harvested Weight (gm)	Production (Kg)
Rohu	12000	10	5	10700	17	50	535
Catla	4000	10	5	3700	18	100	370
G carp	4000	12	7	3500	28	200	700
S carp	10000	12	7	9000	25	100	900
C carp	12000	12	7	10800	28	300	3240

The harvest of two cycle of pen culture operation was used in further stocking of beels.

Production

The fish catch from the beel in the year 2006-07 was 41,400 kg of fish. Apart from the five fish species stocked, other species was also caught. These were *L. bata, L, gonius, L. calbasu, N. notopterus, N. chitala, L. dero, Puntius spp, Colisa fasciatus, C. reba, Wallago attu, G. chapra, A. mola , Chanda spp* etc. The anual trend of production and productivity of Damal beel is given in Figure 4.

Puthimari Beel:

For stock enhancement measures, Pen culture was practiced in Puthimari beel of barpeta district since 2005-06. After the adoption of stock enhancement practice the production and productivity of the beel have gone up sharply. The annual trend in production and productivity is given in figure 5.

Figure 4: Annual trend of production and productivity in Damal Beel

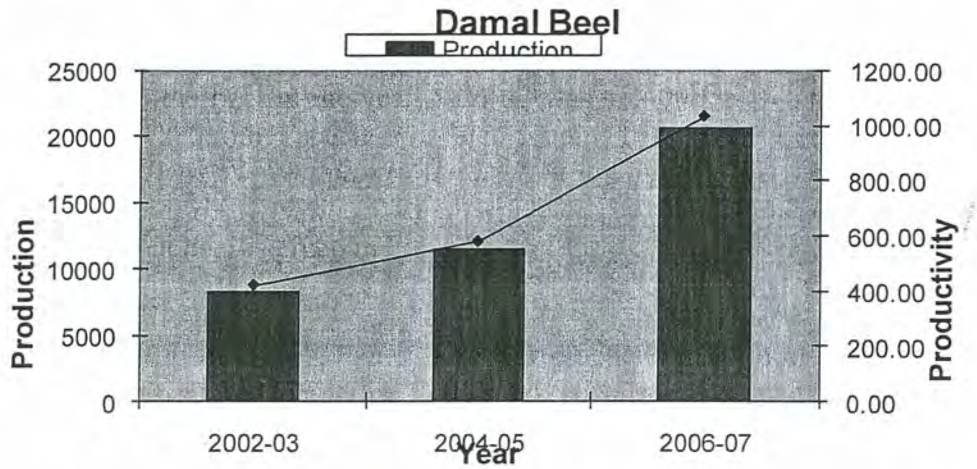
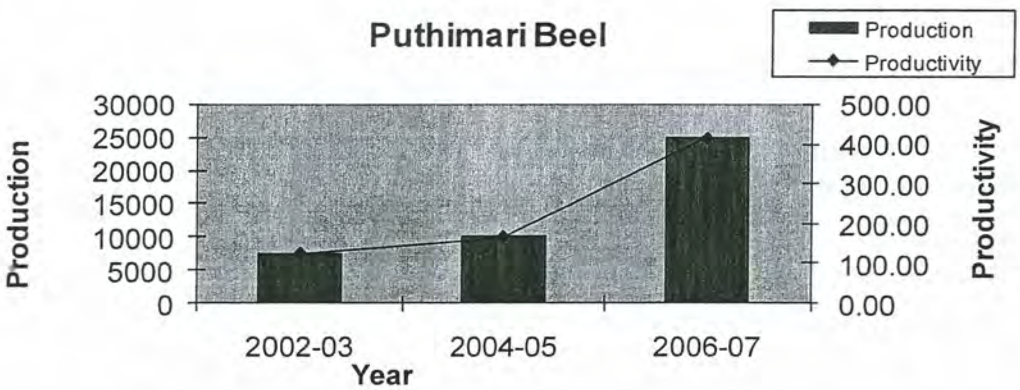


Figure 5: Annual trend of production and productivity in Puthimari Beel



Economics of Beel fisheries Management :

The total capital expenditure incurred by the fisher and the income received after selling of their catch are comes under the economics of beel fisheries management. The fixed cost include the lease amount paid to the government whereas the variable cost includes the expenditure incurred in fishing operation, cost of weed clearance, seed cost and other in practices. The expenditure incurred in lease payment was around twenty percent in Haribhanga, Damal and Puthimari beels. The increase in production of Puthimari beel in 2006-07 after the adoption of stock enhancement as indicated in annual trend has led to the increase of B: C ratio to 3.64. One of the noteworthy achievements was seen in Haribhanga beel despite its large size, the fisher has achieved benefit cost ratio of 3.23 (Table 7). The average farm gate price of the different fish species were in the range of Rs. 25-30/kg for small indigenous fishes, Rs. 40-45 for Silver carp, Rs. 50-55/kg for other exotic carps, Rs. 60-70/kg for Rohu, Catla and Mrigal, and Rs. 100-200/kg for catfishes like *W. attu, N. Chitila*, etc. The prices of these fishes were almost doubled on and around thirteenth January every year due to the *Bhogali Bihu* festival. Almost one harvest was done on eleventh or twelfth of January every year for ripping higher profit.

Table 7: Economics of Beel Fisheries Management

Items	Haribhanga	Damal	Puthimari
Lease amount	575000 (23.96)	51000 (14.08)	54000 (19.71)
weed clearance	280000 (11.67)	61214 (16.09)	35000 (12.77)
Fishing operation including Katal	700000 (29.17)	178572 (49.3)	100000 (36.50)
Seed	400000 (16.67)	40822 (11.27)	40000 (14.60)
Other	425000 (17.71)	25500 (7.04)	30000 (10.95)
Transportation	20000 (0.83)	3658 (1.01)	15000 (5.47)
Total recurring	1825000 (76.04)	311216 (85.92)	220000 (80.29)
Total cost of Beel Management	2400000 (100)	362216 (100)	274000 (100)
Fish production	131250	20600	24900
Return	7750000	1030000	996000
Profit	5350000	667784	722000
B: C ratio	3.23	2.84	3.64

Sharing arrangement

The distribution of income in terms of a part of fish catch or a part of the net income between the lessee and the other fishers are based on the sharing arrangement either fixed before the fishing season or during the fishing calendar. The agreement involves catching as well as transporting them to the market. The share of fishers varies between 30 to 50 percent depending on the availability of catch, ease of catch, type of harvested fish, prevailing fishing practices, provision of craft and gear, membership of the fishing group, provision of food etc.

Some of the sharing arrangements are given as under.

- In Lessee managed beel where stocking, Katal fishing and other fishing enhancement practices like removal of weeds, protection from poaching etc done by the lessee, the share of lessee and other fisher is 75: 25 i.e. Haribhanga beel, Damal beel.
- Similarly in lessee managed beels, having extensive fishing like Puthimari the lessee and fishers share is 60:40.

Higher efficiency of management leads to better income as well as better remuneration to both lessee as well as other fishermen. Share of benefits between the lessee and the fishers in the three culture based fisheries managed beels revealed that more or less every fisher family earn an income of Rs. 11885 to 30273 (Table 8).

