



MANUAL | 1949

## Enhancing Fishery Productivity in Small Reservoir in India

Technical manual prepared for the Project:

Improved fisheries productivity and management in tropical reservoirs,  
CP-PN34: Challenge Program on Water and Food





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## Technical Manual

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This publication should be cited as:

K.K.Vass, N.P.Shrivastava, P.K.Katiha and A.K.Das. 2009. Enhancing fishery productivity in small reservoir in India. A Technical Manual. WorldFish Center Technical Manual No. 1949. The WorldFish Center, Penang, Malaysia. 19 pp.

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Publisher: The Director  
Central Inland Fisheries Research Institute  
Barrackpore, Kolkata  
West Bengal

Printer: The WorldFish Center,  
Penang, Malaysia.

Cover photograph: Mr. Shyam Lal Ary

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# ENHANCING FISHERY PRODUCTIVITY IN SMALL RESERVOIR IN INDIA

## INTRODUCTION

Inland capture fisheries in India have declined in recent years, leaving thousands of fishers to sink deeper into poverty. Freshwater aquaculture in small water bodies like ponds now contributes 80% of the country's inland fish production. However, future growth in freshwater aquaculture to meet rising demand for fish is likely to be constrained by limited supplies of land for digging new ponds and of water to fill them.

In this context, reservoirs offer immense scope for increasing fish production. They can both provide nutritional security in remote areas that lack adequate supplies of animal protein and sustain the livelihood of landless fishers who can no longer survive by fishing in depleted rivers and other natural freshwater bodies. The scientific management of reservoirs to sustainably enhance fisheries can therefore serve the twin purposes of (1) providing rural areas with food and livelihoods and (2) protecting aquatic ecosystems, in particular by facilitating the conservation of indigenous fish species.

## SELECTING A RESERVOIR FOR FISHERY ENHANCEMENT

A small reservoir proposed for experimental fishery enhancement should have clear ownership in terms of the authorities responsible for both environmental protection and fishery management. Stakeholders should be clearly defined. Any proposed development plan that entails intervening in the ecosystem needs to have the consent of all parties concerned.

**General biophysical characteristics.** The reservoir should be accessible, as management will entail moving personnel and materials to and from the reservoir, and the catch from the improved fishery will need to be shipped in a timely way to market.

Any small reservoir smaller than 1,000 hectares (ha) can be proposed for development, but intervention is easier and the impact will be more noticeable in a reservoir in the range of 300-700 ha. A saucer-shaped bottom is preferred, and the reservoir should maintain a depth of at least 4-5 metres to ensure good fish growth and harvesting,

Most small reservoirs in India were created primarily for supplying water to irrigate crops and for other uses. Stocking them with fish would improve the water

productivity of these systems overall, which should provide adequate incentive for water-controlling authorities to retain enough water to maintain the minimum 4-5 metres of depth necessary to sustain fish stocks. Where this is not possible, no attempt should be made to enhance the reservoir fishery. Local rainfall records can help determine the likelihood that the reservoir will be able to maintain adequate depth to be a candidate for fishery enhancement.

**Fingerling cage culture was developed and tested in Dahod Reservoir, near Bhopal, Madhya Pradesh.**



Weeds routinely infest small reservoirs, especially those that are relatively stable. Reservoirs that are selected for fishery enhancement should have macrophyte coverage in the range of 25-30%, dominated by submerged plants of the genus *Hydrilla*, *Potamogeton* and *Vallisneria* and other plants with soft tissues that can serve as food for introduced species such as grass carp. Excessive plant coverage hinders netting and impinges upon ecosystem productivity. Ecosystems excessively infested by aquatic plants like *Eichhornia* should be avoided, as habitat improvement would require heavy investment.

**Pahuj Reservoir, at Jhansi, Uttar Pradesh, was another project site.**



**Water temperature, transparency and oxygen.** The water temperature should be conducive to the feeding and growth of fish. At lower temperatures, fish stop feeding, which slows their growth. Very high water transparency indicates low plankton populations, reflecting low primary production, and should be avoided. Similarly, too little or too much dissolved oxygen is unfavourable for fish. The pH of the water should be mildly alkaline, as acidic or highly alkaline pH affects fish growth. Table 1 shows value ranges for choosing a conducive water body.



