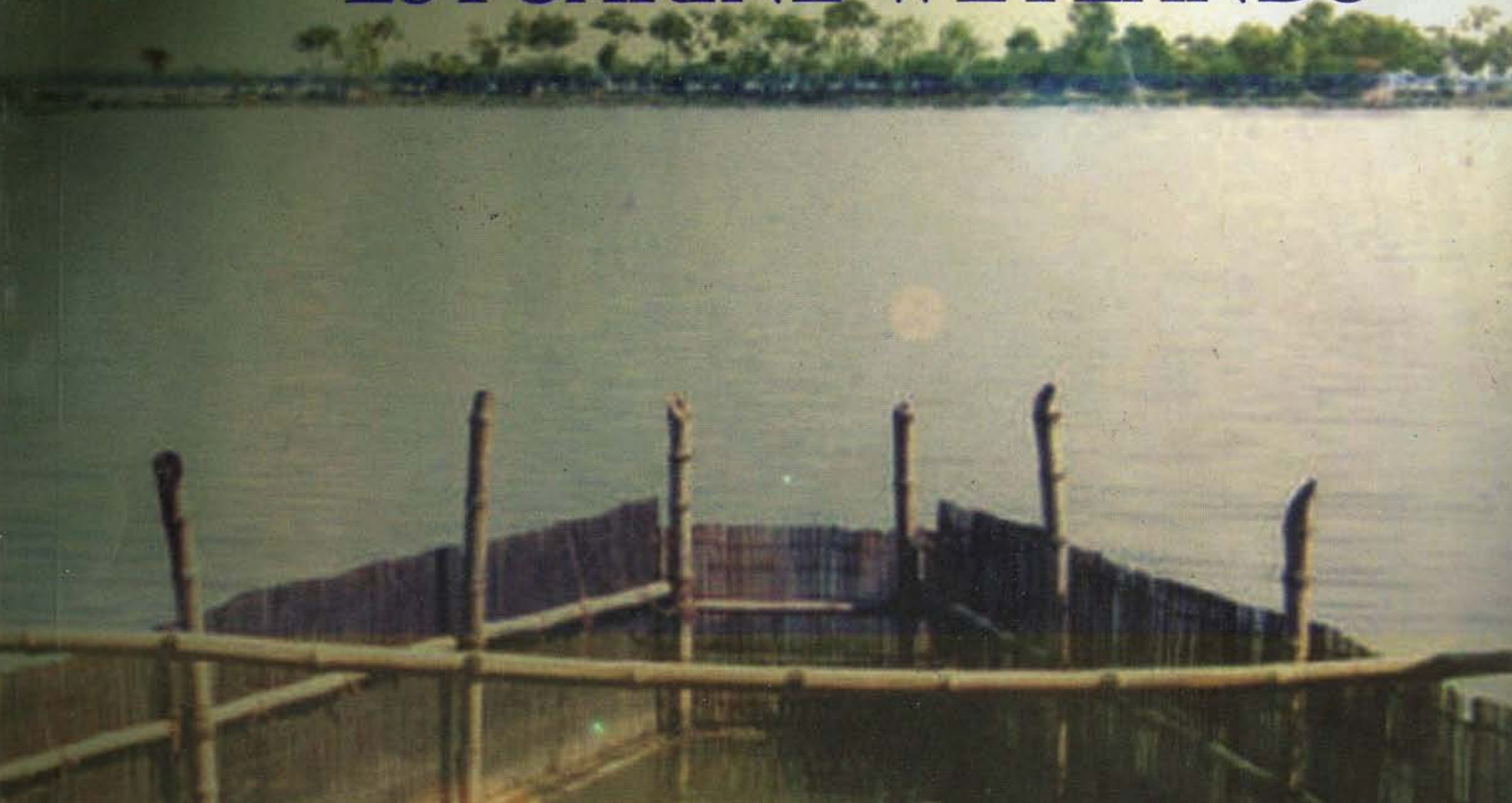
MANAGEMENT OF ESTUARINE WETLANDS



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Barrackpore -743101 ,West Bengal

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Central Inland Capture Fisheries Research Institute
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FOREWORD

Estuarine wetlands, locally known as *bheries* constitute one of the prime fishery resources of West Bengal. With a water spread area of about 40,000 ha and spanning across low, medium and high saline zones, these wetlands offer immense scope and potential for augmenting fish and prawn production through management with scientific approach. However, these ecosystems throw enormous challenges for the scientists, planners and policy makers for proper utilization of these water bodies for boosting production without compromising the environmental safeguards. At the same time, these water bodies are important *vis-a-vis* improving the economic and nutritional status of resource-poor fish farmers/fishermen. Keeping this in view, the Central Inland Capture Fisheries Research Institute has been organising training courses to improve the knowledge, skill and the attitude of the fish farmers. This compendium comprises the lectures delivered at one such training programme. I am sure, this document will be of immense help to extension functionaries, developmental officials, entrepreneurs and fish farmers.

V. V. Sugunan
Director

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ECOLOGY AND FISHERIES OF ESTUARINE WETLANDS OF WEST BENGAL

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INTRODUCTION

The wetlands situated in the east of Kolkata City constitute important Fishery resources of West Bengal. The area covered by bheries of different kinds is over 40000 hectares. These wetlands demonstrate ecotypic differences. Freshwater sewage-fed wetlands situated in the Kolkata spill area in the bed of the defunct Vidyadhari river are exploited for growing freshwater fishes and prawn. The wetlands situated below the Kulti lock gate have water salinities of different magnitudes and are accordingly classified as low, medium and high saline wetlands. These freshwater and saline wetlands situated in the North and South-24 Parganas districts of West Bengal contribute substantially to the total fish production of the state. Traditional cultural practices are adopted for growing fish and prawns in these wetlands by the farmers and there is immense scope of further enhancing the production from these water bodies by introducing proper scientific management practices. These wetlands, locally known as Bheries, are large shallow water bodies embanked by earthen dykes in which the water depth seldom exceeds 1 m. The bhery fishery provides employment to a large number of rural population who are directly and indirectly involved in fishery and related activities.

CLASSIFICATION OF ESTUARINE WETLANDS

The Bheries can broadly be classified as (1) Freshwater bheries and (2) Saline bheries.

The Freshwater Bheries

In the Eastern outskirts of the Kolkata City there exists a vast natural spill area covering about 4000 ha. The wetlands situated in this low lying area receive city sewage and are examples of very low cost sewage utilization systems resulting in production of a huge quantity of aquacrop in the form of fish and prawn. The freshwater sewage-fed bheries can be sub-divided into three categories :

a) The wetlands that receive strong sewage.
b) The wetlands that receive moderately diluted sewage and
c) The wetlands that receive diluted sewage

The Saline Bheries

Depending upon the water salinity the saline wetlands may be classified as :

1. Low-saline bheries where the salinity never exceeds 10 ppt.

2. Medium-saline bheries - where the salinity does not generally rise above 20 ppt. and

3. High -saline bheries-in these water bodies the water salinity may even exceed 30 ppt. and never drops down below 6 .0 ppt.

The classification given above is as per Saha *et.al., (1986)*. There has been considerable changes of the ecology of these water bodies particularly in terms of salinity during the last 15 years and the salinity zones are now required to be re- categorized as per the changed salinity regime. Some of the wetlands in the low- and medium-saline zones (e.g., those at Macchibhanga. Haroa and Minakhan area) receive diluted sewage-mixed saline water and may therefore, be categorized as saline sewage-fed wet-lands.

SPECIES CULTURED IN DIFFERENT WETLAND SYSTEMS

A. Fresh water bheries:

In freshwater bheries Indian major carps, exotic carps (*Hypophthalmichthys molitrix* and *Cyprinus carpio*) together with tilapias - *Oreochromis niloticus* and *O. mossambicus* and *Labeo bata* are rared and the combined stocking stocking density is generally high (45,000-50.000/ha). In recent years some farmers are growing the giant freshwater prawn - *Macrobrachium rosenbergii* though not in a very organized manner. Scientists of CICFRI could achieve success in rearing the giant prawn in a moderately diluted sewage-fed wetland. Miscellaneous species of fishes, e.g., *Mystus gulio, Glossogobius giuris, Puntius spp.*etc., are also encountered in freshwater sewage-fed bodies. Some farmers are trying to rear *Liza parsia* in these water bodies.

B. Saline bheries:

The tiger shrimp, *Penaeus monodon,* and the mullet *Liza parsia* are the most important prawn and fish species reared in the low- and medium saline wetlands. The tilapias - *O. niloticus* and *O. mossambicus* are also stocked. Both the species of tilapias are now breeding in the saline zone and in many cases the wetlands are auto stocked .The giant perch *Lates calcarifer* is not stocked generally but they enter the bheries with ingress water. Presence of *Lates calcarifer, Glossogobius giuris etc.* may cause heavy damage to the prawn and fish crop. In many low and medium saline wetlands carp culture is taken up taking advantages of desalination following monsoon precipitation. During this phase major and minor carps (particularly *Labeo bata*) are reared. Recently some farmers are practising freshwater giant prawn culture during this period. Scientists of CICFRI have demonstrated successfully the rearing possibility of *M. rosenbergii* in medium saline wetlands where almost freshwater condition exists following monsoon precipitation.

In medium saline wetlands *G. giuris, Mystus gulio, Gobioides rubicundus* etc. are also encountered. Some smaller species of Penaeid prawns are usually present in these water-bodies which enter into the system through ingress water.

In the high saline zone besides auto-stocking (seeds entering with the ingress water) selective stocking is done with *P. monodon, Liza parsia* and *Liza tade.* In these wetlands also tilapias are grown along with other species of fishes and prawns. *Lates calcarifer* is not stocked but enter into the system along with ingress water. *Mystus gulio* is also encountered in good numbers and so also some species of Penaeid prawns.