Table 8: Sharing arrangement between lessee and other fishers (2006-07)

Beels	*Haribhanga*	*Damal*	*Puthimari*
Total profit received	7750000	1030000	996000
lessee Share	5812500	721000	697200
Lessee expenditure	2400000	362216	274000
fishers Share	1937500	309000	298800
No. of fisher family depended on the beel	64	26	15
Benefit per family in Rs.	30273	11885	19920

The benefits to fishers per family gives a glimpse of the livelihood to the fishing community at large who are totally depended upon these beels for their survival. One of the major benefits of the adoption of this technology was that apart from the lease holder the other stakeholder also got benefited. The change in income for other fishers in Haribhanga was very significant because earlier they were below the per capita income of Assam and national poverty line but now in 2006-07 they were above the national poverty line of Rs. 21378. The official per capita income of India estimated by the NSSO 61^{st} round is Rs. 21378 (say Rs. 22000) per annum for a household of five members in rural area also known as national poverty line (cited in Anonymous 2008). More and more adoption of this technology will only increase the income of the fishing community in the state.

Conclusion

The beels in Assam offer immense potential for increasing fish production, besides generating additional employment and income for the fishers. Stock enhancement of desirable fish species remains the single most important management tools towards this end. The transformation of these three beels from a low productive beel to high productive beel has been achieved through adoption of stock enhancement measures through pen culture and also due to the risk bearing capacity of the fisher.

This Impact study of three beels namely Haribhanga, Damal and Puthimari describes the entrepreneurial characters of the lessee with the development of strategies to change the vision into reality through the support of research institution and financial organization by adopting the culture based fisheries management practices in wetlands of Assam. These success stories has given impetuous to this need that more adoption of stock enhancement measures would be now required in beel fisheries to boost the fish production in Assam. The present average productivity of beel is only 179kg/ha (CIFRI 2000) and if it can be increased to even up to 500 -600 kg per hectare per year can make Assam a net fish importer to fish exporter state.

This achievement also signifies that the increase in productivity not only increase the contribution of fisheries in net state domestic product but also boost the rural economy of Assam.

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Adoption of cage and penculture of fishes through Community-based approach

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Introduction

During past only the influential and resource rich derived benefits from open water bodies viz. small reservoirs, because of the leasing system and the cost of lease. Resource poor communities living around the reservoirs were utilized as labourers (stocking, netting, fishing, fish selling, guarding etc.) bu t have no opportunity to derive benefits from the production systems. They have never been considered towards management and development programmes of the reservoirs.

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

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

Community-based Co-operative management

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

Community-based Co-operative management, of course, is not a new concept. Many traditional pre-industrial fishery based communities embraced co-operative management of some kind. While some commercial exchange was associated with these systems, they were for the most part artisanal, subsistence fisheries, which were either ignored or legislated away during the emergence of industrial fisheries.

Co-operative management : *conditions for success*

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

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

- Parties have clear motives compatible with public interest;
- Parties agree on the problem/situation/context that has to be addressed;
- Respective, agendas are compatible well defined, and openly acknowledged;
- Participants in a fishery are organised, ready to participate and speak in a united voice;
- Appropriate representative organisations and necessary infrastructures are in place.

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

- the community of eligible users is clearly defined;
- there are clear geographic or other boundaries to the resource system over which the users have control and the community of users is able (informally or formally) to exclude outsiders;
- the communities involved are highly dependent on the resource and are
- vulnerable to non-sustainable use;
- the resource users are relatively immobile: if the resource is overused or the resource system is damaged, the users cannot easily rove to another location or another livelihood; users are able to enforce management rules both against each other against outsiders;
- although users may not be homogeneous in a cultural sens, they share
- relatively homogeneous interests in the resource;
- users invest their own resources in activities such as enhancement and enforcement the costs of management add mismanagement are borne by those who benefit directly

Benefit of community - based co-operative management

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

1. Creates co-operation among individual fishermen and local fishing, groups in planning the improvement or conservation of local fish stocks;
2. Creates the commitment among local fishermen to sharp, both the costs and benefits of their efforts toward enhancement and conservation;
3. Of allocation decisions, creates an appropriate vehicle of conflict resolution among, fishermen; it increases; motivation to negotiate sharing of access which is perceived as equitable;
4. Enhances the position of fishermen so that a more equal negotiating relationship exists between local fishermen art other water resource users;

5. Creates a higher degree of organisation and mutual- commitment among fishermen so that they have a more, equal bargaining relationship with fish buyers;
6. Creates a willingness among both fishermen and government to share data about the resource, and therefore to reach collectively a more complete understanding of the resource;
7. Creates a willingness among both fishermen and government to explore options for regulation which reduce inefficiencies for fishers.
8. Of regulations creates greater trust between fishermen and government and a greater sense of control on the part of so that motivation to invest in competitive gear for first capture is reduced;
9. Creates a higher degree of trust between fishermen and government and improved ability to develop and successfully implement enforcement repines that fishermen perceive as appropriate and legitimate;
10. Creates a higher degree of trust between fishermen and government and greater willingness on the part of government to allow a range of self-management responsibilities to be assumed by fishermen.

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

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

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

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

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

Other resources and landmarks can be added as required.

- Use small groups. Small, homogeneous groups where mutual trust and concern are more co-operative and supportive, at least initially.
- Provide meaningful data and information. For those with no or little education, statistics and academic information cannot be interpreted. Simple graphics, models, numbers and charts should be used.
- Facilitate access to wear information. Take the group to library, a government office, and school or on field trips where they can increase their knowledge base and learn where to go for information in the future.
- Conscientize the group! Only when political awareness has been raised, are people willing and mentally able to help themselves. Thus creation of awareness of the forces that oppress them is one of the most powerful forces for action, and collective action is necessary to achieve progress against oppression. Participation is the way to collective action.

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

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

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

- People's organization should be aimed to focus on the rural poor, those individuals living at or below the subsistence level such as smallholders, tenants, small fishermen, tribal minorities, and include women, men and children.
- Participation of the rural poor is most effectively promoted through the formation of small, informal and homogeneous groups of 6 to 15 members who share common social and economic levels, and are willing to organize around a common activity which addresses a shared problem or interest.
- For long term effectiveness the principle of self help organisation should be safeguarded by developing leadership, managerial capability and mobilisation from within the group. People should themselves select their members, leaders, office bearers and functionaries, and decide on their own rules and activities. Undue dependency of outside assistance should be progressively eliminated.
- Self-identified, income-generating and/or employment activities will create economic benefits which will facilitate self-reliance and long term viability. Group savings and productive investment should be encouraged, with credit provisions where necessary.
- The recruitment and training of suitable group promoters/group organizers as catalysts for group formation and guidance should be seen as a temporary input for about 1-2 years.

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

Participation

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

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

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

Research

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

Steps in Research

- Identify problems
- Select methods and design work plan
- Collect and compile data
- Analyse and present findings
- Draw conclusions and make recommendations

Planning

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

Steps in Planning

- Define the problem
- Set goals and objectives
- Identify resources
- Prepare plan of action
- Plan budget

Management and implementation

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

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

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

The underlying beliefs are:

- People must participate in decision making
- People have the motivation, ability and readiness to take responsibility to work towards change
- People are not by nature passive or resistant to their own needs and goals. They can become so as a result of previous experience.