As excessive plant infestation hinders netting and impinges upon ecosystem productivity, macrophyte coverage should be in the range of 25-30%.



**Table 1: Water property parameters conducive to fish culturing**

Parameters	Conducive (Ideal)	Not conducive
Temperature (°C)	20-30 (26)	<15, >33
Transparency (cm)	40-150 (110)	<40, >200
pH	7.20-8.20 (7.8)	<7.00, >8.5
Dissolved oxygen (ppm)	6.00-8.50 (7.50)	<5.00, >8.5

°C = degrees Celsius, cm = centimetre, ppm = parts per million.

**Primary productivity.** The values of primary productivity and plankton density provide a rough estimate of anticipated production in the ecosystem. Moderate production values are best for rearing fish. Very low or high primary productivity and plankton density do not favour fish growth. Table 2 offers guidelines for appropriate ranges.

**Fingerlings measuring 70-100 millimetres and longer achieve good survival rates and growth.**



**Table 2: Water productivity parameters conducive to fish culturing**

Parameters	Conductive (Ideal)	Not conducive
GPP (gC/m <sup>2</sup> /d)	2.0-6.0 (4.0)	<2.0, 6.4
Plankton (u/l)	1,000-5,000 (3,000)	<1,000
Phyto/zooplankton ratio (%)	60-80/20-40	<50/<20

gC/m<sup>2</sup>/d = grams of carbon per square meter per day, GPP = gross primary production, u/l = units per litre.

**Basic nutrient status.** The concentrations of total alkalinity, nitrates and phosphates impinge upon primary production and the density of plankton, which form the base of the food chain for carp fisheries. Concentrations of nutrients should be reasonable, as too little or too much are detrimental to fish. The suitable ranges are shown in Table 3.

**Table 3: Alkalinity, nitrate and phosphate levels conducive to fish culturing**

Parameters	Conductive (Ideal)	Not conducive
Total alkalinity (ppm)	40-180 (100)	<40, >180
Nitrate (ppb)	50-300 (150)	<50, >300
Phosphate (ppb)	40-280 (100)	<40, >300

ppb = parts per billion, ppm = parts per million.

**Existing fish diversity.** Information from secondary sources or generated through rapid surveys about the natural food chain, in terms of both diversity and concentration, will help to identify vacant food niches that can be exploited with management interventions. It is better to harness the potential of food niches at the primary level.

Information on the number of fish species in the ecosystem should be procured from the fishery department if it is available, from fishers who operate in the ecosystem, or through experimental fishing. The species should be categorized as food species or others, valuable or low-value species, and exotic or indigenous. Ecosystem potential and market price should guide the choice of fish species to be managed and enhanced. Listing any sensitive indigenous fish species is the first step toward ensuring their conservation. The presence of small, medium-sized and large predatory fish species and their percentage in the total catch should be determined, as this information will be essential for guiding the enhancement intervention.

**Current and potential fish yield.** To estimate the trend in fish yield, obtain data on fish catches from the water body for past 3 years from the fisheries department or fishing cooperatives. The data may be by species or by group, distinguishing in particular indigenous species and exotics.

The data generated from the estimates of primary productivity and food chain characteristics can be used to estimate the potential fish yield from the ecosystem. The estimated potential fish yield should be compared with the actual harvested yield from the catch records, thereby estimating the gap between potential and actual yield. The information on the yield gap, vacant food niches, present combination of fish species, and ecosystem nutrient status determines how best to manage the fishery and enhancement its yield in a phased manner.

## ENHANCEMENT STRATEGY

Stocking policy is specific to a reservoir and decided by its biogenic capacity, the growth rate of stocked species, natural mortality, and losses to escape and predator pressure.

Fish should be stocked in environments suitable for their sustenance and growth. They should grow quickly by being highly efficient in utilizing natural food. Fish species that feed low on the food chain are preferred, but they should also offer good eating, economic value and potential for marketing, either locally or in remote markets.

