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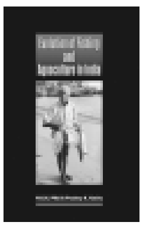

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Profile of inland aquaculture and fisheries technologies

Freshwater aquaculture

The prevalent freshwater aquacultural technologies along with their culture practices are summarised in Table 18.

Polyculture of Indian carps or Indian and exotic carps together (Composite carp culture)

Species Mix

The species mix of 3-6 carps including three indigenous (*Catla catla*, *Labeo rohita* and *Cirrhinus mrigala*) and three exotic (*Hypophthalmichthys molitrix*, *Ctenopharyngodon idella* and *Cyprinus carpio*) carps is very popular. Some of the other fish species and species combination adopted for freshwater aquaculture technologies are *Labeo bata* and *C. reba* in sewage fed, *Ctenopharyngodon idella* (grass carp more than 50%) in weed based, medium and minor carps, *viz., Labeo calbasu*, *L. gonius*, *L. bata*, *Puntius pulchellus*, *P. sarana* and *Cirrhinus cirrhosa* in integrated fish farming with paddy-cum-fish culture.

The low input or fertiliser based, medium input or fertiliser and feed based, sewage fed and weed-based having yield of 1-3 t ha^{-1}, are considered as extensive technologies. The most important carp culture technology i.e. the composite fish culture and intensive carp culture are, considered for discussion.

Carp polyculture or composite carp culture

The research and development efforts during the last five decades have greatly enhanced average fish yields in the country making carp culture an important economic enterprise. It has grown in geographical coverage,

Table 18. Farming practices under different aquacultural technologies

System	Species	Stocking (000 fingerling ha^{-1})	Fertilization / Liming ha^{-1}	Feed day^{-1}	ManagementPractices	Duration of rearing (month)	Yield (t ha^{-1} yr^{-1})
Carp polyculture Low input	3-6 species	3-5	Cow dung 10-15t/ Poultry droppings 3-5t, Urea 0.2t, SSP 0.3t	No feed	Fertiliser use, maintenance of water depth at 1.5-2.5 m	10-12	1-2
Medium input	3-6 species	5-10	Cow dung 10-15t/ Poultry droppings 3-5t, Urea 0.2t, SSP 0.3t	Rice bran and oil cake, @ 2-3% of fish biomass	Maintenance of water depth at 1.5-2 m, Intermediate liming at 3 month interval @100 kg ha^{-1}	10-12	3-6
High input	3-6 species	15-25	Less use of organic manure, Bio-fertilization with Azolla, SSP	Rice bran, oil cake, fish meal, Vitamin and mineral mix, @ 2-3% of fish biomass,	Aeration, water exchange towards later part, intermittent liming at every quarter @100kg ha^{-1}, maintenance of water depth at 2-2.5 m	10-12 Periodical harvest	10-15
Sewage fed	3-6 species + *L. bata*, *C. reba*	30-50 (total in 2-4 intermittent stocking)	Domestic sewage water	No feed	Multiple stocking and multiple harvesting (Size 100-200 gm), Maintenance of water depth at 0.7- 1.5 m	8-10	2-5
				With feed	- do -	- do -	3-7
Weed based	50% grass carp and 50% other species	4-5	SSP 3q for one crop to be applied at 15 days interval Liming @ 100 kg /quarter	Aquatic weed (*Hydrilla*, *Najas*, *Ceratophyllum*, Duck weeds like *Spirodella*, *Lemna*, *Wolffia*, etc.	Maintenance of water depth at 1.5-2 m	10-12	3-4

SSP – single super phosphate

Contd…….