CULTURE METHODS

Freshwater Sewage-fed Wetlands

The sewage from the main sewage canal passes through narrower canals before being drawn into the wetlands through wooden sluices by regulating the flow of water at the entry point so that only the supernatant portion of the effluent is drawn into the bhery. Fifteen to 25% of water is exchanged every fortnightly or some times monthly. At the initial phase the sewage water after being drawn is allowed to stand for a few days till the BOD is reduced and algal bloom appears. Algal bloom results in photo-synthetic activity and the BOD is further reduced. These wetlands are generally shallow having water depth ranging from 50 cm to 1 m. The wetlands are stocked heavily with Indian major carps, exotic carps , minor carps and tilapia. There is ,however, always some auto-stocking of tilapia since it is not possible for the farmers to completely drain out the water and dry up the bottom every year. Initially the rearing is done for a period of 3 - 4 months and harvesting is done when the fishes grow to 150 - 350 g. Table size fishes above 500 g are rarely encountered in the catch. The culture system in the bheries can be called a " continuous stocking and harvesting system" in which the stock is continuously being replenished after harvesting. This may however, result undesirably high stocking densities, sometimes even exceeding 50000/ha which may affect the growth of the stocked fishes. Some of the farmers have started giant prawn farming in this area making provision for feed and aeration. Whenever required the wetlands are drained out by the outlet(s) and required amount of water is drawn in through the inlet.

The Saline Wet-lands

The tidal water from rivers or tributaries are drawn in the bheries during full or new moon days when the amplitude of the tide is high . The ingress water enters through the inlet which is guarded by thick meshed nets to prevent entry of larger carnivorous fishes . A sluice box is fitted at the inlet. In the saline bheries the inlet and outlet points are the one and the same generally. In larger bheries the inlet-outlet channels are more so as to facilitate quick filling and draining of water. The draining of water is done during low tide. Though the exchange of water is normally done fortnightly sometimes the water is retained for longer period of one to two months. The water exchange is necessary to keep the environment conducive for the cultivated fishes and prawns besides providing a continuous source of natural food to them . Previously the bheries were used to be auto stocked but now a days most of the bheries in low- and medium saline zones are selectively stocked . Even the wetlands in the high saline zones are now practising selective stocking in addition to natural stocking. In medium and high saline zones tilapia are stocked normally in spite of the fact that both the species of tilapia- *O. niloticus* and *O. mossambicus* have been ovserved to breed in these zones. In medium and low saline zones *O. niloticus* is preferred as a stocking material while in the high saline zone *O. mossambicus* is preferred.

ECOLOGY OF WETLANDS

A. Freshwater Wetlands

In the freshwater sewage-fed wetlands the DO ranges as 2.6 and 10.5 ppm during the early hours of the day. In the wetlands receiving strong or moderately strong sewage the DO may go up as high as 16-20 ppm in the mid-day and traces-nil in the mid-night. All these wetlands have salinities ranging from traces-1.2 ppt. The total alkalinity of water ranges between 80 and 320 ppm. The primary production in these water bodies has been found to range from 280- 1800 $mgC/m^3/hr$. The freshwater wetlands are rich in nutrients and the NO_3-N,PO_4P etc. are found in good quantities .

The plankton concentration in these wetlands vary from 0.15 to 3.5 ml/50 l. In wetlands receiving diluted sewage , however, the plankton concentration is generally much lower. The principal zooplanktonic forms encountered are *Cyclops sp.,* nauplii of copepods, *Brachionus sp., Keratella sp..,Filinia sp. Moina sp.,Bosmina sp., etc.* The important phytoplanktonic forms encountered are - *Scenedesmus Sp., Pediastrum sp., Spirogyra sp., Lyngbya sp., Oscillatoria sp., Anabaena sp., Merismopedia sp., Microcystis sp., Coscinodiscus sp., Synedra sp, Pinnularia sp.,etc.* There is an over all dominance of myxophyceae in general in this region, Macrozoobenthic fauna in these wetlands is constituted mainly of Chironmid and other depteran larvae, odonate nymphs, gastropods, e.g., *Bellamya sp., Thiara sp., Lymnaea sp., Indoplanorbis sp.* etc. and bivalves and sometimes annelids.

B. Saline wetlands

The salinity of water in the low saline wetlands range between 0.21-10.49 as observed during 1999-2001. The mean value of salinity has decreased considerably compared to that observed by Saha *et al*., 1986. The salinities of the medium and high saline zones are observed to range as 0.21-14.43 and 1.84 -24.95 ppt in some wetlands studied recently. The salinity in some of the high saline bheries even reaches 30 ppt. In recent times the annual mean values of salinity have been observed to be 1.61 ppt to around 3.0 ppt in the low saline zone; 3.0-around 5.0 ppt in the medium saline zone and around 12-13 ppt in the high saline zone. The total alkalinity in the saline wetlands remains with in the normal range and is generally found to be highest in the high saline zone. PO_4-P and NO_3-N contents have been found to be higher in the low-, and medium saline bheries studied recently but higher phosphate values are generally obtained from high saline bheries. Primary productivity has also been observed to be higher in the low-saline zone, particularly in those which have sewage impact. The pH of water ranges from 7.16-9.01. DO in all the bheris is conducive for pisciculture. The free CO_2 is generally found to range between nil and 48 ppm in different wetlands .

The bottom soils of the saline wetlands have pH ranging from 7.6-8.7. Electrical conductivity is highest in the high -saline zone and lowest in the low saline zone. Available nitrogen however, is found to be the highest in the low saline zone and so also the available P.

The plankton concentrations in the saline bheries are generally lower than the freshwater zone. In all the three zones the zooplankters have an overall dominance over phytoplankters. *Brachionus sp., Keratella sp., Filinia sp., Polyarthra* sp., *Cyclops sp., Diaptomus sp.,* nauplii of copepods, *Daphnia sp., Moina sp., Bosmina sp.,*mysids etc. are the principal forms of zooplankters encountered. *Oscillatoria sp.,Lyngbya sp., Anabaena sp., Spirulina sp., Spirogyra sp., Scenedesmus sp., Chlorella sp., Nitzschia sp., Gyrosigma sp., Coscinodiscus sp., Navicula sp., Synedra sp., Pinnularia sp.,etc.* are the principal forms of phytoplankters found in different zones. In these zones Myxophyceae and Bacillariophyceae have edge over the Chlorophyceae.

The macro-zoobenthos is constituted of tanaids, amphipods, molluscs (mostly gastropods), polychaetes , insect larvae (mostly dipterans) etc. in the saline region as a whole.

PRODUCTION FROM WETLAND SYSTEMS

In the freshwater sewage-fed wetlands the yield varies from 5000-10000 kg/ha/yr in case of strong sewage enriched ones, 4000-6000 kg/ha/yr in case of moderately strong sewage enriched wetlands and 2000-3000 kg/ha/yr in case of diluted sewage enriched bheries. In some of the sewage-fed wetlands the production has been reported to have gone down in recent years. In the saline region the medium saline zone earlier had higher productions compared to other two zones. Recent studies conducted in some bheris in the three zones have shown that the production in the low-saline zone bheries is higher compared to medium and high saline zones. This may be attributed to the introduction of carp culture in a large scale in the low-saline wetlands. *P. monodon* production ,however , is highest in the medium saline zone compared to those of the low- and high-saline wetlands. Recent studies show that the production from saline wetlands on the whole has come down to a little extent compared to those obtained by Saha *et al.*,1987 and Ghosh *et al.*, 1997. One of the reasons for getting low production of tiger shrimp in the wetlands was the heavy infestation of white spot disease which caused heavy damage to the monodon crop.

SUGGESTIONS FOR FURTHER DEVELOPMENT

There is immense scope for further enhancing production from estuarine wetlands. The productions from some of the wetlands have gone down in recent years. Followings are some of the measures which can be adopted to augment production from wetlands.

1. The bottom soils of the wetlands should be excavated atleast every three years so as to remove the accumulated muck at the bottom which may hinder the production.
2. Some of the wetlands , particularly in the freshwater and low-saline zones, have heavy infestations of molluscs which create problem to the culture of fishes and prawns. In these wetlands *Pangasius sp.* may be introduced. Pangus ,however, is to be introduced judiciously as it is a carnivorous fish and take fishes , prawns etc., as its food besides, molluscs.
3. Farmers are growing tilapias in their wetlands but reduction of size due to heavy recruitment very often causes problem. The tilapias if reared separately using *Lates calcarifer* as a biocontrolling agent for the recruitment of tilapias the farmers may get good sized tilapias and a good crop of the priced perch, *Lates calcarifer.*
4. The giant freshwater prawn *Macrobrachium rosenbergii* may be introduced in freshwater and low/medium saline wetlands.
5. Carp culture may be taken up in the *medium* saline zone during monsoon and early post-monsoon period.
6. Culture of minor carps e.g., *Labeo bata* , *Cirrhinus reba* ,*Puntius spp.,* and some other spesies of fishes like *Mystus gulio* may be taken up in freshwater zone. These fishes fetch good price.
7. Regular monitoring of the water bodies is the prime pre-requisite for maintaining water quality which will not only help boosting production but will also help in preventing disease infestations.
8. Pen and cage culture can be tried.
9. Adoption of rice-fish culture system in low- and medium saline wetlands, with or without sewage influence, may help getting higher yields from such eco-systems.
10. People involved in wetland fisheries should be given proper training with regard to scientific management practices so that they may tackle some problems themselves as and when such problems arise.

CONCLUSION

Kolkata city is gifted with the vast wetland in its eastern fringe which form an effective tool for waste recycling for productive purposes. Proper management measures like (i) waste water treatment to eliminate contamination of various substances deleterious to fish and prawns; (ii) regulated intake of treated sewage so that the BOD load remains at a desired level; (iii) regular supply of sewage at the time of requirement ; (iv) stock/species manipulation etc., may help boosting yield from such water bodies. More wetlands in the estuarine zones can be developed for piscicultural purposes but it should not be done at the cost of forests. Adoption of proper management measures may help augmenting the production from the existing area under pisciculture. Conservations of these wetlands with such unique ecology is a prime need of the day. If the wetlands are not protected from destructive human interference the whole system will be threatened and the Kolkata city face severe problems. The fishery of this kind provides employment to a large number of rural people, directly or indirectly and if the conservative measures on bhery eco-systems are not initiated immediately the rural population thriving on these fisheries will loose their job, the existing biodiversity will perish and there will be an imbalance in the ecology of this area as a whole.

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ROLE OF ABIOTIC FACTORS FOR INCREASING FISH PRODUCTION IN SEWAGE-FED WETLANDS

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INTRODUCTION

Sewage effluents are produced in urban areas which should be removed from the locality with minimum cost. Initially sewage was disposed off to a nearest river but now-a-days it is felt that the city sewage should not be liberated to a river since it may pollute the aquatic environment. The city sewage is very rich in organic and inorganic nutrients and the treated effluent may be profitably used for fish culture as an important source of nutrients. As fish live in water, the water quality of sewage fed wetlands should be monitored for getting optimum sustainable fish production. The physico-chemical parameters should be in the conducive range for high fish production. If the abiotic factors are not in congenial conditions, the aquatic organisms will be under stress which may lead to poor fish production or fish mortality.