Attempts to stock fry have done little to enhance production in Indian reservoirs. Studies suggest that fish fingerlings 70-100 millimetres (mm) and longer achieve better survival rates and good growth.

Small reservoirs measuring less than 1,000 ha can be stocked at a rate of 800-1,000 fingerlings/ha, taking into account the impact of existing catfish in the ecosystem and also the likely loss by escape.

Normally a combination of different Indian major carps can be used to enhance the reservoir catch. The combination is determined by the vacant food niches identified previously. If the density of phytoplankton and zooplankton is high, equal proportions of *Catla catla* and *Labeo rohita* can be stocked. The percentage of *Cirrihinus mrigala* and *Cyprinus carpio* should be decided based on the benthic population and detrital load in the reservoir, but they should not be more than 30% of fish population, as they are difficult to harvest. If the system has a lot of *Hydrilla* and *Potamogeton*, grass carp can account for about 10% of stock to control vegetation while boosting fishery productivity.

Stocking species in appropriate ratios can help shift the composition in favour of economically valuable species over low-value ones.

**Balancing wild and stocked species.** Enhancing production through stocking should not endanger the sustainability and conservation of indigenous species, especially if ecologically sensitive species are present. Small reservoirs should not be converted into production systems. Stocked species should not exceed 60-70% of the fish population, with indigenous species accounting for the remainder.

The number of seed required is estimated on the basis of the proposed stocking density, targeted production amount, area of the water body, species combination, fingerling availability and cost including transportation to reservoir site, and budget.

**Options for procuring fish seed.** After deciding upon the total seed requirement, a viable, economical approach is adopted to deliver the total seed in phases to the reservoir site. Considering the high cost of fingerlings that are large enough to survive, efforts should be made to source them locally, as this holds down the costs and mortality associated with transporting fingerlings. A hatchery or farm that can supply the entire requirement of healthy seed should be identified in advance. In many cases, the entire seed requirement cannot be met by local suppliers because they normally do not rear the seed to fingerling stage. The other option is to rear fry to fingerling size at the reservoir site in cage units, as was successfully demonstrated recently at two study sites.

**Fish seed should be procured nearby to minimize the costs and mortality associated with its transportation.**



Fish seed is transported in polythene bags. Transported fish seed is conditioned in a hapa.



## REARING FINGERLINGS ON SITE

A pen installed along the reservoir margin can be used to rear fingerlings up to stocking size. This is risky in small reservoirs, however, as their water level may change dramatically as water is draw down, leaving pens high and dry. To reduce this risk, a floating cage unit can be installed in the pelagic zone of the reservoir and produce fingerlings even during the dry season. Cages are preferred to pens in most situations.

**Cage culture.** A cage unit in the reservoir is used to rear fish fry to fingerling size for subsequent stocking in the reservoir to ensure better survival rates and faster growth of the stocked fish. A floating unit with eight cages can be used to rear 75% of the fingerling requirement of a reservoir measuring 200 ha. For larger reservoirs needing more seed, additional units can be installed.

**Cage fabrication and installation.** Locally available bamboo is the cheapest material for the cage frame. Two frames are required, one above the floats and the other below. To make a battery holding eight cages, each measuring 5×3×3 metres, the battery should be of 13.75 metres long and 11.05 metres wide.

The cage unit is constructed on site using locally sourced bamboo to hold down costs.



Used steel drums provide buoyancy.



The bamboo frame is floated in the reservoir.



The battery of eight cages is buoyed in the water by used steel drums sandwiched between the two frames. The drums are placed near the corners and joints to provide the frames with balanced buoyancy. The drums are bound to the frame using glazed iron wires. The frames are anchored at the selected site.

One frame holds a battery of eight Netlon cages that hang in the water, with the bottom corners and sides of the nets tied to sinkers to hold the sides vertical. The bottoms of the cages should remain at least 1-2 metres above the lake bottom to avoid damage.