……… contd **Table 18**

System	Species	Stocking (In 000 Fingerling ha^{-1})	Fertilization / Liming ha^{-1}	Feed day^{-1}	ManagementPractices	Duration of rearing (month)	Yield ($t\ ha^{-1}\ yr^{-1}$)
Integrated: Cattle (3 – 4 ha^{-1}) Duck (300 ha^{-1}) Poultry (500 ha^{-1}) Pig (50 ha^{-1})	3-6 species	5-10	No fertiliser use, liming	Rice bran and oil cake, 2-3% of fish biomass	Maintenance of water depth at 1.5-2 m	8-10	3-5
Paddy- cum- Fish	3-6 species and Medium & Minor carp	5-10	Cow dung 10-15 t	Rice bran and oil cake, 2-3% of fish biomass	Maintenance of water depth at 1.5-2 m in pond	6	0.5-2.0 of fish 3-6 of paddy
Pen	3-6 species	5-10	Liming	Rice bran and oil cake, 2-3% of fish biomass	Maintenance of water depth at 1.5-2 m	8-10	3-5*
Cage	Single species			Experimental stage			10-15*
Running water	Single species			Experimental stage			20-50*
Air-breathing	Mono-culture	20-50	Cow dung 10-15t/Poultry droppings 3-5t, Urea 0.2t, SSP 0.3t	Rice bran, oil cake and Fish meal	Maintenance of water depth at 1-1.5 m	8-10	3-6
Freshwater Prawn	Mono-culture	20-50	Cow dung 10-15t/ Poultry droppings 3-5t, Urea 0.2t, SSP 0.3t	Pellet feed	Maintenance of water depth at 1-1.5 m	6-8	1-1.5
Polyculture of Carp with Prawn	2-3 species of carp + Prawn	Fish 5 + Prawn 10-15	Cow dung 10-15t/ Poultry droppings 3-5t, Urea 0.2t, SSP 0.3t	Rice bran and oil cake, 2-3% of fish biomass	Maintenance of water depth at 1-1.5 m	10-12	Fish 3-4 Prawn 0.3-0.5

* $kg\ m^{-2}\ yr^{-1}$

Source: Katiha *et al.*, 2002

diversification of culture species and methods, besides intensification of farming systems. The three Indian major carps, *viz*., catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*) were the principal species cultured by the farmers in ponds since ages and production from these systems remained significantly low (600 kg ha^{-1} $year^{-1}$) till the introduction of carp polyculture technology. The introduction of exotic species like silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*) into the carp polyculture system during early sixties added new dimension to the aquaculture development of the country. With the adoption of technology of carp polyculture or composite carp culture, production levels of 3-5 tonnes ha^{-1} $year^{-1}$ could be demonstrated in different regions of the country. Probably it is the technology of carp polyculture that has revolutionized the freshwater aquaculture sector from a level of backyard activity to that of a fast growing and well organized industry and placed the country on the threshold of blue revolution. The average production in the ponds has gone up from 600 kg ha^{-1} $year^{-1}$ to over 2 t ha^{-1} $year^{-1}$, with several farmers demonstrating higher production levels of 8-12 t ha^{-1} $year^{-1}$. A haul from a pond is depicted in Fig. 2.

Fig. 2. Catch from a pond adopting composite fish culture

The standard recommended carp culture in India involves three species of Indian major carps or the combination of three Indian major carps with three exotic carps, depending on the market demand and resource availability. Standardized package of practices for carp polyculture include predatory fish and weed control by use of certain chemicals or plant derivatives; stocking of Indian major carps and exotic carps at densities of 4,000-10,000 fingerlings ha^{-1}; pond fertilization with application of organic manures like cattle dung or poultry droppings and inorganic fertilizers; provision of supplementary feed; and water quality management.

Intensive carp culture technology

The average production of the country from still water ponds is about 2 t ha^{-1} $year^{-1}$. With the packages of practices developed in the ICAR (Anon., 2000a) there are possibilities of producing 10 to 15 t ha^{-1} yr^{-1}. Standardized package of practices for intensive carp polyculture include:

i) predatory and weed fish control by use of certain chemicals or plant derivatives;

ii) pond fertilization with application of *Azolla* at 40 t ha^{-1} yr^{-1} at weekly split doses as bio-fertilizer, substituting traditional organic and inorganic fertilization;

iii) stocking of Indian major carps and exotic carps of 25-50 g size at densities of 15,000-25,000 fingerlings ha^{-1};

iv) provision of balanced formulated supplementary feed, comprising rice-bran, ground nut oil-cake, soybean flour, fish meal and vitamin mineral premix;

v) provision of 4-6 paddle-wheel aspirator/aerators per hectare of water to keep dissolved oxygen within desirable limits, especially during night, maintenance of water column of 1.5-2 m,

vi) water replenishment depending on the water quality, and

vii) fish health management through prophylactic and curative measures depending on the necessity.

Though harvesting of the table-size fish is done usually at the end of 10-11 months, partial harvesting of bigger size fishes is done during monthly samplings, after a growth period of 6-7 months, which provides congenial environment for remaining fishes and reduces the amount of supplementary feed. Stocking of larger size of seed, preferably 25-50 g minimizes mortality during initial months and thus leads to higher survival at harvest. Supplementary feed being major input, contributing over 60-70% to the input cost, needs judicious application, and the quantities are determined based on the fish biomass present at any given point of time. Supplementary feed in the form of dry pellet, offered in 2-3 rations per day, helps in effective utilization and minimal wastage.