For optimal survival and growth of fish in sewage fed wetlands, following physico chemical parameters are more important for water quality management.

1) Temperature, 2) Dissolved oxygen, 3) pH, 4) Total alkalinity,5) Free CO_2, 6) B.O.D, 7) Nitrogen, 8) Phosphate ,9) Hardness, 10) Free ammonia.

Temperature

Indian major carps and other fishes in our country grow well in temperature ranging between 20-30 ^{0}C. If the water temperature is higher than 35^{O}C in summer, the fishes may be under stress. Some floating weeds (water hyacinth) may be provided in the water body at one corner in such cases to keep the temperature under control. Fish growth is also low if the water temperature is below 15^{O}C due to lower metabolic rate.

Dissolved oxygen

The sewage fed-wetlands should have adequate dissolved oxygen content which is absolutely essential for growth and survival of fish. Dissolved oxygen content ranging between 5.0 and 10 ppm is considered optimum for fish rearing. If the oxygen content is low, reduce the intake of sewage into the wetland or stop intake until condition improves. In case of severe oxygen deficiency, aerate the water body with a suitable aerator until the oxygen level reach 5.0 ppm in the water. At higher temperature (in summer) solubility of oxygen in water is low, so aeration may be more necessary during summer, than that during winter.

Water pH

pH is the negative log of hydrogen ion activity. pH generally denote the acidic or alkaline nature of water. Slightly alkaline water reaction (pH 7.2 - 8.2) is optimum for fish production. Fish will be under stress in both moderately acidic or alkaline water and fish will die if the water is strongly acidic (pH 4.0 or below) or strongly alkaline (pH 10.5 or above)

Total alkalinity

Fish growth is optimum when the total alkalinity of water range between 80 and 160 ppm. Poor alkalinity (5-20 ppm) indicates poor fish health and low production. A water body having low alkalinity may be easily modified by liming. Application of lime in the water body also increases the hardness to a desirable level.

Hardness

Water hardness above 20 ppm is considered congenial for fish health. However, hardness content ranging between 80-150 ppm may be highly conducive for fish production in sewage fed wetlands.

Free CO_2

Free CO_2 is required for photosynthesis by phytoplankton and algae. However excess free CO_2 is not congenial for fish health since it may disturb oxygen absorption from the atmosphere. In sewage fed wetlands the free CO_2 content should be below 20 ppm. The optimum free CO_2 content in a water body is 5 to 10 ppm.

B.O.D

The Biochemical oxygen demand of raw sewage is quite high ranging between 100 and 400 ppm. In the sewage fed wetlands the B.O.D. content should be kept below 30 ppm for optimum growth and survival of fish. High BOD level may lead to oxygen deficiency causing stress on fish (Ghosh *et al.* 1985).

Nutrient elements

Nitrogen , phosphorus and potassium are three elements which enhance the productivity of any water body. Fish food organisms (phytoplankton, zooplankton, algae etc.) grow profusely if the nutrient elements are present in adequate quantities. In fish ponds these elements are supplied regularly as fertilizer or manure to get high production of fish. In sewage fed wetlands, application of fertilize and manure are not necessary, since, the sewage itself is very rich in organic and inorganic nutrients. Domestic sewage contains 10-70 ppm nitrogen, 7-20 ppm phosphorus, 12-30 ppm potassium, and sufficient organic matter. The organic matter in the sewage have protein, carbohydrate and fats in varied proportions, depending on nutritional status and food habits of the population. Usually organic matter in sewage have 40-50% protein comprising several amino acids serving as sources nutrients for microbes and small animal. In carbohydrate readily degradable starch, sugar and cellulose were noted.

Though the sewage effluent is very rich in nutrients and organic matter, it should be used in such quantity that there is not much algal growth in the wetland. Excess algal growth in any system is not desirable since they will consume the dissolve oxygen during night time causing stress on fish and other organisms. In case of algal growth stop sewage intake and maintain the D.O.

level always above 2-3 ppm and preferably above 5 ppm by aeration. In carp culture system , the silver carp may control the algae.

Water hyacinth for control of algaes heavy metals and temperature :

In general, the algal growth is more frequent during summer when the temperature is high and water level low. Introduction of water hyacinth to the system may be helpful to control the algal bloom and high temperature of water. The water hyacinth should be kept at the margins of wetlands barricading them with bamboo poles to prevent spreading of the weed throughout the wetland. If the sewage effluent contains heavy metals these can also be removed by water hyacinth. When control by biological means fails due to excessive algal growth, Simazime (@) 0.5 - 1.0 ppm is recommended for application. Aeration may be necessary during the period of algal death to overcome oxygen deficiency.

Free ammonia

Since the sewage effluent is rich in nitrogen and organic matter, ammonia may be liberated into the system when the oxygen level is lower than 2-3 ppm. Free ammonia is very toxic to aquatic organisms even at comparatively low level. Ammonia content in the range of 0.002-0..05 ppm is safe for tropical fish and prawn. Sublethal effect was noted depending upon the species in the range of 0.05 - 0.4 ppm. But ammonia content ranging between 0.4-2.5 ppm may be lethal to many fishes and prawns. Unionised ammonia is highly toxic to fish but ammonium ion is relatively nontoxic. The higher the pH and temperature the higher is the percentage of total un ionised ammonia (Nath 1998).

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ROLE OF BIOTIC FACTOR FOR ENHANCING THE FISH PRODUCTION IN SEWAGE-FED FISHERY

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INTRODUCTION

The sewage includes all discarded urban, industrial and biological excreted wastes. Along with the water it contains different nutrient elements which can be utilized for various productivity purposes after it is detoxicated.

The concept behind the culture of fish is that these effluents along with the various elements contain nitrogen and phosphorus which act as fertilizer and increase the nutrient status of the ecosystem. These stimulate the production of fish food organisms and provide a rich productive environment for fisheries. In addition sedimentation of suspended organic material at the bottom provide nutritive media for different bottom dwelling organisms which also form the food for certain fishes.

BIOTIC ORGANISMS

Because of rich nutrients status there is tremendous growth of biotic organisms. These organisms mainly comprise micro and macro flora and fauna.

MICROPHYTIC FLORA AND FAUNA

These microscopic floral and faunal organisms are called plankton, remain suspended in water. Their movement is governed by the physical movement of water body. The plankton consisting of plant part are known as phytoplankton and animal part, as zooplankton. The phytoplankton mainly constituted of chlorophycae, myxophycae, bacillariophycae etc. Zooplankton constituted of protozoans, rotifers, cladocerans copepods, ostracods etc. Besides, there are other microplankton less than 60 micron in size called nanoplankton constituting of algae, many diatoms and bacteria. The phytoplankton and photosynthetic bacteria are the primary producer. These are able to synthesize the organic carbon using solar energy and nutrients.

Zooplankton are the primary consumer and feed upon the phytoplankton. The population of the planktonic organisms depend upon the concentration of the effluents in the system or richness of organic matter present in the bottom. The common planktons of sewage fed ecosystems are *Ankistrodesmus, Scenedesmus, Chlorella, Closterium, Microcystis, Merismopedia, Oscillatoria, Spirulina, Nostoc, Navicuia, Synedra, Moina, Daphnia, Cyclops, Diaptomus, Brachionus, Keratella, Filinia, Asplanchna* etc.

MACROPHYTIC FLORA

These nutrient rich ecosystems also support the growth of macrophytes or larger plants. Some of these are emergent in nature and flourish in swampy place along the margin of the water body. Others are submerged, rooted to the bottom in deeper water with floating leaves and flower above the surface or remain completely submerged. There are still others which float on the surface. Common macrophyte are *Eichhorina, Wolfia, Pistia, Hydrilla, Najas, Ceratophyllum, Potamogeton, Nymphaea* etc. These are also primary producers and can synthesise organic carbon like phytoplankton.

MACROPHYTE ASSOCIATED FAUNA

These macrophytes support a dense growth of macro invertebrate fauna by providing food, shelter, breeding and rearing grounds of young progenies. The bulk of the fauna comprises insects, molluscs, annelids, ostracods, decapods, arachnids etc. These serve as food items for carnivores and also help in maintaining equilibrium in the system by their various activities.

BENTHOS

Animals or plants that inhabit at the bottom of the water bodies are called benthos or benthic organisms. Many of these organisms are sessile, some creep over or burrow in the mud. The number and type of organisms found at the bottom is not only related to its substrate but also to the depth, kind and quality of aquatic plants present in it. These organisms are distributed in littoral, sublittoral and profundal zones. Profundal bottom typically shows the presence of fungi, bacteria and certain protozoan due to lack of light, low oxygen and higher concentration of CO_2. Besides some bivalve molluscs, oligochaets, tubificids, dipteran larvae, leaches, hydrachnids and many insects are found *in littoral* and *sub littoral* zones. These organisms also form the food for certain fishes.

ROLE OF BIOTIC FACTOR IN FOOD CHAIN

Producers

The components of 1st trophic level consist of green plants including micro and macro in nature which are able to synthesize the organic carbon using solar energy and nutrients. These include phytoplanktons and macrophytes.

Consumers

These organisms are unable to synthesize the organic carbon and depend upon the producers for sustenance. These are mainly herbivorous and form the component of the 2nd trophic level. Zooplankton, insects and other herbivores belong to this category. They are able to convert the stored energy to animal protein.

Carnivorous

These are the organisms of 3 rd trophic level. They live on either herbivores or carnivores and themselves form the 1st level carnivores. These are the energy source for predatory fish and omnivores which form the component of 4th trophic level. Besides, there are two important agencies like decomposer and transformer occupying important position in the level of trophic chain. These consist of bacteria and other micro organisms which act on the dead and decaying material and are responsible for breaking down of complex substances into simple inorganic forms which are being consumed by the producers. This is typical planktonic food chain.

However, in case of macrophyte infested ecosystem, macrophyte being the primary producer, the food chain is either direct or through detritus chain. This is the shorter chain unlike phytoplankton food chain

There is another food chain working in the system that is detritus chain. All the dead and decaying organisms settle at the bottom forming detritus. These form the food items for many benthic organisms and fishes.