**A stocking density of 250 carp fry measuring 12-18 mm per cubic metre is suitable for cages.**



**Stocking fry and rearing fingerlings.** Healthy carp fry measuring 12-15 mm in length, or up to 25 mm, are suitable for rearing into

**Netlon is fitted into the floating bamboo frame.**



fingerlings for stocking a reservoir. A stocking density of 250 carp fry measuring 12-18 mm per cubic metre is suitable for cages. The seed should be transferred late in the day or early in the evening after being properly conditioned at the site of procurement and acclimatized at the cage site. Prior to release in the cage, the fry are dipped in a salt or potassium permanganate solution as a prophylactic measure.

**A completed battery of eight cages is unaffected by fluctuations in water height.**



Rearing carp fingerlings in cages generally requires 60 to 120 days, depending on the natural productivity of the water body. Providing supplementary feed minimizes the grow-out period. Rice bran and mustard oil cake is blended at a ratio of 1:1 and provides available vitamins and minerals at a mix of 0.01% in a flaky powder. The feed is broadcast inside the cages twice a day, at 8 am and 5 pm, at a rate of 3-5% of fry body weight.

Cage and stock maintenance demands several routines: regular monitoring of water quality for dissolved oxygen, pH and ammonia; cleaning cages with soft brushes fortnightly to remove fouling organisms; routinely checking cages for loose twine, mesh torn by predators, and the state of anchors and sinkers and promptly repairing any problem found; routinely check fingerlings for signs of disease, such as surfacing, lesions, rashes, spots, lumps, excessive mucus formation, wool-like mat formation on the body, bulging eyes, or fin and tail erosion; and periodically recording fingerling growth rate to inform a strategy for fish health and feeding, as well as a harvesting schedule.

**Fry should be transferred late in the day or early in the evening after being properly conditioned at the site of procurement and acclimatized at the cage site.**



Fingerlings should be removed in batches by size, removing those that have reached a length of 70-80 mm and leaving smaller fingerlings to grow further.



Two crops can be harvested annually from one battery of eight cages, which is adequate to supply 75% of stocking materials required per year for a water body of 200 hectares.

Feed is broadcast inside the cages twice a day, at 0800 and 1700 hours, at a rate of 3-5% of fry body weight



**Fingerling harvest and release.** Fingerlings should be removed in batches by size, removing those that have reached a length of 70-80 mm and leaving smaller fingerlings to grow further, without having to compete with larger fingerlings for feed.

**Costs and benefits.** Two crops can be harvested annually from one battery of eight cages, which is adequate to supply 75% of stocking materials required per year for a water body of 200 ha.

The assessment of the economic viability of rearing fish fingerlings in cages revealed the cost of production for one crop to be Rs28,407, with 21% being fixed costs and 79% variable costs. The major components of variable costs were fish fry (42%), feed (11%) and labour (11%). Recent experiments found the survival rate a moderate 70%, producing 70,000 fingerlings per crop. The



cost of production per fingerling was 0.40 rupees. With a fingerling price of 1 rupee each, the benefit:cost ratio was 2.5, confirming the viability of rearing fingerlings in cages in reservoirs.

## FOOD FISH HARVEST AND POSTHARVEST HANDLING

The recapture of stocked fish should be phased so that each species is allowed to grow to at least its minimum marketable size. *Catla catla*, should weigh at least 1.5 kg, and *Labeo rohita* and *Cirrhinus mrigala* should weigh at least 1 kg. The mesh size of fishing nets must be determined by the minimum marketable size of the various fish species, with an eye toward sustaining fish stocks. To avoid catching undersized fish, gill nets with a mesh smaller than 50 mm should be barred. Fishing effort should be gauged to anticipated production, based on the number of seed stocked and regulated to sustain the yield of desirable species. Developing better management practices requires keeping a daily record of catches during the fishing season, so fishers should be trained to keep records.