Mono/ Polyculture of air-breathing fishes

The air-breathing fishes are distinguished by possession of an accessory respiratory organ, which enables them to survive for hours outside water or indefinitely in water with low oxygen content. They are extremely hardy for environmental stresses and adaptable for the waters unsuitable for conventional cultivable species.

Magur (*Clarias batrachus*), singhi (*Heteropneustes fossilis*), koi (*Anabas testidineus*) and murrels, giant murrel (*Channa marulius*), stripped murrel

(*C. striatus*) and spotted murrel (*C. punctatus*) are the most important culturable species in India.

The air-breathing fish culture is particularly oriented to shallow waters (2-3 ft depth). The material inputs needed are the fingerlings (6-10 g) and feed. Replenishment of water is essential in case of very heavy stocking and multiple cropping to obtain high yields. Pond size of 0.1-0.2 ha, is considered optimum for effective management. Magur and singhi grow very well in water temperature upto 32^{o}C. Fishes are stressed at around 35^{o}C and mortality starts at 38^{o}C. Collection of seed from nature continues to be the dependable source for stocking material. The peak season for collection of seed is pre-winter period. Availability of air-breathing fish seed is plenty in parts of Assam, Andhra Pradesh, Bihar, West Bengal and Karnataka. The fry-rearing phase in murrels is complex due to cannibalism. It can be reduced with supplementary feeding.

The monoculture of magur and singhi permits high stocking density (40-50 thousand ha^{-1}), while for polyculture with carps it varies between 20-30 thousand ha^{-1}. For monoculture of murrels the stocking density could be between 15-25 thousand ha^{-1}, with the lowest for giant and highest for spotted murrels. Feed for singhi and magur includes fish offal, slaughter house waste, dried silkworm pupae mixed with rice bran and oil cake in the ratio of 1:1:1. The mixture of rice bran, oil cake and biogas slurry in the ratio of 1:1:1 also proved successful. The feeding schedule varies over the culture period and for different species. Feeding may be done by broadcasting the feed in small quantity or by lowering feed basket near the banks in addition to broadcasting. The culture period for these fishes may vary between 8-10 months with an average yield of 3-6 t ha^{-1}.

Mono/Polyculture of freshwater prawn

In India, freshwater prawn (Fig. 3) culture is becoming popular. Monoculture of *Macrobachium rosenbergii* and its polyculture with carps are common. They are available in freshwater bodies like rivers, streams, canals, beels, swamps, lakes, *etc*. The prawn seeds can be collected from natural resources or produced at government / private prawn hatcheries. They feed on algae, insect larvae, molluscs, worms, smaller weed fishes, cereals, slaughter house wastes, oil cakes, etc. Freshwater prawns can tolerate very high range of salinity, but salt concentration upto 5 to 6‰ is preferred. Rectangular ponds of 0.1-2.0 ha size having unpolluted freshwater, with high concentration of oxygen is considered ideal. Liming and pond fertilization helps freshwater prawn in attaining quicker and the healthy

Fig.3. Freshwater prawn

growth. Normally stocking density ranges from 20000 to 50000 ha^{-1}. Male grows bigger than females and attains about 70 g average weight in 6-8 months.

Periodic sampling to monitor growth, survival and to decide the feeding dosages is essential. The production ranging from 1-1.5 t ha^{-1} can be achieved in scientifically managed system. Freshwater prawn farming is assuming greater importance due to very high demand, good price and high returns.

Integrated fish farming

Integrated fish farming refers to two or more farming sub systems, which are components of a larger farming system (Anon., 2000a). Such farming systems can broadly be categorized into two types:

(i) Systems with no direct byproduct utilization from one to other sub system, but optimal utilization of farming space and time e.g. paddy-cum-fish culture, and

(ii) Systems where byproduct i.e., waste from one subsystem is being utilized for sustenance of other e.g., fish-pig/poultry/duck farming.

Paddy-cum-fish culture

The practice (Fig. 4) is undertaken in deep-water bodies with fairly strong dykes to prevent escape of cultivated fishes during floods. Presence of channels, small ponds or sump near the field is essential to give shelter to fish against heat and predators. In India, fish species like catla, rohu, mrigal, common carp, murrel, magur, etc. at 5000-10000 ha^{-1} are used in paddy-cum-fish culture. The excreta of fish and leftover supplementary feed help in fertilizing soil thereby increasing paddy

Fig.4. Paddy-cum-fish culture

production. Some fishes eat harmful insects and their larvae, which otherwise can cause problems to paddy. A production level of 0.5-1 t fish ha^{-1} and 3-6 t paddy ha^{-1} can be achieved in a well-managed system.