Steps in Management and Implementation

- Study the plan and commit to action
- Carry out the actions
- Monitor and review
- Solve problems as they arise
- Market products and share benefits

Monitoring and evaluation

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

Steps in Monitoring and Evaluation

- Identify areas, organise and prioritise
- Develop indicators
- Develop monitoring and evolution materials; assign responsibilities
- Collect data, analyze, and provide feedback

- Report and disseminate

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

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

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

Areas of change

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

Special considerations

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

Communication in group/people's organization

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

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

Human communication is a form of social interchange for a mutual purpose. It is through communication that man is able to interact with others in his society. By communicating with others, he relates himself with them. Through this, socialisation becomes possible. Thus without communication, there will be no society.

Functions of Communication in a Society

Information

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

Socialization

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

Motivation

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

Debate and Discussion

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

Education

Communication transmits knowledge that develops intellect, character, and skills.

Cultural Promotion

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

Entertainment

Communication provides entertainment.

Integration

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

Communication Methods in Group/Organisation

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

- Express the needs and character of the organisation;
- Grow in a climate of trust and confidence
- Form an integral part of each task;
- Be stimulated to share information;
- Be directed to purpose and person; and
- Keep the lines of communication as clear and direct as possible.

Organisational Communication Methods in Co-operative management

Method	Advantages	Disadvantages
Telephone	Verbally fast Permits question and answers Convenient Two-way flow Immediate feedback	Less personal No record of conversation Message might be misunderstood Timing may be inconvenient May be impossible to terminate
Face-To face	Visual Personal contact Can "show and explain" Two-way flow Immediate feedback	Timing may be inconvenient Requires spontaneous thinking May not be easy to terminate Power or status of one person may cause pressure
Meeting	Can use visual Involves several minds at once Two-way flow	Time consuming Timing may be inconvenient One person may dominate the group
Memorandum	Brief Provides a record Can rethink the message Can disseminate widely	No control over receiver Less personal One-way flow Delayed feedback
Formal Report	Complete, comprehensive Can organise material at writer's leisure Can disseminate widely	Less personal May require considerable time in reading Language may not be understandable Expensive One-way flow Delayed feedback

Conclusion

Apart from allowing quick yield enhancement at minimal capital investments and environmental costs, culture-based fisheries of small reservoirs directly benefits some of the weakest sections of our society. The benefits accrued due to increase in yield and income directly contribute to the quality of life of fishers. This, being a community-based development process, has a direct bearing on our rural populace. Thus, for yield enhancement and improving the socio-economic status of the fishers, participatory community-based cooperative approach is warranted.

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Economic evaluation of cage and pen culture of fishes

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The enormous inland open fisheries waters are available in India in form of rivers, reservoirs estuaries and floodplain lakes. The rivers and estuaries has comparatively limited scope for human intervention to increase fish production or enhance fish yield due to their vast expanse and multiple uses. Further, a declining trend over past few decades has been observed in the fish production from these natural waters and probably it is difficult to reverse this trend. Indian fisheries sector has great responsibility of bridging the widening fish demand supply gap. Considering the present resource-wise production, including both the inland and marine sector, the open water inland fisheries resources are recognized as most potential waters for enhancing the fish production. The reservoirs are often called the sleeping giant for fisheries development. Similar is the case of floodplain lakes, which have immense scope to increase the fish productivity. These are amenable for culture-based fisheries, particularly utilizing stock enhancements. The major constraint to exploit this untapped production potential is non-availability of quality fish seed in time and space. The best solution to overcome this quality fish seed deficit lies in adoption of the pens for raising the stocking material of own choice and requirement at the water body site itself. It also solves the problem of mortality during seed transport and eliminates the transport cost. Subdividing the water body into easily manageable smaller compartments (pens and cages) to rear desirable fish species up for seed and table size to enhance productivity is now followed in many countries like China, Indonesia, Thailand, etc. This technology is yet to be commercialized in India. These structures are most suited particularly in waters with aquatic weed infestation. Weed clearance in a small portion of floodplain may be used for pen and cage culture and in turn fisheries enhancements. About one fifth of central fisheries sector budget (400 crore) has been allocated for fisheries development of reservoirs and wetlands only emphasizing the importance of these waters. The technologies have been perfected for fish seed production in pen and cages for these waters. The only step needed is mass scale adoption of these technologies. The most important issue for success of any technology is its viability in terms of quantum of profits it makes on sustainable basis. Number of experiments has been conducted to verify the viability of pen and cage culture and improve the practices. These technologies are recognized as the most easy and eco-friendly for fish culture. the pen culture technology has already been successfully implemented in floodplains of Assam, West Bengal and Bihar and reservoirs of Tamil Nadu, Uttar Pradesh, Jharkhand and Madhya Pradesh. The cage culture experiments were successful in reservoirs of Madhya Pradesh, Uttar Pradesh, Tamil Nadu, Karnataka and Maharashtra. These are under finalization in the wetlands. It can be extended to other parts of the country. The success of raising of fish seed in pens in Assam floodplains, the beels, forced the state government to make it mandatory for lessee to adopt pen culture technology for fish seed raising. It was the pre-requisite for leasing in the beel. Recognizing the success of pen and cage culture technologies, many financial institutions, like NABARD (National Bank for Agriculture and Rural Development) are coming forward with financial and technical support schemes for these activities. National Fisheries Development Board (NFDB) also advocating for cage and pen culture in inland open waters in a big way. This chapter is devoted to explain the economics of pen farming towards fish seed and table size fish production and prawn production in reservoirs and floodplains and cage culture for fish seed production in the reservoirs.

Methodology for evaluation of economics of pen culture

To assess the economic viability of any production process both primary and secondary information is required and pen and cage culture is in no way an exception. The primary data collected from the sampled fishers and fishers' organisations on the inputs and outputs over the period may be utilised for this purpose. This part elaborates the computational procedure to evaluate cost items e.g. inputs, output and other items. The basic methodology for computation of economics of pen and cage culture of fish will be almost same for both the enclosures. Therefore, following pages cover it for both pen and cage culture. However the estimates for different inputs and outputs are mentioned in separate tables.

Inputs

The inputs for pen culture process consists primarily of two types. First is the fixed, which is not affected by magnitude or level of output/production e.g. material for the pen/cage, fishing requisites e.g. gear (net) and craft (boat). The others are variable inputs which vary according to intensity of production process e.g. fish seed, feed, maintenance costs and labour to perform these activities. The other costs may be in the form of license fee, boat rent, royalty or fishing rent, and commission paid, etc. The following paragraphs explain the fishing cost structure.

Pen/cage material

The pen and cage material and items utilized for their preparation include bamboo, HDPE net, polyprolene twine, coal tar and labour for purchase of inputs, preparation of bamboo split, interlacing of bamboo split, installation/repair of pen and cage, painting with coal tar, *etc*. The quantity and rate of these are recorded either from primary or secondary sources to valuate the expenses incurred.

Gear or net

The type of net, its material, mesh size, dimensions, size of net per kg are generally recorded in addition cost of net and its preparation. The average life of net and annual repair and maintenance costs are the other items used in calculating the cost of net.

Craft or boat

The type of boat, material used, dimensions, and annual expenses for repair and maintenance are the necessary items to compute the cost of boat. The average initial cost, life and depreciation are components of cost of boat for the fishers with own boat, while average boat rent prevailing in the selected areas may be considered for fishers with hired boat.

Labour

In general, only family labour carry out the fishing operations. The opportunity cost of the family labour may be computed @ per day daily wage prevailing in the area. In case of hired labour, the amount paid may be considered.