Solar energy + Abiotic elements			
Photosynthesis			
Aquatic vegetation (Phytoplankton, Macrophytes etc.)			1st trophic (Autotrophs)
Decaying or Decomposed organisms settle at the bottom as Detritus	Zooplankton	Herbiovorus fish And other animals	2nd trophic level
Benthic organisms And detritivores	Zooplanktivores	Carnivores	3rd trophic level
Predatory Fish	Predatory Fish	Predatory Fish	4th trophic level
Detritus chain	Grazing chain		

ROLE OF BIOTIC ORGANISMS

The biotic communities besides contributing a major part as fish food organism have a role in keeping the system in balance. Plankton plays an important role to reduce the CO_2 level from the system by increased activity of the photosynthesis. This results in liberation of dissolve O_2 that is being utilized by the bacteria for breaking down of organic matter and thus BOD level of the system is maintained.

Aerobic, facultative and anaerobic bacteria are instrumental in breaking down the various organic compounds in the wastewater and thereby releasing nutrients and minerals, that are utilized by the producers. Denitrifying bacteria under anaerobic condition help in decomposition of organic matter and release ammonia, which are utilized by the fish food organisms. Transformation of bottom organic substances in inorganic form (mineralisation) is done by the activity of varying groups of micro organisms present in the soil. Benthic invertebrates by virtue of their different types of feeding habits and movements help in turnover of nutrients and ultimately increases the productivity of the system

During summer, bacterial decomposition of organic material results in the formation of CO_2. This CO_2 is used by the primary producers for photosynthetic activity and in this the O_2 is liberated in the system.

For suitable production of fish from such type of ecosystem and to maintain ecological balance of the highly variable fish food organisms, judicious stocking of different species of fish in suitable combination should be done to utilize all the food niches of the system.

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ROLE OF PRIMARY PRODUCTION FOR ENHANCING FISH YIELD IN SEWAGE-FED WETLANDS

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INTRODUCTION

Photosynthesis by green plants, phytoplankton or algae adds chemical energy and organic matter to ecosystems, a fraction of which becomes available to consuming organisms. In most ecosystems organic matter is formed by primary producers (autotrophic organisms)and is degraded to carbon dioxide and nutrients by heterotrophs, mainly animals and bacteria. Formation and degradation pathways are called chains or webs according to their complexity. In any system the flow of energy coming from the sun's radiation is unidirectional and most of it is transformed to heat within the system.

The biological productivity of a water body is influenced by climatic, edaphic and morphometric features. The productivity of any ecosystem depends on available solar energy, transparency of water, turbulance, concentration of important nutrients and primary producers.

PRIMARY PRODUCERS

Primary producers are chlorophyll bearing aquatic organisms which utilize the solar energy to synthesize complex organic matter according to the reaction.

$$(CO_2)n+(H_2O)n \xrightarrow[\text{(Chlorophyll, Catalyst)}]{\text{Solar energy}} C_n(H_2O)_n+nO_2$$

In this reaction CO_2 is converted to carbohydrate and oxygen is evolved. Phytoplankton. Algae, some bacteria, and submerged and floating aquatic vegetation are primary producers in sewage fed wetlands. However their contribution may vary significantly depending upon the nature of the ecosystem. The sewage fed wetlands may be of two types depending upon the nature and quantum of sewage discharge.

(1)) weed free and (2) weed infested.

In weed free wetlands the dominant primary producers are the phytoplankton and algae. In general, the ecology of the weed free wetland is more congenial for aquatic habitat and productivity is generally higher in such ecosystem.

But if the quantum of raw sewage discharge in the water body is moderately high or if the sewage contains heavy metals in significantly high amounts then there are possibilities of algal bloom, microbial load in the produce, accumulation of heavy metals and pesticide residues in fish. Studies have shown that about 1 million liters per day of domestic sewage could be treated over an area of one hectare through water hyacinth, reducing the BOD and COD by 89% and 71% respectively, along with removal of nitrogen and phosphorus to the extent of 89 and 50% (Ayyappan, 2000). Similarly, Duckweeds such as *Azolla, Spirodela, Wolffia* and *Lemna* serve as nutrient pumps, reduce eutrophication effects and provide oxygen from their photosynthesising activity. The harvested duckweeds could be used as feed for grass carp in fish ponds or they may be used for composting. Polyculture of carp (six species) is preferable over monoculture in sewage fed wetlands.

Sewage fed wetlands serve as facultative ponds for sewage treatment, also providing oxygen input from the photosynthesizing algae and macrophytes. The macrophytes also serve as nutrient pumps, reducing the eutrophication effects that the sewage is likely to cause in the natural water body. It has been recorded that ponding reduces bacterial loads by 2-3 log units and bacteriophage loads by 3-4 log units even at a sewage loading of 100 kg COD/ha/day. Faecal coliform concentrations reduced by 4 log units within 24 hours of retention in the ponds (Ayyappan, 2000).

Indian inland fisheries has a dominance of carps and related fish species that are sustained by two food chains *viz.* Photosynthetic food chain and detritus food chain. In the former, phytoplanktion and algae form the basis of ecological pyramid and energy transfer is mediated by different levels of secondary producers, consumers or grazers, while in the latter, decomposers and saprotrophs play dominant role in breakdown and utilization of the dead and decaying organic matter by tropic components. Aquatic habitats contain many microbial communities like bacteria, fungi, and actinomycetes that greatly contribute to these processes.

In a fish pond, the role of primary producers such as phytoplankton, algae or macrophyte is considered to be extremely important since they supply organic matter as food to fish and other organisms. So, fish production is directly dependent on the primary production by the producers.

Indian fresh water fish ponds under different management practices had gross primary production ranging between 2 and 6 g C/m^3/day. However semi-intensive fish ponds of West Bengal had gross primary production of 2.4 - 9.14 g C/m^3/day (Nath and Tripathi, 1997).

The fish production efficiency based on photosynthetic energy fixation and total carbon input at production levels of 4-6 tons/ha/yr work out to 1-3% (Ayyappan, 2000). However in open water system, the fish production potential =1.2% of the gross primary production.

The factors which regulate the magnitude, seasonal pattern and species composition in phytoplankton phytosynthesis are light, temperature, nutrients, physical transport process and herbivory. Photosynthetically active radiation or light from 400=700 nm is a most important factor for photosynthesis which provides the major source of energy for these autotrophic organisms. Phytoplankton require N,P, Si, Mo, Zn, Mn, Ca, CO_2 and vitamins for their growth and sustenance. However, the most important are the macro-nutrients (C, N, P, Si). Phytoplankton growth and photosynthesis are in general congenial in the temperature range of 20 to 25°C. Above 30°C the phytoplankton productivity may be affected adversely.

Nutrient cycle

Primary production in any system is dependent on its nutrient status. High production is expected from water bodies which have rich nutrient status. The proper functioning of an aquatic ecosystem is dependent on the circulation of essential nutrients particularly nitrogen and phosphorus. Nutrients enter the cycle through autotrophic photosynthetic production. A portion of the organic matter (containing the nutrients) is passed to the higher trophic level and the remainder reaches the bottom after the death of the producer organisms. This process is repeated at each trophic level upto the top which has no predator and now all the material reaches to the bottom. Now all the organic matters which have reached to the bottom are oxidized by decomposers and inorganic nutrients (nitrogen, phosphate, sulpher etc.) are again released and become available to be used by the producers (phytoplankton, algae etc.) again. In shallow water bodies the circulation of nutrients is not a problem, but in deep waters with chemical stratification, the nutrients may be locked in the tropholytic zone and become unavailable to the system. In weed infested wetlands, the nutrients may be locked by macrophytes and release only after the death and decay of these macrophytes. However circulation of nutrients is very fast in sewage fed wetlands which are free from aquatic vegetation.

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POSSIBILITY OF REARING *Pangasius pangasius* (Ham-Buchn) IN SEWAGE-FED WETLANDS OF CALCUTTA SPILL AREA

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INTRODUCTION

The vast wetlands in the spill area on the east of Kolkata City exhibit a unique example of waste water utilization for productive purposes. The high nutrient status of these sewage-fed water bodies has led to the development of a lucrative fish production system. Indian major carps, some exotic carps, tilapias, minor carps, some miscellaneous species of fishes and sometimes fresh water prawns are grown in the freshwater zone, while in the low-saline sewage fed wetlands the aqua-crop production is principally based on tiger shrimp, *Penaeus mondon* and the mullet species, *Liza parsia* though some farmers grow Indian major and minor carps taking advantages of monsoon precipitation. Most of these wetlands have sizeable population of molluscs, particularly gastropods. Control of molluscs in these sewage-fed wetlands by mechanical or chemical means is not possible. David (1963) observed molluscs to be a principal food item of *Pangasius pangasius* from Hooghly, Matlah and Kulti estuaries. The authors also observed in some ponds in Khulna (now in Bangladesh) that the species had wholly thrived upon mollusks in some fish culture ponds. Hora (1952) also suggested control of molluscan fauna using *Pangasius* as the bio-controlling agent. As reported by David (1963) these fishes can withstand very low dissolved oxygen content of water. The juveniles of the species in the Kulti estuary, as stated by David (1963) "where instead of being eliminated within the highly septic waters almost devoid of dissolved oxygen continued to thrive when all other species had disappeared". The gut of the specimens studied by David were free of fishes as an item of food. Ghosh and Saigal (1981) regarded the species as an omnivore and found the digestive enzyme equipment to bear a correlation with the food habit of the fish. These authors suggested that the species could be cultured in jute-retted water bodies where DO level goes down drastically during retting and continues to be so for 5-7 weeks after retting is over. Ghosh (1999) suggested the introduction of the species in sewage-fed water bodies to exploit the unexploited food source in the benthic mollascan fauna.

ABOUT THE FISH

Pangasius pangasius has a wide range of distribution. The fish is well available in the Ganga river system and has been recorded from Yamuna. A good fishery of this cat-fish exists in the Hooghly-Matlah estuarine system. The fish is found in all the east coast rivers of India. Khalilur Rahaman *et al.* (1995) has given a detailed account of the distribution of the species in Bangladesh. As reported by David (1963) its distribution was extended to Thailand by Hora (1923). The fish is found in countries like Thailand Cambodia, Pakisthan, Malaysia, China, Indonesia and Burma. Several species of *Pangasius e.g. P. pangasius, P. sutchi, P. larnandi* etc. are cultured in Indfo-Pacific region.