Fish-cum-cattle farming

The pond embankments can be used for cattle shed and their washings drained directly into pond. A better way to utilize dung is in the form of slurry. About 30-60 t slurry ha^{-1} could be applied to pond. It has been estimated that dung and urine obtained from 3 to 4 cattle is sufficient to fertilize a pond of 1 ha. The production levels of 2-3 t $ha^{-1} yr^{-1}$ can be achieved from this system without addition of any supplementary feed.

Pig-cum-fish farming

The excreta from 30-50 pigs have been found adequate to fertilize 1 ha pond. The pig waste acts as an excellent fertilizer and for some fish species this acts as feed. Production levels as much as 3 t $ha^{-1} yr^{-1}$ of fish have been achieved along with 1.6 t pig meat ha^{-1} (live weight) from such an integrated pig cum fish farming (Fig. 5).

Fig.5. Pig cum fish farming

Duck-cum-fish culture

Ducks feed on tadpoles, snails, flies, insects, etc. A total of 200-300 ducks are sufficient to fertilize 1 ha pond. The embankments are used for night shelter. During day when they are in search of food they also aerate pond water, in addition to helping pond bottom raking effect. The fish yield from duck-cum-fish farming system (Fig. 6) ranges from 3-5 t $ha^{-1} yr^{-1}$, in addition to 4000-8000 duck eggs and 500-750 kg duck meat ha^{-1} from the unit.

Fig.6. Duck cum fish farming

Poultry-cum-fish farming

Fig.7. Poultry cum fish farming

In this system 500 country birds are adequate to fertilize 1 ha pond. The dosage of application of poultry manure is about one third the rate of cow dung. A production of about 3-5 t fish, 70,000 eggs and 1.0 t meat ha^{-1} is expected from this farming system (Fig. 7) in a year.

Aqua feed Technologies

Over the last decade fish farming has been fast developing from traditional extensive system to semi intensive and intensive culture system by increasing the fish stocking density to maximize the utilization of water resources. As density exceeds the natural carrying capacity, dependence shifts from natural food to nutritionally favourable exogenous feed (Fig. 8) to achieve optimum growth and production (Mukhopadhyay, 1998).

The supplementary feeds provided in most of the freshwater aquaculture systems are still confined to traditional bran oil cake mixture. Researches have been initiated with regard to the amino acid, fatty acids, vitamins and mineral requirements, provision of additives like growth promoters, antioxidants, preservatives and probiotics, formulation of diets for various life stages of different cultivable species in different culture systems *viz*. ponds, cages and pens, raceways and flow-through system needs.

Fig.8. Common fish feed ingredients and preparation of palleted feed at CIFA

Pheretima spp. have great nutritive value and are used as food for aquarium fishes. Aquarium fish enjoys consuming chopped earthworm. In the maintenance of fish in an aquarium, formulated marketable feed is often seen to be very expensive. The eco-friendly economical method to produce aquarium fish food with no toxic residue is certainly a promising area (Mitra, 1999).

Cost and returns of freshwater aquaculture

The cost structure, returns and benefit cost ratios for different aquacultural technologies are presented in Table 19. Cost structure has primarily the items of lease value of the water body, cost of organic manure and inorganic fertiliser, seed, feed, management and harvesting. The specific costs related to particular technology include expenses on bird/animals in integrated fish culture, cost of paddy cultivation in paddy-cum fish culture, construction of pens in pen culture, etc. The feed is the most important component of cost, accounting for more than 50% share in total cost. The lease value varies depending on the fertility and property and management regimes of the water body. The cost of inputs varies according to intensity of their use across different technologies in accordance with requirements. The higher cost in the case of high input carp culture (Rs 3.06 lakh) was primarily due to feed cost. The lowest cost was for low input carp polyculture (Rs 41925), due to absence of supplementary feed. The net profit per ha ranged between Rs 18950 for pen culture to Rs 1.39 lakh for prawn culture. The benefit cost ratio was maximum for pig cum fish culture (2.58). For other technologies, it ranged between 1.22 for high input carp culture to 1.86 for low input carp polyculture and prawn culture.