**Table 4: Calendar for co-managing a reservoir proposed for fishery enhancement**

Months	Input/Output
January to March	Community discussion, repair of nets and boats, cage and pen installation, nursery repair, interaction with all stakeholders including the technology provider, fishing of previous stocks including wild fish
April to June	Procurement of fry for rearing in nursery cage or pen to fingerling size measuring 70-80 mm for stocking and sale of any surplus
July to August	Closed fishing season observed for stocked species but not for wild stocks
September to March	Fishing of stocked species as per protocol and of wild stocks as per market demand

**The recapture of stocked fish should be phased so that each species is allowed to grow to at least its minimum marketable size.**



The price of fish varies according to species, size and condition. Segregating and grading the fish catch according to species, size and condition is necessary prior to display for sale either at a wholesale or auction venue or a retail fish market. This helps fishers or marketers fetch better prices.

**Segregating and grading the fish catch according to species, size and condition helps fishers or marketers fetch better prices.**



**Assembling the fish catch at a landing centre and delivering it to market collectively reduces transportation and storage costs.**



Assembling the fish catch at a landing centre and delivering it to market collectively reduces transportation and storage costs. Fitting bicycles with iceboxes is a low-cost solution that maintains the condition of the fish, so it can fetch higher prices at the market.

Adopting collective disposal of the catch strengthens fishers' bargaining position with local dealers. Additionally, fishers can create more efficient marketing channels and earn more from their catch by marketing directly through a fisher society shop established at the wholesale fish market with deep-freeze storage. If the catch oversupplies local demand, some of it can be sold in secondary and retail markets.

**Fishers can create more efficient marketing channels and earn more from their catch by marketing directly through a fisher society shop established at the wholesale fish market.**



For direct marketing to succeed, fishers need market information and financial support to develop marketing infrastructure to handle processing, transportation, storage and display.

**Fitting bicycles with iceboxes is a low-cost transportation solution that maintains the condition of the fish, so it can fetch higher prices at the market.**



## **SOCIOECONOMIC ANALYSIS**

Reservoir fishery management is a participatory process, requiring the community's active participation at every stage. Fishery enhancement that entails rearing fingerlings in cages in the reservoir crucially entails the involvement of the local fishers and should not proceed until they have expressed their willingness to participate.

Reservoirs generally have multiple uses and stakeholders. They may be used for irrigation, flood control, hydropower generation and domestic water supply, as well as for fishing. The divergent interests of various users may give rise to conflict. Fishery enhancement can succeed only where conflicts are minimal.

Fishers constitute one of the poorest communities in society. Fishery enhancement requires investments for producing fish seed or procuring seed from hatcheries, and fisher communities also need money to lease fishing rights and buy their gear. This will often require financial support.

Fisher communities generally lack organization, leadership and political support. The success of fishery enhancement depends on the capacity of the community to coordinate and implement the practice. Fishers further require strong leadership to argue their case in conflicts with other reservoir users, coordinate and implement successful fishery management, and negotiate fair remuneration for the catch.

Remuneration for the catch is a function of fish prices, which reflects market demand for fish, so demand should be sufficient, if not in local markets then in more remote markets. Whether near or far, markets must be readily accessible and institutionally welcoming.

The success of any production process depends on economic feasibility. The process cannot continue in the long run if it lacks economic feasibility and incurs continuing losses. Fishery enhancement is no exception, and its economic viability must be worked out by comparing expenses with potential returns.

## ACKNOWLEDGEMENTS

Consultative Group on International Agricultural Research Challenge Program on Water and Food, Project CP34: Improved Fisheries Productivity and Management in Tropical Reservoirs

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WorldFish gratefully acknowledges the highly valued unrestricted funding support from the Consultative Group on International Agricultural Research (CGIAR), specifically the following members: Australia, Canada, Egypt, Germany, India, Israel, Japan, New Zealand, Norway, the Philippines, Republic of South Africa, Sweden, Switzerland, the United Kingdom, the United States of America and the World Bank.



This document is part of a series of 5 technical manuals produced by the Challenge Program Project CP34 "Improved fisheries productivity and management in tropical reservoirs".

The other Technical Manuals are:

- Cage Culture in Reservoirs in India.
- Building fish enclosure in Lake Nasser.
- Engaging local communities in aquatic resources research.
- Producing Tilapia in small cage in West Africa.

2009

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