David reported that the species attains a maximum total length of 1.342 m (26.62 kg). According to Talwar and Jhingran (1991) the cat-fish grows upto 1.5 m. The colour of the fish is dusky yellowish - on the back or slightly blackish with light reddish-yellow fins, the head is slightly granulated above with two large eyes and two pairs of fairly well developed barbels. Dorsal spine moderately strong with serrations on both sides. The adipose fin is fairly developed. Caudal fin deeply forked. A fairly well developed anal fin. The ventral portion is white or a little yellowish. There is no sexual dimorphism. The catfish is a migratory one exhibiting a long distance migration from the estuarine off lower delta to the middle or to the rocky upper middle of river Yumuna covering a distance of more than 1,000 km. As per David the species matures in the estuaries and migrates to freshwater zone to spawn. Maturity and spawning of the species is confined to freshwater due to damming on Cauvery, Krishna and Godavari rivers have been reported by the author.

The eggs of Pangas are small and in well-grown females the number of eggs may even be six millions (David 1963). The fish spawns during the monsoon months of June - July and as stated by Daivd spawning occurs in the freshwater zone. The larvae and small fry are drifted by currents to the estuary. The breeding, however, may take place even in the month of May depending upon the monsoon. Fry/ juveniles are available in Hooghly, Matlah and Kulti estuaries during August to November. Seeds of 35-60 mm are generally collected by scoop nets. Fry at this stage has almost all the characteristic features of the adults. The compressed head, barbels, serrations in the dorsal spine, upper lobe of the caudal fin distinctly longer than the lower lobe , the shape of the anal fin etc., are all adult like. The colour is blackish gray on the dorsal and whitish on the ventral aspect of the body. The fry are basically zoo-planktophagous taking copepods, amphipods, small insects etc. The food habit of the species at different stages is required to be studied in more details for formulating proper culture practices. The authors of the present article, however, observed small prawns and fishes in the stomach of *P. pangasius*

ADVANTAGES OF PANGAS AS A CULTIVABLE SPECIES

1. *P. pangasius* can withstand wide range of variation of dissolved oxygen and can tolerate a low DO level and therefore, can be reared in such aquatic environment as that prevails in sewage fed water bodies.
2. The fish can be reared in both freshwater and low-saline water bodies.
3. The species has a faster growth rate.
4. The seeds of the fish is well available in the near vicinity of the sewage-fed wetlands and therefore, stocking material is not a problem for the freshwater and low-saline sewage fed water bodies in the Kolkata spill area.
5. The fish, as different reports indicate, is an omnivore and can thrive on a wide range of food available in a water body.
6. Can be employed for controlling molluscan population.
7. The fish has good market demand.
8. Pangas is a priced fish.

PANGAS AS A PROBABLE COMPONENT IN POLYCULTURE

1. Though advocated by some workers that *P. pangasius* is compatible with carps in poly-culture presence of fish and prawns in the stomach of the species being not uncommon, its suitability as a component in poly-culture operations needs to be verified by proper laboratory and field investigations.
2. Though the fish has been reported to be an omnivore the R.L.G. is indicative of its inclinity towards carnivory.
3. Smaller specimens of *Pangas* should be introduced only after the commercial species of fishes and prawns have grown to a considerable size so that they escape predation by Pangas.

DISCUSSION

Though Davied (1963) concluded from some preliminary experiments that *Pangasius pangasius* is compatible with Indian major carps and did not adversely affect their growth, the present authors have some reservations about it. It has been observed that a *P. pangasius* collected from a freshwater sewage-fed wetland had in their stomach only fishes and prawns. The first author observed a few smaller *P. pangasius* which also indicated an inclinity to carnivorous habit with prawns and small fishes as the principal food items. The relative length of gut (RLG) of Pangas is well below 1.0 and presence of teeth in their mouth are all indicative of their inclinity towards carnivory. *P. pangasius* may by reared in ponds with mollusc infestation but with cautionary measures *e.g.* i) should be introduced in smaller size groups when commercial species of fishes and prawns have grown to a considerable size, so as to escape perdition by *P . pangasius*, ii) in sewage-fed wetlands, where continuous stocking and harvesting system is followed. Pangas should be mono-cultured otherwise, their presence may have detrimental effects on smaller size groups of fishes.

Macrobrachium rosenbergii (Galda) AS A POSSIBLE CANDIDATE SPECIES FOR REARING IN SEWAGE-FED WETLANDS

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INTRODUCTION

Among the different species of *Machrobrachium,* the giant freshwater prawn (Locally known as Galda), *M. rosenbergii* is an important species for aquaculture. Its importance as an aquacultural commodity, however, has been felt only recently. Even now, Galda is generally reared along with carps and other fish species and constitutes a bye-product of the aqua-crop in the state of West Bengal. The culture of *M. rosenbergii* is still at its infancy in India but in its recent past the production has been increased considerably (according to an estimate about 7140 mt) in Andhra Pradesh and West Bengal contributing 61.76 and 25.49% respectively.

The Calcutta city is blessed with a natural spill area in its eastern outskirts. This area constitutes a unique sewage-fed ecosystem and produce substantial quantity of fish that feed the Calcutta fish market daily. Rearing of galda in such system may help improving the rural economy by producing a sizeable crop of this priced prawn. Possibility of rearing Galda in fresh water sewage-fed wetlands was demonstrated by Ghosh *et. al.* (1995). De, Ghosh and Bhakat (1999) obtained a production of 1080 kg/ha/9 months in a sewage-fed wetlands which is probably the only commercial venture in this direction on record.

SUITABILITY OF GALDA AS A CULTIVABLE SPECIES

Of the different species of freshwater prawns Galda is the most popular species not only because of its test and size but because :

a. Its compatibility with fish species like carps and tilapias

b. Its comparatively tame and less cannibalistic behaviour
c.Fast growth rate
d. Higher tolerance to wide range of temperature
e. Wide range of salinity tolerance
f. Can tolerate conditions prevailing in sewage-fed impoundments.
g. Seed of *M. rosenbergii* is by and large available.
h. Accepts wide variety of foods while flesh of molluscs and crustaceans appear to be easily accepted.

BREEDING PERIOD, FECUNDITY AND SEED AVAILABILITY

The prawn breeds during December to July with peak in March to May in the Hooghly estuary.The fecundity of the species has been reported to vary from 7000 - 1,11,400 (Rajyalakshmi, 1961) in the Hooghly estuary. This figure , however, is highly variable in different coastal areas of the country. In West Bengal seed of Galda is available in different parts of the Hooghl;y estuary, Ichhamati river (Intindaghat), different parts of Rupnarayan estuary and Ghatal (Midnapur) on river Silabati. Recent investigations conducted by CICFRI has demonstrated that seeds of Galda are available in plenty at Diamond Harbour, Birlapur and Godakhali.

Food habit

Different authors have studied the food habit of Galda from different environment. The giant prawn is an omnivorous species as per most of the workers. The prawn accepts wide variety of food ranging from grains to flesh of crustaceans, molluscs and even fishes. Some authorities (*e.g.* Forster and Beard, 1973; Desimaru and Shigeno, 1973 etc) opined that flesh of molluscs and crustaceans appeared to be easily acceptable best food. Ghosh and others (1995) used *Lamellidens* meat in their experiment in sewage-fed impoundment.

Growth rate

Kurian and Sebastain (1982) stated that the giant prawn grows to around 200 mm/100g in 5-6 months is culture. Ghosh *et. al.,* (1995) obtained average increment of 27.12 g from initial 2.77 g in 145 days at a stocking density of 4,000/ha (combined stocking density of 20,000/ ha with fish) in sewage-fed wetlands. De *et.al.,* (1999) obtained 60-70g for male sand 30 to 35 g for females from initial weight of 0.5-1.0g in a large sewage-fed water body at a stocking density of 5/m^2.

Cultural possibility

Investigations conducted by CICFRI to evaluate the possibility of rearing the giant freshwater prawn in sewage-fed freshwater bheries, and bheries with low water salinity have clearly demonstrated that the prawns can be grown in such water bodies. Restrictions on the tiger shrimp farming with in the Coastal Regulation Zone have shifted the interest of the farmers to grow more freshwater prawns in the fresh to low/medium-saline zones. According to an estimate about 4200 ha of different types of water bodies are presently being utilized for growing *M. rosenbergii* (Bhaumik, 2001).

In West Bengal the farmers mostly grow freshwater prawns along with carp and as such, there is little information available on the mono- or poly culture (with fish) of giant prawn.

In freshwater sewage-fed wetlands *M. rosenbergii* can be cultured by provding adequate aeration facilities and adopting other scientific measures. The bheries after drying up are prepared following conventional methods. It is filled with supernatant water (locally called Sadajal) from adjacent wetlands. The water is allowed to stand for about a week to facilitate the growth of plankton and ***Lab-Lab*** before stocking. Smooth and little sandy bottom is congenial for the growth of prawns. Date palm and coconut leaves are placed in the water body to produce adequate substratum and to facilitate growth of periphyton. Though giant prawns are cannibalistic, adequate shelter requires to be provided for the moulting prawns. This can be done by putting brick-bats and pebbles at the corners of the water body. Since, in the sewage-fed wetlands, fluctuation of DO is a major problem proper care be taken to maintain DO level within the range of 4-6 ppm. Proper aeration should be provided during night hours by pumping water from the same impoundment and sprinkling on a split-bamboo platform or by other mechanical aeration devices (like aerators). The aeration should be done at least 1 to 2 hours daily at the initial phase of culture operation. The BOD of the water body should be kept below 30 ppm. A portion of the water body may be covered with floating weeds like *Pistia/ Eichhornia* so that the prawns can take shelter under sheds during the warmer period of the day. This is required since the water depth in the sewage-fed wetlands ranges normally between 60 and 90 cm. The prawns can be stocked at a weight of 1.0-2.5 g. to withstand the prevailing ecological conditions of the sewage-fed wetlands. The prawns can be fed with boiled molluscan meat @ 3 to 5% of body weight. The feeding rate is generally kept low to avoid possible decomposition of the left over food which may increase organic load . Commercial feed and crustacean meal can also be used. Since the sewage-fed farms are facing problems of over population of tilapias, it is suggested that boiled and dried tilapia meat can also be used for growing giant prawns. The stocked prawns when grow to larger size can be fed with *ad libitum* but the removal of the left over food should be ensured. The feeding should normally be done during afternoon/evening hours with the help of earthen tray/haudies. In both freshwater and low-saline sewage-fed impoundments entry of crabs and carnivorous fishes should be prevented . Giant prawn males may be of three morphotypes of which the blue-clawed largest ones suppress the growth of the smaller males. The smaller males ,however, grow to larger size when the bull males are withdrawn from the system. Sampling should be done at regular intervals to determine the growth of the stocked prawns. The prawns can be reared for a period of 4 to 6 months when they grow to marketable size. Since giant prawn culture involves a period of winter the culture period may be extended for one more month.