Investment needs for dominant freshwater technologies

The micro-level investment needs for adoption of various technologies may be calculated on the basis of the gross costs mentioned in Table 20. The estimation of budget requirements for macro-level adoption and implementation of these technologies are done after assessment of their prospects for adoption at national level.

The main freshwater aquaculture technologies are predominantly for carp culture. The distribution of potential area under different carp culture technologies is given in Table 6. The investment needs for intensive, semi-intensive and extensive carp culture in the entire cultivable area has been estimated as Rs 111.37 billion (Table 20). Maximum investments could be for semi-intensive carp culture (66%) followed by extensive carp culture (20%) and intensive carp culture (14%). Most potential states for investments would be West Bengal, Andhra Pradesh and Uttar Pradesh. The investment for intensive carp culture would be in the states of Andhra Pradesh, Haryana, Punjab and West Bengal, while the investments in semi-intensive and extensive aquacultural technology would cover most of the states of India.

Table 19. Cost and returns (Rs ha^{-1}) for different freshwater aquaculture technologies

	Carp Polyculture			Sewage fed		Weed	Integrated				Pen	Air-	Prawn	Carp-
	Low input	Medium input	High input	without feed	with feed	Based	Duck	Poultry	Pig	Paddy	culture	Breathing	culture	Prawn Culture
Cost														
Lease value (year^{-1})	10000	10000	10000	10000	10000	10000	10000	10000	10000	5000	2000	10000	10000	10000
Pond preparation	7500	7500	7500	7500	7500	7500	7500	7500	7500	2000	7500	7500	7500	7500
Fertilizers & Lime	10000	7500	7500	2500	2500	2500	2500	2500	2500	2500	7500	7500	7500	7500
Fingerlings (Seed)	3500	7000	20000	7000	7000	3500	3500	3500	3500	3500	7000	20000	30000	15000
Bird/Animal							3600	4000	4500					
Paddy										7500				
Pen											30000			
Feed (Birds/Animals)							10000	50000	7500					
Fish Feed		60000	200000		30000						20000	80000	60000	50000
Sewage cost				7500	7500									
Labour (Management Weed CollectionHarvesting)	5000	15000	30000	10000	15000	20000	15000	15000	15000	15000	15000	30000	30000	15000
Miscellaneous	3000	5000	10000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Interest	2925	8400	21375	3712.5	6337.5	3637.5	4282.5	7312.5	4162.5	3037.5	7050	12000	11250	8250
Total cost	41925	120400	306375	53212.5	90837.5	52137.5	61382.5	104812.5	59662.5	43537.5	101050	172000	161250	118250
Fish yield (t ha^{-1})	2.5	6	12.5	3	5	3	3	3	3	1	4	4	1.5	3
Other							Meat 0.7 t Egg 8000	Meat 1.0 t Egg 70000	Meat 1.6 t	6 t				0.5 t
Returns														
Fish/ Prawn	75000	180000	375000	90000	150000	90000	90000	90000	90000	30000	120000	240000	300000	90000
Others							30000	92000	64000	36000				100000
Gross returns	75000	180000	375000	90000	150000	90000	118000	182000	154000	60000	120000	240000	300000	190000
Profits	33075	59600	68625	36787.5	59162.5	37862.5	56618	77188	94338	16463	18950	68000	138750	71750
B:C ratio	1.79	1.50	1.22	1.69	1.65	1.73	1.92	1.74	2.58	1.38	1.19	1.40	1.86	1.61

Source: Katiha *et al.,* 2002

Table 20. Investment needs (Rupees in crores) of the dominant freshwater technologies

States	Intensive Carp culture	Semi –intensive Carp culture	Extensive Carp culture	Total
Andhra Pradesh	6127.50	13244.00	2934.75	22306.25
Assam		1444.80	125.78	1570.58
Bihar		4816.00	1257.75	6073.75
Goa			62.89	62.89
Gujarat		2408.00	838.50	3246.50
Haryana	1531.88	481.60		2013.48
Himachal Pradesh		36.12	8.39	44.51
Jammu & Kashmir		481.60	209.63	691.23
Karnataka		1204.00	5869.50	7073.50
Kerala		240.80		240.80
Madhya Pradesh		2408.00	2096.25	4504.25
Maharastra		1204.00	838.50	2042.50
Orissa		4816.00	1257.75	6073.75
Punjab	1531.88	240.80		1772.68
Rajasthan		1806.00	2096.25	3902.25
Tamil Nadu		2408.00	3354.00	5762.00
Uttar Pradesh		10836.00		10836.00
West Bengal	6127.50	24080.00		30207.50
North-east		1204.00	1677.00	2881.00
Other States		60.20		60.20
Total	15318.76	73419.92	22626.94	111365.64
% of total	13.76	65.92	20.32	100.00