The variable inputs may be valued as per the expenses incurred on them.

Other costs

The cost items other than inputs are in accordance with local management and property regimes. These may be location specific. But the most common among them are as under

License fee

The local fishers may have to pay license fee to the owner or manager of the reservoir/floodplain lake for fishing. It may be fixed in accordance with a) number, dimension or weight of fishing gears, b) fixed amount irrespective of fishing gears, c) fish catch.

Depreciation

Straight-line method of estimating depreciation on inputs is most common. The depreciation on the fixed assets used in fishery operations is calculated on the basis of cost of input and its life.

Interest on fixed and working capital

The interest on fixed capital is generally computed as per the bank rate of interest per annum, while for working capital it is calculated biannually at the same rate, with the assumption that the working expenses are distributed normally over the year.

Boat rent

The prevailing boat rent per annum in the selected reservoirs may be directly treated as boat rent.

Fishing rent or royalty

Sometimes fishing rent or royalty is charged by the owner / contractor / manager of the reservoir. It may be fixed or linked with quantum and quality of fish catch. It is generally charged towards fisheries management or transfer of fishing rights.

Commission to fishers' organisation / co-operative

The fisher's organisations, *e.g.* co-operatives charge a part of the fishers' remuneration towards services provided by them in the form of assistance in production and marketing activities. It may be in the form of percentage or fixed amount.

Valuation of output

Fish catch is generally the only output of fishers. The price of fish/prawn catch may vary according to fish species, size and season. The value of fish catch can be estimated as

$$Y = \sum_{i=1}^{n} \sum_{j=1}^{12} P_{ij} X_{ij}$$

Where

Y = Value of fish catch;
P_{ij} = price of i^{th} fish species for j^{th} season; and
X_{ij} = quantity of catch of i^{th} fish species for j^{th} season.

The average price received for the catch may be considered for different fish species. The value of catch of these fish species is to be summed to work out total value.

Costs and income concepts

The costs and returns concepts used in farm management studies have also been extended to fishery management (Katiha, 1994). The costs and returns components and their composition considered is mentioned below :

Costs concepts

a) Cost A_1 = Cash expenditure, license fee, boat rent and depreciation on fixed capital, interest on working capital;
b) Cost A_2 = Cost A_1 + fishing rent or royalty;
c) Cost B = Cost A_2 + imputed value of interest on fixed capital; and
d) Cost C = Cost B + imputed value of family labour.

ii) Income concepts

Returns on cost A_1 = Gross income - Cost A_1
Returns on cost A_2 = Gross income - Cost A_2
Returns on cost B = Gross income - Cost B
Returns on cost C = Gross income - cost C.

Comparative economic analysis

The comparative economic analysis was done to identify the most profitable pen/cage culture system for adoption in farm level. Non-discounted measure (e.g. Pay back period) and discounted measures (Net present value, Benefit cost ratio & Internal rate of return) were used to appraise the economic viability of different types of management systems. But for the purpose of simplicity only pay back period is mentioned.

Pay back period

It simply estimates time required to recover the initial investment out of expected earnings from the investment before any allowances for depreciation. It was estimated by following formula:

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

Where, T= Pay back period

C= Initial investment cost
E= Average annual profits expected from the investment before depreciation.

Net Present Value (NPV)

The most straightforward discounted cash flow measure of the project worth is NPV. The calculation of NPV requires the determination of an appropriate discount rate. NPV under this study has been estimated as follows:

$$NPV = \sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t} \text{ - initial investment}$$

Where, B_t = Benefit; C_t = Cost in year t and r is the discount rate over n years.

If, NPV >0 it is profitable;
NPV <0 it is not profitable;
NPV =0 it is at break even point

Benefit cost ratio (BCR)

The formal selection criterion for BCR of project worth is to accept project with ratio 1 or greater, where costs and benefit streams have been discounted at opportunity cost of the capital. Among the alternative projects, the project with highest BCR would be preferred. This can be obtained when the present worth of the benefit stream is divided by the present worth of the cost stream. BCR has been estimated by the following formula:

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

Internal rate of return (IRR)

IRR is the rate of return at which the net present worth of a project will be zero. It is the maximum interest that the project could pay for the resources used if the project is to recover its investment and operating costs and still break even. After determination of all cash inflows and outflows, IRR was determined by an iterative process. Initially the cash flows were discounted by choosing a discount rate (8%) and if the net present value was not zero then another appropriate guess was made and this process was continued till the NPV comes close to zero. Then the exact IRR was found out by interpolation method. IRR has been estimated by the following formula:

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

The internal rate of return is a very useful measure of project worth and tells us the earning rate of the money invested in the project (Katiha, 1999).

Production function analysis

The production function analysis is generally conducted to find out the most important factors of production and their contribution towards the output. The costs incurred on factors of production is converted in monetary terms and considered for the analysis. The production function used was

$y = f(x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8) + u$

y= Total value or gross returns from pen/cage culture

x_1 = Seed value

x_2 = Feed value

x_3 = Cost of lime, prophylactic measures, etc

x_4 = Cost of prophylactic measures

x_5 = Cost of labour for different operational activities

x_6 = Harvesting cost

x_7 = Transportation cost

x_8 = Capital/fixed cost

u = disturbance term

The data collected on these parameters from the sampled ponds was utilized to estimate different forms of functions mentioned below. The exercise was conducted to find out the best suited form.

Linear

$$y = a_0 + \sum_{i=1}^{8} a_i x_i + u_1$$

Cob-Douglas (in logarithmic form)

$$\ln y = \ln b_0 + \sum_{i=1}^{8} b_i \ln x_i + u_2$$

Quadratic

$$y = a_0 + \sum_{1=1}^{8} a_i x_i + \sum_{i=1}^{8} c_i x_i^2 + \sum_{i=1}^{8} \sum_{j=1}^{n} a_{ij} x_i x_j + u_3$$

Transcendental (in logarithmic form)

$$\ln y = \ln a_0 + \sum_{i=1}^{8} a_i x_i + \sum_{i=1}^{8} b_i \ln x_i + u_4$$

Translog (in logarithmic form)

$$\ln y = \ln a_0 + \sum_{i=1}^{8} b_i \ln x_i + 0.5 \sum_{i=1}^{8} \sum_{i=1}^{8} d_{ij} \ln x_i \ln x_j + u_5$$

The y and x_{is} are same as mentioned above.

The coefficient of multiple determination was worked out and tested for combined affect of the explanatory cost variables on the gross income/total value of shrimp adopting F-test adopting following formula

$$f = \frac{R^2 (n-k)}{(1-r^2)(k-1)}$$

Considering the number of factors of production, no function gave significant results. Therefore, the results are not included in results and discussion section.

The average estimates for economics of pen culture for fish seed production (Table 1), table size fish production (Table 2) and prawn production (Table 3) are mentioned below. The estimates of costs and returns for fish seed production in cages are given in Table 4.