CONCLUSION

Until recent past, culture of giant freshwater prawn received little attention of the aquaculturists. Only during recent years *M. rosenbergii* has received momentum in aquaculture system. Experimental studies conducted during recent years (Ghosh *et. al.*, 1985; Ghosh *et. al.*,1995; De *et al.*, 1999; Vinci *et. al.*,2002) clearly indicate the immense possibility of developing galda culture in West Bengal. Being motivated with its economic returns some farmers in the freshwater and low saline sewage fed wetlands have started growing freshwater giant prawns but mostly in an unorganized manner. As galda can be grow in low/medium saline wetlands there is tremendous possibility of growing the species in such water bodies. The farmers need to be motivated for taking up giant prawn farming by providing all possible information on culture system.

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Scope and prospects of pen culture in estuarine wetlands of West Bengal

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INTR O D U CTI O N

In India there are about 132 sewage-fed fish farms covering an area of 12,000 hectares. In Kolkata the city sewage-fed wetlands are the part of River Bidyadhari, a tidal creek associated with Matlah River System. A number of city sewage water channels are connected with these wetlands making them rich in nutrients. Phosphorus and Nitrogen are readily available in huge quantities which directly promotes primary production.

The saline wetlands were prepared for brackishwater fisheries from the year 1850. The tidal creek Bidyadhari was the source of water which was declared dead by the Irrigation Department of Bengal in 1928. The whole area became derelict and unuseful for fishery activity. At this stage, in the year 1929-1930 on an experimental basis sewage water was diverted to this area for fish culture. However, sewage-fed fisheries spread only after the completion of the Outfall Drainage Scheme proposed by Mr .B.N .Dey .The current yield rate from the bheries ranged from 5.4- 8.6 t/ha (Rahara fish farm, Personal communication).

Pen culture can be a viable proposition in large water bodies to enhance fish production where traditional fish culture, environmental enhancement and use of different gear are not possible. Pen culture is generally adopted in reservoirs which are located in remote areas where transportation of stocking materials with minimum mortality is difficult. In such situations pens are utilized to rear fry of Indian major carps exclusively for stocking in the reservoirs. In bheries also pen culture of Indian major carps for stocking material can be done. Culture of giant freshwater prawn will also be very profitable in sewage-fed bheries with less input in the form of feed .

What is a pen

Pen is an enclosure for culturing animals with its three sides are covered while bottom is free. Here the cultured fishes have free access to the bottom of the water body.

What are the steps to be taken for pen culture

Site Selection

In any culture experiment, selection of site for the purpose is very important The most important aspect for a good site is the water level. About 1-2 metres depth is needed because less water level can expose the animals to extreme heat. The bottom may be sandy-clayey or loamy- clayey. The site should be free of pollution and away from outfalls of industries. It is better to install the pen towards the bank to economise the construction cost, easy management of pens and also for easy harvesting. The pen site should be approachable by road and nearer to market. The social set up of the locality also matters, it should be peaceful and free from poaching activity.

Species selection

Since culture is adopted to maximize the profit, it is advisable to go for highly priced species, viz. , giant freshwater prawn, *Macrobrachium rosenbergii*, brackishwater prawns, and cost effective carnivorous fishes. Indian major carps, *Catla catla, Labeo rohita* and *Cirrhinus mrigala* can be grown in pens to stock in the vast bheries.

Materials for the construction

The main construction materials are (i) frame; (ii) screen; (iii) net lining. Locally available materials will be economical. Bamboo is the most commonly used frame material in the states of Assam, West Bengal and Bihar. Split bamboo screens are used as they are cheap. However , iron mesh can also be used especially where there is crab problem. Synthetic nets are the most suitable screen material considering their durability. Mesh size of the screen can be fixed according to the initial size of the fish at the time of stocking. Net lining gives additional protection against unwanted entry and exit of organisms in pen. Nylon lining should be cleaned periodically to give enough water exchange. Nylon or coir ropes are used for fastening the pen frame and screen.

Stocking

To rear table size fish/prawn, the stocking size may be 2.5 -5 g (average) for prawn and 100 mm for fish. If prawns are the target species, the stocking size should be uniform to avoid cannibalism.

Preparing the pen

The pen area must be thoroughly cleaned off unwanted fishes, macrophytes etc. The water quality must be verified before stocking the animals. Lime application may be done if need arises.

Stocking density is as follows :

Table size production

Prawn :	40,000 nos/ha
Fish . :	5,000 nos/ha

Stocking material (Seeds)

IMC -	3 lakh fry/ha

Morning hours is the best time for stocking as the temperature is low and stable in the pen.

Feeding

Pen culture is an extensive type activity and so the concept of pen culture is to utilize the natural food available in the system. In the present case the pen culture site is sewage-fed bheries where the nutrients are lavishly available. Hence the question of feeding does not arise. However, feeding is done where the target species are highly priced prawns or carnivorous fishes and the nutrients available are not sufficient. The feeding rate is 2 - 4% of body weight once daily. For prawns tray feeding is preferred than broadcasting. Since prawns are nocturnal feed may be given at evening or early morning. Feed consumption may be monitored daily and increase or decrease the ration accordingly to avoid pollution inside the pen.

Pen Monitoring

Regular monitoring of water quality inside the pen is very essential especially when the culture is done in sewage-fed water body. Excess of sewage water can cause plankton bloom, depletion of oxygen and increase of BOD. Water level should be stable. Lack of water inside the pen will lead to thermal stress to the stocked animals. Therefore, regular monitoring of the pen is utmost important.

Harvesting

Harvesting may be done with *sadd jal* or drag net for prawns and cast net for fishes. If the culture is to produce stocking materials, a portion of the pen may be opened to release the fingerlings after assessing the final production. -

CONCLUSION

Enclosure culture is often viewed as desirable as it can generate employment, income and food with less pressure on land. In this system competitors and predators are controlled with ease; fish handling and mortality is reduced; daily observation promotes better management and early detection of drawbacks and also total harvesting is possible. Pen based nursery systems are cheap, easy to construct and manage. Therefore, in many culture-based fisheries it is used for producing fingerlings to stock. However , there are a few disadvantages also involved in pen culture-affected by rough weather, inadequate water exchange within pens, rapid fouling of pen screen, poaching is easy and labour cost may be high. Even after giving allowance to these drawbacks, pen culture is considered to be a very profitable system of fish culture.

MONITORING OF FISH HEALTH AND CONTROL OF DISEASES IN SEWAGE- FED BHERIES

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INTRODUCTION

The increasing demand of fish as human food in India has gradually converted fish farming in freshwater, estuarine and brackish water as an important economic activity.

To enhance fish production new methods of fish culture had been elaborated and is being widely used in India in addition to traditional methods of culture. Sewage-fed fish culture, the traditional methods of using sewage for aquaculture practiced in the wetlands, cast of Calcutta is significant in this context. All these new methods of culture greatly influence the fish health aspect of fish rearing farms and hatcheries and result in origination of new diseases.

Fish pathologists know vary well that diseases in fishes usually increase when fishes are reared in artificial conditions. High density of the fish population and a lot of stressors result in tremendous increase of pathogens population which is seldom seen in natural ecosystem.

ROLE OF ENVIRONMENT IN FISH DISEASE OUTBREAK

Fish is in a state of equilibrium with the environment and fish disease organisms, many of which are always present in the environment. A change in the environmental parameters beyond the tolerance limit disturb this equilibrium resulting in a stress response in the fish and making it vulnerable to fish disease. The response of fish to stress from the environment is known as stress response. The most extreme response is mortality but below this level there may be several other responses viz. i.) changes in fish behaviour ii) reduced growth/ food conversion efficiency iii) reduced reproductive potential iv) reduced tolerance to disease v) reduced ability to tolerate further stress.

Environmental parameters to be monitored, its significance.

Dissolved Oxygen - Three main physical factors affect the amount of oxygen a water body can hold.
Temperature - Water holds less oxygen at higher temperature.
Salinity - Water holds less oxygen at higher salinites.
Atmospheric pressure - Water holds less oxygen at low atmospheric pressure.
Other factors which affect the amount of DO in water include phytoplankton blooms, organic loading and respiration of fish and other aquatic vertebrates and invertebrates.

The dissolved oxygen concentration may be controlled by (i) aeration (ii)correct stocking and fertilization of ponds (iii) increasing water flow (iv) good pond design.
Ammonia - It is commonly the second important parameter after DO. The total ammonia concentration in water consists of two forms.

NH_3 - unionized ammonia
NH_{4+} - ionized ammonia (NH_4 ion)

The unionized ammonia (VIA) fraction is most toxic to fish. As a general rule, the higher the pH and temperature the higher the percentage of total ammonia i.e. in the toxic unionized form. Ammonia in water can originate from the following sources

(a) decomposition of organic matter
(b) industrial and domestic pollution
(c) excretion by aquatic organisms, particularly fish in intensive aquaculture system
(d) denitrification
(e) death of phytoplankton.

The methods used to reduce effect of ammonia on fish populations are :

i) improvement of overall DO by aeration.

ii)good pond management.
iii) stocking and feeding control and improved water flow
iv) chemical treatment.
v). biological filtration.

Nitrite - Nitrite is highly toxic to fish. On absorption by fish it reacts with haemoglobin to form methaemoglobin and this given brick red colour to gills. Problems of nitrite can be corrected by

i) correct stocking, feeding and fertilization practices, particularly by keeping ponds well oxygenated
ii). addition of NaCI @ 250 mg/I (iii) biofiltration

Suspended solids - May originate in catchment area of a water supply through natural weathering of rocks and land erosion or pollution. Within fish farming systems, suspended solids and turbidity may also be important in reducing the penetration of light into culture ponds, reducing productivity and increasing risks of deoxygenation.

pH - The optimum range of pH for most freshwater fish species is 6 to 9 There are many factors affecting the toxicity of acid to fish *viz.*

i). CO_2 - high CO_2 increases the toxicity of acid .
ii). Ca, Mg, Na and CI ions - The primary effect of acidity is to disrupt the ionic balance of fish. Thus an increase in the concentration of these cations will help to protect fish from harmful effect of acids
iii) Species, size age, acclimation - The hatchlings or fry are normaly most vulnerable to .acids. Rapid changes in pH are most damaging to fish, particularly if fishes are acclimated to high pH.

Waters with low alkalinity have low buffering capacity and consequently very vulnerable to fluctuations in pH due to rainfall or phytoplankton bloom .

Carbon dioxide - Free CO_2 is toxic to fish. High concentration of free CO_2 hinders the uptake of DO by fish and thus the effects of high CO_2 are made worse at low DO concentration,.

Effect of pathogenic infection on fish health.

Protozoan disease

Gill spot disease - Gills are covered with whitish cysts thereby reducing the absorptive surface, with excessive secretion of mucus and gills become pale. The fishes surface and die. The causative organisms are *Thelohanellus catlae* and *Myxobolus bengalensis.*
Scale spot disease - The scales are covered with whitish cysts. In acute cases scales become perforated, degenerated with abnormal mucus secretion. Scales bcome loose with frequent ulceration. The causative organisms are *Myxobolus rohitae, Myxobolus sphericum.*
Trichodinosis - Mainly caused by the species of the genus *Triichodina,* and *Tripartiella.* Heavy infection of these parasites are accompanied by excessive mucus secretion in gills. Fishes suffer from respiratory distress.

Helminth diseases

Dactylogyrosis and *Gyrodactylosis* - Species of the genus *Dactylogyrus* and *Gyrodactylus.* They infest the gills and body surface of carps. Common symptoms are fading of colours and excessive secretion of mucu. Often infection occur in combination with trichodinids causing fish mortality. Black spot disease - is caused by metacercaria of *Diplostomum sp.* They destroy the symmetry of fish.

Crustacean diseases

Argulosis - The causative organisms of this disease is the species of the genus *Argulus.* They crawl freely on the body surface of fishes and cause extreme irritation to the host. *Argulus* draws blood from soft portion of fish by penetration of its proboscis. The affected fishes get emaciated.
Lernaeosis - The causative organisms of the disease is *Lernae sp.* It attacks the host by anchoring with hooks and sore develop at the point of attachment. Fishes get emaciated and lose weight.
Ergasilosis - The disease is caused by parasites of the genus *Ergasilus.* The parasites attacks the gills, operculum and fins and attaches itself by its strong

clawed antenna causing hemorrhage and in heavy infection fishes get emaciated lose weight and often die.

Bacterial diseases

A number of bacterial diseases have been recorded from fishes. Dropsy, ulcers, loss of barbels, cataract of eyes in carps and catfishes are often encountered and is caused by bacteria of the genus *Aeromonas* and *Pseudomonas*.

Columnaris disease - The disease begins with external lesions on body surface and gills. Whitish ulceration and hemorrhages may also be observed. Stressed fishes are more frequently prone to *Columnaris* disease.

Fungal diseases

Gill rot - Caused by the filamentous fungus *Branchiomyces* attacking the gill filaments. It obstructs blood vessels causing discolouration and degeneration of gills.

Tail and fin rot - Mostly caused by the pathogenic fungus species *Saprolegnia, Ichthyophonus* and *Achlya,* predominantly *Saprolegnia* which is also found to infest eggs and hatchlings in carp hatcheries.

Managerial aspects of fish health protection

For successful aquaculture management the following parameters of fish health monitoring are to be taken into consideration.

Environmental monitoring

It is extremely important that the water used for pisciculture should be made pollutant and pathogen free. For optimum condition of their ecosystem the pH of water should be 7-8, dissolved oxygen level should remain above 5 ppm and water should be almost free from heavy metals. BOD levels should be restricted to 30 ppm. Care should be taken so that the resultant metabolites accumulated by use of manures, supplementary feed and other chemicals remain within optimum limits. Lime upto 500kg/ha is frequently used for sanitation purpose with proper spacing and frequent raking. $KMnO_4$ being oxidizing agent can be used as an when necessary @ 2 ppm.

Fish stock and nutrition

The different ponds have different ecological and productive potential. As such the stocking density of fish is dependent upon its primary productivity. Over stocking always affects fish health. Most of the parasitic infections, especially myxozoans are mostly prevalent in the summer and monsoon month which also synchronize with the spawning season of carps in India and the infection is mostly transmitted from the brood fish or adult ones. It is essential that ponds where brood fishes are stocked or where spawn, fry or fingerlings are stocked should be made parasite free by proper prophylactic treatments. The role of a balanced supplementary feed is very important. A nutritive food will help in good growth while a deficient food will impair fish health by causing deficiency and susceptibility to infections.

Chemotherapy

With all precaution being taken still fish disease manifest and as a result chemotherapy becomes essential.

Bacterial disease

Antibiotics (Terramycin, Sulphamerazine, Sulphadiazine, Oxytetracyclin, Nalidixic acid with erythromycin) @ 100 mg per kg of feed is effective . Routine application of disinfectants ($KmnO_4$, NaCl, acriflavin etc.) to fish after handing or hauling will effectively control bacterial infection resulting from skin and gill injuries.

Fungal diseases

Affected fish eggs or fishes are dipped in 0.5 ppm - 1ppm Malachite green. It is reinforced with 3% bath of NaCl.

Animal diseases

For animal parasites bathing in 2.5% solution of NaCl for 3-5 minutes have been found to be effective. 250ppm formalin solution treatment is effective in combating flukes. Moreover, a mixture of 0.25ppm malachite green and 100 ppm formalin can help in combating protozoan parasites.

PARTICIPATORY RURAL APPRAISAL FOR MANAGEMENT OF SUSTAINABLE FISHERIES IN ESTURINE WETLANDS

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INTRODUCTION

India is bestowed with vast expanse of open water resources which possess tremendous potentiality for enhancing fish production through judicious management. The expected management need be flowed towards sustainable production in stead of yield maximization. The notion of *sustainable development* was promulgated in the 1970s with the formulation of the World Conservation Strategy. Further consideration followed in the 1980s and early 1990s during debates, which led to the formulation of our *common future* and *caring for the earth*. Subsequently, sustainable development has embodied in the policies of many international organizations and national government where India is no exception.

In broad terms, sustainable development aims to improve and maintain the health of ecosystems and well being and livelihoods of people, while sustainable development includes a broad menu of components *(viz.* Better education, improved access to basic needs such as water, food and shelter and many others), viable ecosystem are seen as the basic life support system. A basic tenet, to us, is the conserving ecosystem functions and integration of culture operation in open water systems will be a fundamental vehicle for sustainable development. Thus, culture based capture ecosystem approach is being considered as one of the tools for achieving sustainability.

Successful ecosystem management for enhancing fish production usually depends upon the creation of partnership between the different users and beneficiaries. Thus, People are an integral part of culture-based-capture fisheries management.

Common property resource *vis-à-vis* conflict

Wherever their is multiple use of natural resources, there is potential for competition and conflict between the users. Typical examples are : Utilization of reservoirs for fish production by the Fishery Department, *versus* for irrigation by the Irrigation Department; or the use of a wetland for purification of waste water instead of maintaining its use for fish production. The potential for conflict will be probably increasing with growing population because more users will be trying to use the same usually diminishing the resource. This is particularly true where more than one community is exploiting the same resource in order to survive. An aim of ecosystem-based management is to ensure that a number of different users can be made of a system, simultaneously, while minimizing conflict or loss of values.

While conflicts over resource use are never favourable, when they do occur they can be used to demonstrate the need for a community-based resource management which is one of many possible forms of co-management. Co-management is the sharing of authority and responsibility among government and stakeholders, a decentralized approach of decision making that involves user groups.

In reality, conflict over natural resource use are rarely completely resolved, but specific agreements may be reached over the scale, location or zones and the time frames governing resource uses. The main aim in conflict resolution should be to attain balance between different uses, while ensuring that overall exploitation is kept within the capacity of the system. Thus, sustainable development of common property resource it is essential to involve local communities and other stakeholders. It is often easier and more appropriate to work with existing groups of stakeholders rather than trying to create new interest groups. A mechanism should be sought for brining together representatives of the various categories of stakeholders and participatory rural appraisal tools may be applied to identify constraints & deferences, resolve conflicts, review progress, make collaborative management decision etc.

PARTICIPATORY RURAL APPRAISAL

Community-based organizations in fisheries sector whether in rural or urban contexts, have a key role to play in motivating its members to participate in culture-based capture fishery efforts. Such organizations can rise awareness of the programmes at local level and mobilize the community or groups within it to take steps to participate in developmental activities in open water systems. Historically, promoters of participatory approaches have taken different altitudes towards their role and purpose. Some of the main differences in the recent history of participation revolve around questions of knowledge and power.

One of the most effective of the first generation methods of participation was the highly influential *conscientisation* approach developed and promoted by the Brazilian educator Paslo Freie in the 1960s, which used literacy programmes as a means of enabling poor people to discuss and analyze conditions in which they lived their lives and the underlying causes of those conditions. Freire's ideas had a considerable impact on smaller-scale development initiatives especially in Latin America. His approach was overtly political. He believed that poor people are poor because they were powerless, that their knowledge base is fundamentally flawed because they have been controlled and dominated by others to keep them in their place. Keeping this in view the farmers' knowledge base has to be changed and participation is closely linked to liberation.

During the 1970s, ideas of about participation began to develop and were put into practice in Asia, especially in farming systems. Academicians and practitioners from developing countries became aware of these trends. Chambers since the late 1970s, has continued to articulate the aims and methods of the basket of approaches often described as Participatory Rural Appraisal (PRA) or more recently as Participatory Learning and Action (PLA). PRA/PLA may be considered as second-generation (in case of PRA) and perhaps even third-generation (PLA, with greater emphasis on action) approaches to participation. The humble attitude in the approach is: l***ocal communities and their members are the experts and the outsider is the ignorant one. The main aim here is not to change the system by overthrowing rich but to learn from the poor***.