Table 1 Economics of fish seed production in 0.1 ha pen

S. No	Name of the input		Year	
I	Cost	I	II	III
A	Fixed / Capital cost	22700	1700	1700
	% of total cost	46.07	4.36	4.34
B	Operational cost	23150	35325	35525
	% of total cost	46.98	90.67	90.69
	Interest on fixed cost @ 10%	2270	170	170
	Interest on variable cost @ 10% for 6 months	1158	1766.25	1776
	Total amount of Interest	3428	1936	1946
	% of total cost	6.96	4.97	4.97
	Total Cost	49278	38961.3	39171
II	Gross returns	75000	112500	112500
	% of total cost	152.20	288.75	287.20
III	Net profit	25723	73539	73329
IV	Repayment period	One year		
	NPV of costs @ 10% discount rate	116071		
	NPV of returns @10% discount rate	267375		
	NPV of net returns @10% discount rate	157903		
	B:C ratio	2.30		
	IRR	19%		

Table 2 Economics of table size fish production in 0.1 ha pen

S. No	Name of the input	Year		
I	**Cost**	I	II	III
A	Fixed / Capital cost	22700	1700	1700
	% of total cost	48.39	7.11	7.05
B	Operational cost	20900	21000	21200
	% of total cost	44.55	87.79	87.86
	Interest on fixed cost @ 10%	2270	170	170
	Interest on variable cost @ 10% for 6 months	1045	1050	1060
	Total amount of Interest	3315	1220	1230
	% of total cost	7.07	5.10	5.10
	Total Cost	46915	23920	24130
II	Gross returns	80000	80000	80000
	% of total cost	170.52	334.45	331.54
III	Net profit	33085	56080	55870
IV	Repayment period	One year		
	NPV of costs @ 10% discount rate	87988		
	NPV of returns @10% discount rate	216800		
	NPV of net returns @10% discount rate	133840		
	B:C ratio	2.46		
	IRR	26%		

Table 3 Economics of prawn production in 0.1 ha pen

S. No	Name of the input	Year		
I	**Cost**	I	II	III
A	Fixed / Capital cost	22700	1700	1700
	% of total cost	37.74	4.67	4.64
B	Operational cost	33500	32900	33100
	% of total cost	55.70	90.35	90.38
	Interest on fixed cost @ 10%	2270	170	170
	Interest on variable cost @ 10% for 6 months	1675	1645	1655
	Total amount of Interest	3945	1815	1825
	% of total cost	6.56	4.98	4.98
	Total Cost	60145	36415	36625
II	Gross returns	112000	112000	112000
	% of total cost	186.22	307.57	305.80
III	Net profit	51855	75585	75375
IV	Repayment period	One year		
	NPV of costs @ 10% discount rate	122585		
	NPV of returns @10% discount rate	303520		
	NPV of net returns @10% discount rate	187719		
	B:C ratio	2.48		
	IRR	30%		

Table 4 The economics of fish seed raising in cages in Indian reservoirs

S. No.	Item/Particular	Two crop/year Cost per crop (Rs)	Three crop / year Cost per crop (Rs)
A.	Non recurring		
a)	Capital cost		
1	Floats (PVC drums)	660.00	440.00
2	Bamboo	616.00	410.67
3	Nut bolt	54.00	36.00
6	Iron wire	700.00	466.67
7	Iron wire	875.00	583.33
8	Saw cutter	5.00	3.33
9	Measuring tape	5.00	3.33
10	Cutting Pliers	35.00	23.33
11	Net cage	1600.00	1066.67
12	Silk rope (Diameter)	100.00	66.67
13	Nylon rope (Diameter)	116.67	77.67
14	Nylon rope (Diameter)	160.00	106.67
15	Bucket, Mug, Strainer	9.00	6.00
16	Paint	37.50	25.00
17	Paint	120.00	80.00
	Fixed capital cost	5093.17	3395.44
18	Labour for Frame/repairing	200.00	133.33
19	Labour for Net tie/repairing	125.00	83.33
20	Labour for Paint/repairing	200.00	133.33
21	Interest on fixed capital	449.45	299.63
	Total fixed cost	6067.62	4045.07
B	Recurring		
1	Seed	12000	12000
2	Feed	3240	3240
3	Agrimin	135	135
4	Transportation	800	800
5	Feeding	3000	3000
6	Cleaning	1000	1000
7	Harvesting	400	400
8	Miscellaneous	500	500
	Total expenditure	21075	21075
	Interest on variable cost	1264.5	1264.5
	Total variable cost	22339.5	22339.5
	Total cost	28407.12	26384.57
	Fingerling production (Number)	70000	70000
	Cost of production/Rs/fingerling	0.41	0.38
	Value of fingerlings	70000	70000
	B:C Ratio	2.46	2.65

Economics of fish marketing

Any production process needs to be supported by efficient marketing system to sustain it at an economic optimum. With this view, the fish marketing system also needs to be appraised. To estimate the fisher's share in the consumers rupee, some fish markets may be selected depending upon physical flow of the fish catch from the study water. Accordingly, the marketing channel(s) are to be investigated. After defining these channel(s) the expenses incurred and amount received at different stages of channel should be recorded to study economics of fish marketing and fish price spread.

1. Marketing costs

The marketing costs are to be recorded at all the stages of marketing channels starting from fisher to consumer.

a) At fisher level

The marketing costs of fishers vary according to marketing practices followed. But, in general these may include expenses on handling of catch, its transportation to landing centre / fish market; storage, and commission paid to co-operative or any fisher organisation conducting fish marketing.

b) At market level

The costs incurred by different market intermediaries on various marketing operations like procurement, storage, grading, packing, loading, unloading, transportation, commission paid to wholesaler-cum-commission agent, octroi, market fee, postage, telephone charges, etc. are to be taken into account .

Price spread

To estimate and improve the remuneration of the fisher/aquaculturists, it is necessary to study the distribution of retail or consumer price over the marketing channel and fisher/aquaculturist, therefore, the information may be collected on price spread which entails distribution of fish consumer's/retail price among the market functionaries and the aquaculturists. It may be computed by concurrent or multistage method. It is expressed as the percent of retail price.

The marketing concepts used for estimation of price spread are: price prevailing as a percentage of retail price (PPRP), percentage share in retail price retained (PSRP), percentage share in retail price incurred as cost (PSCO) and percentage share in retail price retained as net margin (PSNM) . These can be calculated as under

$$PPRP_i = \frac{P_i}{R_p} \times 100$$

where P_i = fish price in Rs/kg received by i^{th} market intermediary and
R_p = fish retail price in Rs/kg

$$PSRP_i = \frac{PR_i}{R_p} \times 100$$

where PR_i = price retained by i^{th} intermediary in Rs/kg

$$PSCO_i = \frac{C_i}{R_p} \times 100$$

where C_i = Cost incurred by i^{th} intermediary in Rs/kg of fish

$$PSNM_i = PSRP_i - PSCO_i$$

The total percentage share of marketing costs and margins in the retail price are estimated as

$$PSCO = \sum_{i=1}^{n} PSCO_i$$

where n = number of market intermediaries in a channel

Similarly the total percentage share of marketing margins was calculated as

$$PSNM = \sum_{i=1}^{n} PSNM_i$$

Fish marketing efficiency index (E)

The fish marketing efficiency indicates the movement of fish from fisher to consumer at lowest price, in accordance with the provision of services desired by the consumers. For various markets and marketing channels, it may be computed (Katiha, 1994) as

$$E = \frac{R_p - MC}{R_p} \times 100 \quad \text{where} \quad MC = \sum_{i=1}^{n} C_i$$

R_p and C_i are same as above.

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PROJECT FORMULATION AND ITS APPRAISAL

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Project formulation involves the development of the concept of the project, defining its various parameters, conducting feasibility study, undertaking investment appraisal and making the decision to invest in the project. The main aspects which need to be covered for development of the project concept and conducting the feasibility study include salient features, need and justification, policy aspects, demand and market, technical, infrastructure and manpower, environmental aspects, project implementation plan, cost estimates, project income/revenue, financing of the project, financial analysis, economic analysis and sensitivity analysis. In simple language a project is a time-bound intervention consisting of a set of planned and interrelated activities executed to bring about a beneficial change. FAO defined the production project as a proposal for investment with the definite aim of producing a flow of output over a specified period of time. Project is a coordinated series of actions resulting from a policy decision to change resource combinations and levels, so as to contribute to the realisation of the country's development objectives.
A project is generally conceived in order to meet the following objectives:

- To meet the need or demand in the domestic or export market.
- To exploit natural and other resources available in a given area
- To create wealth.

The main reason for initiating most projects is to meet domestic and /or international demand. Analysis of the market demand, therefore, is very important. A project has a start and a finish, involves a multidisciplinary team collaborating to implement activities within constraints of cost, time and quality, and has a scope of work that is unique and subject to uncertainty.

Elements of a project

Inputs
Are the means for executing activities, such as human resources, equipment, facilities, spare parts, financial resources and time.
Activities
Are the actions – such as training, mapping, surveys and extension – that transform inputs into outputs.
Outputs
Are the goods and services that a project produces and delivers to beneficiaries.
Outcome
Is the change that is brought about under the influence of the project.
Impact
Is a longer-term effect of the project intervention.

Result
Is a describable or measurable change that is derived from a cause-and-effect relationship: it can be an output, an outcome or an impact.

Working backwards, the project proposal formulator identifies the outcomes that are needed to achieve the desired impact, the outputs needed to achieve the desired outcomes, the activities that must be carried out to achieve the outputs, and the inputs needed to carry out the activities. With this model, the focus of the project management cycle is on intended outcomes and impacts. This is far preferable to focusing on outputs and activities, which tends to direct attention to the use of planned inputs and diminishes the potential for achieving the desired outcomes.
An investment project may be anything from a single programme to an entire integrated programme that includes the following:

- Fish pond
- Hatchery
- Feed plant
- Ice plant
- Cold Storage
- Processing Plant
- Wholesale and retail market
- Training, Extension etc.

Cost estimates
Cost element is the most crucial element in the total project and often it is the most pressing constraint. The project costs are normally of two types:
Capital cost
Operation and maintenance cost

1. Capital cost

   Capital costs represent the expenditure incurred on the project components and generally a onetime expenditure. Normally this would cover:

   - Land
   - Buildings
   - Other civil and structural works
   - Plant and machinery
   - Manpower
   - Consultancy
   - Technical know-how
   - Erection and commissioning expenses
   - Utilities (electricity, water, etc) needed during construction
   - Administrative expenses
   - Interest payments during construction
   - Pre-production expenditure
   - Margin money for working capital
   - Other capital costs

- Contingencies

2. Operation and maintenance cost

   These types of cost relates to the operation and maintenance of the project i.e. when it enters the operation phase and generates the output goods and services. Such costs would include the following:

   - Raw material
   - Manpower
   - Utilities (electricity, water, etc)
   - Consumable materials and spares
   - Royalty/license fees
   - Other production expenses
   - Marketing/selling expenses
   - Corporate and other taxes

The project development cycle

A typical project would go through a **development** process having the following three distinct phases:

1. **Pre-investment** phase, leading to the authorization (investment decision) for a particular project idea under prevailing conditions;
2. **Investment** phase, involving detailed design and actual implementation, leading to fructification of erection of relevant assets;
3. **Operation** phase, following the "commissioning" (or start-up) of the completed project. Now the project would hopefully produce 'the stream of "benefits" for which it was originally conceived.

We shall briefly examine these phases in the following paragraphs.

1. **The pre-investment phase.** This phase would usually involve the following four stages:

   Identification of relevant investment opportunities (or project ideas) through appropriate type of opportunity studies;

   Pre feasibility studies;

   Project formulation, resulting in the detailed (techno-economic) feasibility report for the each project idea considered worthy or further examination at the previous stage;

   Final evaluation and decision: This is to be based on pre-selected, clear, and objective criteria derived from legitimate and reasonable expectations and requirements of various stakeholders, and culminates in the evaluation report.

2. **The investment phase.** This phase involves several inter-disciplinary tasks and a task-force approach has generally been found to give the best results for successful conclusion of this phase. This covers detailed site investigations and tests; design and approval of plant lay-out, preparation and approval of engineering drawings and blue-pints, time schedules and PERT charts, final selection of technology and equipments, and detailed estimating, construction & Erection, involving actual construction, erection, or installation and work, interpretation and follow-up of the contracts, project management, and making

suitable changes in design & engineering on account of unforeseen factors and changes in scope, trial Runs, Commissioning and Optimisation, followed by handling over of the proven project by the contract (s) to the management or owners.

3. **The operation phase.** This phase involves day to day operation of the completed project, and is expected to yield results which meet the original objectives for which the project had been conceived, formulated and implemented.

These three phases involve **five distinct stages** in the existence of a project, namely, identification, preparation, appraisal and agreement, implementation, and monitoring and evaluation. These are shown in the schematic representation (Fig.1).

Stage 1: **Project identification**

- The project idea is translated into a preliminary description of the project
- Terms of reference for the project reconnaissance team are established
- Analyses of existing situations are performed
- A broad evaluation of the future "with" and "without" the project is made
- The extent and limits of the project are proposed. Different approaches to the project are identified, and a judgement made regarding which option should be taken forward to project preparation.

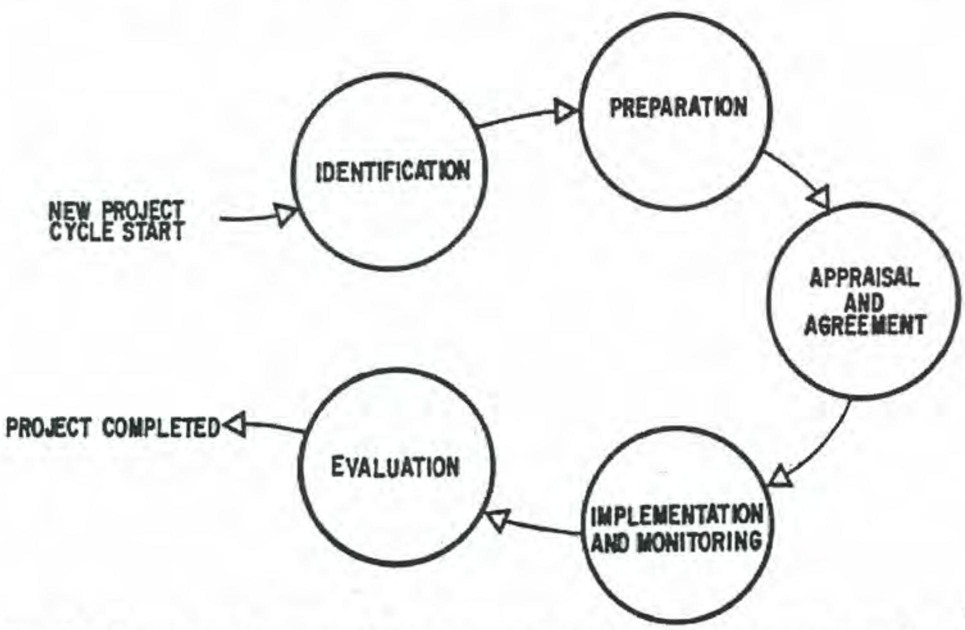

Fig. 1 Schematic diagram of the project cycle Adapted from "Guide for Training in the Formulation of Agricultural and Rural Investment Projects", FAO 1986

Stage 2: **Project preparation**

- Objectives, pre-requisites, inputs, outputs, organization, participants, are all defined.
- Costs and earnings are calculated, a financial plan is prepared
- The socio-economic and environmental impacts are estimated
- The provisional and final project documents are prepared.