Some sources of PRA

The past decade has witnessed more shifts in the rhetoric rural development than its practice. These shifts include the now familiar reversals from ***Top down to Bottom up*** from centralized standardization to local diversity and from blueprint to learning process. Linked with these, there have also been small beginning of changes in modes of learning. To move here is away from extractive survey questionnaires and towards participatory appraisal and analysis in which more and more the activities previously appropriated by the outsiders are instead carried out by the local rural or urban people themselves.

In these changes, a part has been played by two closely related families of approaches and of methods, often referred as Rapid Rural Appraisal (RRA) which spread in the 1980s and its further evolution in PRA which begun to spread in the 1990s.

PRA has been called as *an approach and methods for learning about rural life and conditions from, with and rural people.* It extends into analysis, planning and action. PRA as a term is also used to describe a variety of approaches. To cover these, a recent description is that PRA is : *a family of approaches and methods to enable rural people to share, enhance and analyses their knowledge of life and conditions, to plan and to act.*

Five streams which stand out as sources and parallels to PRA are;

a) Activist Participatory Research
b) Agro-eco system analysis
c) Applied Anthropology
d) Field research in farming systems
e) Rapid Rural Appraisals

Principal of PRA

For both RRA and PRA, good performance requires that practitioners and facilitators follow basic principles. Some are fully shared and some have been additionally emphasized in PRA.

THE RRA-PRA CONTINUUM

Name of process	**RRA**	⟷	**PRA**
Mode	**Extractive-elective**	⟷	**Sharing, empowering**
Outsiders' role	**Investigators**	⟷	**Facilitators**
Information owned, analyzed and Used by	**Out siders**	⟷	**Local people**
Methods used	**RRA**	⟷	**PRA**

Principles shared by RRA and PRA

i) *A reversal of learning* : to learn from rural people, directly, on the site and face to face, gaining from local physical, technical and social knowledge.

ii) *Learning rapidly and progressively* : with conscious exploration, flexible use of methods, opportunism, improvisation, and iteration and cross checking.

iii) Offsetting biases : by being relaxed and not rushing, listening not lecturing, probing instead of passing to the next topic, being unimposing instead of important and seeking out the poorer people and women and learning their concerns and priorities.

iv) Optimizing trade offs :relating to costs of learning to the useful truth of information with trade offs between quantity, relevance, accuracy and timeliness.

v) Triangulating :meaning using a range (sometimes three) methods, types of information, investigators and/or disciplines to cross-check.

vi) Seeking diversity :maximizing the diversity and richness of the information.

The menu of methods of RRA and PRA

In its early days, RRA seemed to largely organized commonsense. During the 1980s, through creative ingenuity was applied and more methods borrowed, adapted and invented many with a more participatory mode.

→ *Secondary sources* : such as files', reports, maps, aerial photographs, articles and books.

→ *Do-it-yourself* : asking to be taught to perform village tasks *viz.* Aquatic weed control predatory fish control, stocking, liming & manuring, sampling, harvesting etc.

→ *Key information* : enquiring who are the experts and seeking them out.

→ *Semi-structural interviews* : increasingly it is using participatory visual as well as traditional verbal method.

→ *Groups* : group interviews and activities are the part of many of the methods.

→ *Sequences or chains of interviews* : from group to group; or from group to key informant etc.

→ *They do it* : villagers as investigators and researchers. They do transect, observe, and interview other villages, analyse data and present results.

→ *Participatory mapping and modelling* : in which people use ground, floor or paper to make social demographic, health, natural resources or farm maps or construct three dimensional model on their land.

→ *Participatory analysis of aerial phographs* : to identify water resources, extent of weed infestation, soil type, land conditions etc.

→ *Transect walks* : systematically walking with informats through an area, observing, asking listening, discussing, identifying different zones, local technologies, introduced technologies, seeking problems, solution and opportunities, mapping and diagramming resources and findings.

- *Time lines* : chronologies of events, listing major remembered events in a village with approximate dates.
- *Trend analysis* : people's accounts of the past of how things close to them have changed, ecological histories, changes in customs and practices, changes and trends in population migration, fuels used, education, health, credit etc.
- *Ethno biographies* : local histories of crop, fish crop, animal, pest etc.
- *Seasonal diagramming* : by major seasonal or by month to show days & rains, crops, agricultural labour, fish farmer, fishermen, diet, food consumption, animal fodder, income, expenditure, debt etc.
- *Livelihood analysis* : stability, crisis & coping, relative income, expenditure, credit & debt etc.
- *Participatory diagramming* : of flows, causality, quantities, trends, ranking -----making system diagrams, bar diagrams, pie charts, Venn diagramming etc.
- *Wellbeing or wealth ranking* : identifying clusters of house holds according to wellbeing or wealth including those considered poorest of the poor.
- *Analysis of difference* : especially by gender, social group wealth/poverty, occupation and age.
- *Scoring and ranking* : especially using matrices through scoring.
- *Estimates and quantification* : often using local measures, judgements and materials such as seeds, pellets, fruits or stones etc as counters.
- *Key local indicators* : such as poor people's criteria of wellbeing.
- *Key probes* : questions which can lead direct to key issues such as - what do you talk about when you are together ?
- *Stories, portraits and case studies* : such as household history and profile, coping with crisis, how a conflict was and how it was resolved.
- *Team contracts and interactions* : contracts drawn up by teams with agreed norms of behaviour; modes of interaction within teams etc.

- *Presentation and analysis :* where maps, models, diagram and findings are presented by villages or by outsiders, checked, corrected and discussed.
- *Participatory planning, budgeting and monitoring :* in which villagers prepare their own plans, budgets and schedules and monitor progresses.
- *Brainstorming* : by villagers alone, by villagers and outsiders together or by outsiders alone.

CO-MANAGEMENT FOR SUSTAINABLE DEVELOPMENT

In fisheries, the issue of linkages between stakeholders comes up under the topics of community-based management, user participation in management and co-management. Co-management deserves special attention. It is one of many different possible relationships between government agencies and local communities concerning resource management. Co-management involves power sharing. Other relationships include consultative and advisory roles for local communities. The co-management strategy is distinct from community-based management in that it explicitly recognizes that government agencies often must be involved in a community's affairs for a variety of reasons including needs for resources not available in the community. However, it also recognises importance of community control over and responsibility for many aspects of resource management.

Efforts have been made in recent years to incorporate the basic notions of sustainable development and eco-system management approaches in national and regional sustainable development strategies and in policies dealing with biodiversity, conservation and others. Success in achieving the same, is dependent on the understanding the characteristics of the ecosystem and the factors driving change within it, However, there needs to be an interactive relationship between management actions and information requirements. The needs of management must be used to set the priorities for ecological and socio-cultural information to be gathered and management actions should be adapted in accordance with this new information.

Why Co-management ?

Experimentation with fishery co-management is taking in global scale. The worldwide interaction co-management arises in part because under other management processes effective linkages between public sector, private sector and communities have often failed to develop.

Co-management carries particular appeal in open water systems especially for small scale fisheries because of the conditions under which such fishery takes place. Moreover, because of vastness and common property resource, fishery in openwater systems is often most in need of effective management. Small-scale fisheries may have local or regional importance disproportional to their size. In many areas fish are the basis for protein food security of low-income people who depend on the resource base for survival.

For these reasons, finding effective ways to link stakeholders through resource management is critical to management success. The direct involvement of resource stakeholders in the planning and control of resource use offers the potential for improving resource sustainablility. The idea behind co-management as a means to link stakeholders is that people vested in planning attention and decision making are move likely to pay to system level resource effects than those who are not.

CO-MANAGEMENT: FUNCTIONS AND ELEMENTS

Co-management must perform the same functions like any other fishery management process. It develops goals for resource conservation. It develops rules to allocate the resource between competing interests. It monitors fish population status and the impacts of regulations. It is responsible for the enforcement of rules and the resolution of conflicts. The expectation is that co-management has certain attributes that make it more effective in these functions because of different linkages it creates.

Co-management is based on several elements of group decision-making. These elements applying to the background conditions under which fishery management takes place the structure of decision-making, the transactions cost of decision-making and the human capital requirements of decision-making. All affect the establishment of effective linkages.

BACKGROUND CONDITION

- *Property rights :* The set of entitlements to access and rules of use from people's expcetions about their claims to the fishery. Property rights in some form are necessary for co-management because without them there is no definition or assurance of legitimate participation or of the conditions that link user groups to each other and to the government. As long as rights are assigned and clearly specified and type can provide the appropriate background for co-management.

- *Uncertainty :* Uncertainty is background for all fisheries. Ecological systems vary market expands and contract and government policies change. The type of uncertainty that exists in fishery shapes expectations and behaviour and so also affects the links between users and government. There are ways that co-management can minimize the effects of uncertainty by broadening the sources of monitoring information, creating coordination between user groups, maintain consistency in rules and incentives and clearly specifying procedures of decision making.

Co-management structure

- *Boundaries :* When co-management is applied within clearly defined boundaries, decision making is brought into line with existing ecological and political systems. Boundaries serve several functions; they define and limit the number of legitimate users, they define areas of control and they reference decision making to an eco-system.

- *Scale :* Community-based management is nested within larger institutional jurisdictions, requiring that co-management process build compatible incentives at different levels creating consistency in incentives at different levels is not easy because both ***scaling up*** small scale properties to large scale systems and ***scaling down*** large scale properties to local scale can not be done proportionately. The number of boundaries or scales over which co-management directly affects costs and the effectiveness of establishing links.

- ***Representation :*** Linking stakeholders into management process is a critical element of co-management. The organizational task is to maximize representation so that decision reflect the full array of interests and so stakeholders are vested as possible in the process.

- ***Participation :*** Various levels of user participation are possible within a co-management process, ranging from information exchange to consultation to active self-governance. The type of participation is determined by the human capital embedded in stakeholders and in the resource available for co-ordinance.

- ***Transaction cost :*** Any organizational structure embodies cost. The structure of co-management importantly influences its costs because it determines how stakeholders are organized, how information is generated and used, how decision are made and how monitoring and enforcement takes place. These costs are called transaction costs and while costs are an inevitable part of resource management, their magnitude and so their influence can be influenced by management.

CONCLUSION

Building consensus among stakeholders about the objectives and levels of use of natural resources is essential for sustainable development. Government may decrease their involvement in the extensive day-to-day responsibility of resource management at community levels through collaborative management agreements like co-management with participatory approach.

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