Stage 3: **Project appraisal**

- Appraisal documents are prepared from the project
- Appraisal meetings, clearances, and financing negotiations take place.
- This brings the project to the point of meeting the required start-up agreement conditions, sometimes after revision and adaptation of project schedule, cost, objectives, and financing.

Stage 4: **Project implementation**

- The project management and lines of command are established
- various implementation procedures established.
- In the course of implementation project progress is monitored, revisions and adaptations are made for unexpected events, and finally the project is brought to completion.

Stage 5: **Project evaluation**

- It takes place at a suitable time after the project has been implemented
- Project objectives, project implementation, and project benefits are appraised.
- This evaluation may result in the project being extended or in the identification of a new project, and may lead to a revision of the method(s) by which similar projects will be formulated in the future.

Methods of project appraisal

There is no one best technique for estimating project worth. These measures are only tools of decision making. There are many non-quantitative and non-economic criteria for making project decisions. In economic terms the process of project appraisal mainly concentrates on economic feasibility analysis, when it is used for private sector it is referred as financial analysis. There are several measures to appraise and compare the economic feasibility of investment in projects. These may be classified into

A) Non-discounting measures

B) Discounting measures

A) Non-discounting measures

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

1. Urgency

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

2. Ranking by inspection

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

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

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

3. Pay back period

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

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

where T = payback period (years)

C = initial investment cost

E = average annual profits expected from the investment before depreciation.

The major limitations of this measure are

i) it does not account for profits realised after the capital recovery period; and

ii) it fails to consider the timing of expenditures and incomes.

This is generally used in high-risk conditions.

4. Average rate of returns

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

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

R = average annual rate of returns

E = average annual profits expected after depreciation

C = initial investment

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

B) Discounted measures

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

Discounting

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

Mathematically compounding is expressed as

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

where, r = interest rate,

A_0 = present value, and

A_t = value after t years.

By reversing the process, we get

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

which is the discounting formula. The factor $(1+r)^{-t}$ is called the discounting factor.

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

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

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

1. Net present worth (NPW)

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

Mathematically,

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

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

The criteria for net present value measurement is that
If NPW >0, the project has +ve incremental net benefit stream, it is profitable
NPW < 0, the project has -ve incremental net benefit stream, it is not profitable
NPW = 0, the project has no incremental net benefit stream, it is at a break even situation

2. Benefit cost ratio (BCR)

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

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

The formal selection criterion for BCR of project worth is to accept project with ratio 1 or greater. Among the alternative projects, the project with highest BCR ratio would be preferred. One convenience of the benefit cost ratio is that it can be used directly to note how much costs could rise without making the project economically unattractive.

3. Internal Rate of Return (IRR)

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

Mathematically it is discount rate r such that

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

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EFFECTIVE COMMUNICATION STRATEGIES FOR TECHNOLOGY TRANSFER

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The term communication stems from Latin word 'Communis' meaning common. According to Rogers and Shoemaker "Communication is the process by which messages are transferred form a source to receiver" .Van den Ban and Hawkins defined communication as the process of sending and receiving messages through channels which establishes common meaning between a source and receiver. Legans defined communication as a process by which two or more people exchange ideas, facts, feelings or impressions in ways that each gains a common understanding of the meaning, intent and use of messages. Communication thus is an attitude and the like with others.

Process of Communication:

Communication has been defined as a process. The process is a concept which is dynamicand ever-changing in nature. It implies that events and relationships are seen as dynamic, flexible and continuous and must be considered as a whole, a dynamic interaction both affecting and being affected by many variables. Thus, process has at least four elements — acts or action, a continuous change in time, advancement or progress over time, and a goal or result. Therefore, process implies a time dimension as well as a space dimension in which action unfolds in a continuously changing progression towards some goal.

Most of us are familiar with the five-step process occurring between a sender and receiver.When they communicate :

1. The sender generates an idea in the mind.

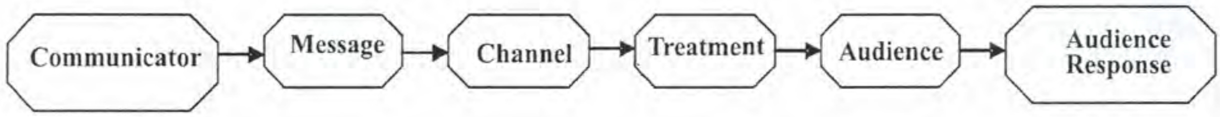
2. The idea is then converted into words, pictures, sounds, symbols, actions. This is called 'encoding the idea'.

3. The encoded idea is transmitted to the receiver.

4. The receiver receives the encoded message through the senses and perceives it in the mind.

5. The receiver then decodes or converts the messages back into meaningful ideas in his / her own mind.

Communication Process Model (Leagans):



The choice of a communication method generally depends on the number and location of the target audience and the time available for communication. The communication methods used in the dissemination of information may be broadly classified into two categories, the traditional communication methods and the modern methods. Traditional media sources can further categorized in three different categories viz. individual communication, group communication and mass methods of communication.

Traditional methods of Communication

Individual methods: in this method, the extension agent communicates with the people individually, maintaining separate identity of each person. This method is followed when the number of fishers are very few, are conveniently located nearby, and sufficient time is available for communication. The methods are Farm and home visit, Fishers call, personal letter, adaptive trial, fish farm clinic etc.

Group methods: A group may be defined as an aggregate of small number of people in reciprocal communication and interaction around some common interest. Group methods are adopted when it is necessary to communicate with a number of people simultaneously, who are located not far off, and reasonably good time is available for communication. The size of the group may vary on the number of persons involved viz. small (15-25), medium (25-50) and large (50-100). The group methods are Demonstration (method and result), group meetings, small group training, field day, farmers' day, study tour etc.

Mass methods: In this method, a vast and heterogeneous mass of people, are covered without taking into account their individual and group identity. This method is followed when the audience is large and widely dispersed and to be communicated in a short time frame. The size of the audience may be a few hundred in mass meeting, few thousands in campaign and exhibition, and millions in news paper, radio and television. These methods are farm publication, mass meeting, campaign, exhibition, newspaper, Radio and television.

Modern Methods of Communication:

The information and communication Technology (ICT) revolution has accentuated new modes of knowledge transfer and communication pattern. It has been opened up opportunities countries in terms of providing low-cost access to information. This is considered as one of the fastest growing tools of communication ever.

ICT : A Catalyst for Rural Development:

Over the years farmers of India have failed to benefit from technological advances resulting into stagnation of productivity and decreasing of incomes. This is not due to lack of technology but lack of awareness about the utilization of technology or technology being made relevant to the needs of the rural community. ICTs play a catalytic role in developing the rural sectors by

- Making the decision –making process more faster
- Offering online advisory services provide information on education and training,monitoring and consultation
- Cheaper and faster on-line trade
- Empowering rural community
- Targeting marginal groups
- Creating employment opportunities
- Triggering knowledge revolution

The world today is an information society. Information is increasingly used in all aspects of human activity, and many technologies assist in providing information in a timely manner. Lack of technical advice on utilization of these resources for fishery development has been one of the reasons for low production. It is expected that the future growth in the productivity of fisheries will largely accrue from the improvements of productivity from different aqua systems with regional specialization and sustainable management of natural resources. Furthermore, increase in the productivity is likely to come from more effective use of inputs. Technology recommendations will be tailored to specific groups of fishers and more narrowly defined production environment. Innovation will require more knowledge and information input from extension services with information transferred in an educational rather than directive approach.

Fishers need up-to-date information on sources availability and cost of inputs, also on the potential of different techniques and technology used for production and processing. It is important that this information is available in an appropriate format and language and that the fishers have the capacity to analyze it and act on it.

Information Communication Technology can provide vital access to information, markets by connecting the rural poor and marginalized to the world's information resources and opportunities. However, not all persons have access to this information. The inequality in opportunities presented by ICT is widest between urban and rural groups, rich and poor, men and women and the educated and uneducated. Despite this, ICT use in rural areas is increasing, such as the internet and cell phones and the individual, community and national benefits they bring by making information available at the fingertips are forever emerging.

ICT: Prospects and Problems

The advancements in ICT can be utilised for providing accurate, timely, relevant information and services to the farmers, thereby facilitating an environment for more remunerative agriculture/dairying/fishery. However, all the ICT initiatives are not uniform with disparities between regions in the level and quality of telecommunications, information and the effort of individuals, public and private organizations, and differentiated nature of demand of the farmers in different areas. As a result, there have been many successes, failures, lessons learned and experience gained, so far. While these initiatives are intended to address the needs of the farmers through ICT, their actual usage and their ability to bring significant impact on the farm productivity and socio-economic development of the intended beneficiaries is to be understood. *Barriers* can be considered as those occurrences that hinder ICT implementation. Some of these factors for failure are listed below.

- Infrastructure
- Finance
- Poor data systems and lack of compatibility
- Skilled personnel
- Leadership styles, culture, and bureaucracy
- Attitudes

Effective Communication methods for farmers:

The communication media are used singly or in combination by taking some factors into consideration.

- The teaching objectives
- The nature of subject matter to be taught
- The nature of audience
- Physical facilities
- Kind of assistance provided by local leaders

The instructional media can be selected depending upon the stages of teaching process.

- **Methods useful in getting attention:** Variety of teaching methods are to be used to place ideas before people as well as to keep them afloat until attention is obtained.

  Motion, contrast, colour, size, frequency and intensity are devices to win peoples attention. Picture related to the subject, demonstration, news stories, posters, radio talk, display exhibits, etc., may be used to capture people's attention.

- **Methods useful in developing interest**: To learn people tend to expose themselves to opportunities that are in line with the interest they already hold. Interest usually represents the objective or goal of an individual. Interest is an important phase of motivation. It gives satisfaction when they take successful action to meet it .

- **Methods useful in creating desire:** Desire comes only when the subject or plan of action suggested is considered favorable by a person as it applies to his individual situation. In creating desire, appeal to the facts and logic were presented to develop interest. To create desire, a mental picture of the new situation which the individual will face will be required.

Real object, participation in demonstration, circular letter, working model leadership in action, exhibits, etc., are some of the methods found useful.

- **Methods of developing confidence:** Development and maintenance of confidence should be parallel to all other changes in peoples' attitudes and behaviour. It should grow in intensity, as desire is created and followed inturn by action and satisfaction. Some of the tools useful in developing and maintaining confidence are bulletins, circular letter, result demonstration, method demonstration, group discussion, personal visits, etc.
- **Methods useful in ensuring action:** Conviction should be followed by action This implies that people can easily convert the confidence established by taking action. If action does not follow soon after conviction, the new conviction fades away and people continue as before. This phase of extension, teaching often receives the least attention. Consequently a variety of teaching methods must be planned and used to assure action those results in benefit to people. Certain methods like the following are useful in the efforts to promote action-leaders at work, news stories, farm and home visit, circular letter, office call, result demonstration, method demonstration, etc.
- **Methods useful in maintaining satisfaction:** Satisfaction depends upon the development of confidence, pride and success, in accomplishment. Old habits have to be dropped and new ones formed. After a person has adopted a practice it is important to remain in touch with him, otherwise, in many instances he may cease to follow the new practices unless by doing so he experiences real satisfaction

Developing communication strategies:

The communication strategies can be developed in the following steps:

- the development of a list of themes or issues to be communicated;
- an understanding of the *context* within which the communication takes place;
- identification of possible partners or allies for building the communication process.

In both cases, the process began with rapid audience analysis with different groups in rural areas (districts) to learn about their communication patterns and understanding of the change that was about to be put in place:

- what they knew about the new policies and approaches;
- what media channels they preferred and could afford to use;
- who were their trusted sources and disseminators of information;

- the differences between men's and women's preferred times to listen to radio/watching TV etc;
- what feedback mechanisms existed for communities to respond and voice concerns;
- what training was needed at all levels.

Subsequent to the audience research, the individual communication strategies were developed to respond to the above context and audience preferences. A range of communication products in different and complementary media were developed to enable communities to appreciate the new procedures, voice their concerns about them, and define the training they needed in order to assume the new roles.

Components of Strategy on Transfer of Technology (eg. Cage Culture)

Information and Communication needs	Dissemination of Cage-culture
Communication actors	Fisheries Service providers
Communication actors	Fisheries Service providers
Information and Communication needs	Dissemination of Cage-culture
Communication Objective	Technology Transfer
Target audiences	Fish Farmers / Entrepreneurs /Fisherman Cooperative Society
Message	Assure supply of Quality seed in time
Communication:	• Meeting • Village Workshops • Radio • Posters • Brochuers • Newspapers • Field visits • Demonstrations
Outcome indicators:	Will reach to fish farmers with effective information and communication
Collaborating Partners	Local government and NGOs, Research and Academic institutes

Conclusion:

All extension and farmer-outreach programs face three major challenges viz. ensuring cost-effective outreach, designing solutions tailored to needs of individual farmers and cultivating an image that is farmer-friendly. Large sections of the farming community, particularly the rural folk, do not have access to the huge knowledge base acquired by research institutes, universities, extension centers and businesses. However, internet and mobile networks have the potential to provide agro-information services that are affordable, relevant to needs (timely and customized), searchable and up to date. An integrated research extension approach emphasizes the importance of interactive, mutual learning between formal and informal knowledge/technology system and stresses linkages with fish farmers so that they actively participate in technology evolution process. For effective dissemination of technological information an effective linkage between researcher, extension and fisher is highly required.

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Cage Construction and Installation

Demonstration of Cage Culture

Cage Construction in a Reservoir

Cage Management

A View of Cage culture site in M.P. Reservoir

NFDB Sponsored Cage Culture programme in Maithon Reservoir

Enclosure Culture Management

Cage fabrication and installation
at Kalindi Wetland

Construction of Pen