Source: modified from Katiha and Bhatta, 2002 & Katiha *et al*., 2002

Brackishwater Aquaculture

The problems of fast growing human population and protein deficit, particularly in the developing countries, continue to exert pressure on the fisheries resources available for exploitation in the wild waterbodies. The increasingly limited opportunities in the capture fisheries sector have generated considerable interest in aquaculture. The potential of aquaculture in meeting the increasing demands for fishery products, generating income and profits and contributing to sustainable food supplies is considered to be quite significant. Environmental and socioeconomic management of coastal aquaculture through the diversification of shrimp aquaculture and seafarming is a challenging task. Coastal aquaculture and seafarming are very diverse in terms of the people involved, the resources used, the farming practices followed, and the environmental characteristics of the existing and potential sites. There are, however, opportunities for greater expansion, adaptation and integration in the onshore saline aquaculture sector (in inland saline ecosystem and coastal ecosystem) and seafarming.

Shrimp farming

Shrimps being highly valued export commodity, shrimp farming (Figs. 9 and 10) is considered a lucrative industry. Depending on the area of the pond, inputs like seed, feed and management measures like predator control, water exchange through tidal effects or pumping etc., farming systems have been classified into extensive, modified extensive, semi-intensive and intensive (Table 21). In the coastal low lands (*Pokkali* fields in Kerala, *Khar* lands in Goa, *Khazans* in Karnataka and *Bheri* in West Bengal) of India, there is a traditional practice of shrimp farming in rice fields done as a rotational crop after rice harvest and which yields production of upto 0.5 t $ha^{-1} year^{-1}$.

According to the Marine Products Export Development Authority (MPEDA) which is the main agency promoting shrimp farming and export through various schemes and subsidies, during 2001-02, about 156500 ha was under shrimp culture, with an average production of 0.7 t ha^{-1} $year^{-1}$. Currently 80% of the shrimp production comes from small and marginal holdings, with farms of less than 2 ha constituting 49.24% of the total area under culture, between 2-5 ha (15.76%), 5-10 ha (12.91%) and the rest >10 ha.

Presently, there are also 200 operational shrimp hatcheries with a total annual production capacity of 10.8 billion seed (PL 20), most of them located on the east coast with state of the art facilities. There are also 33 feed mills with a total installed capacity of 150000 t to cater to shrimp industry.

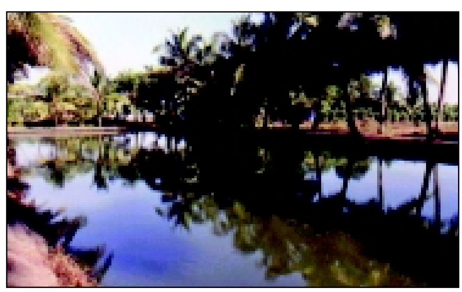

Fig. 9. Shrimp farm

Fig. 10. Farmed shrimp

Unemployment is a serious issue, especially in the rural areas of India. Consequent upon the establishment of shrimp farms, employment is reported to have increased by 2-15% and the average income of farm labourers has increased by 6-22% (CIBA, 1997). The average labour requirement for

Table 21. Shrimp farming systems of India

Characteristic	Extensive	Improved extensive	Semi-intensive
Pond size	1-2 ha	1ha	0.25-1ha
Pond preparation	None	Predator removal using Mohua oil cake(@2-2.5 t ha^{-1}) or tea seed cake (0.5-1 t ha^{-1}); Liming depending on pH of the water (0.3-0.4 t ha^{-1}) and fertilization with urea and superphosphate (25-100 kg/ha of each, Superphosphate alone mixed and kept overnight) and silica	Pond drying in between crops. Other steps same as for improved extensive
Stocking	20000 seeds ha^{-1}	50000 seeds ha^{-1}	1-2 lakh seeds ha^{-1}
Water quality management	Tide fed ponds, no water exchange	10 –15% water exchange regularly after 20 days of stocking, increasing as culture progresses to 20 –25%; aerators for improving oxygen levels provided	Daily water exchange 10- 25%; more number of paddle wheel aerators
Feed	Farm made using rice bran, fish /prawn meal or fresh clam/mussel meat	Pelleted feeds of feed conversion ratio 1-2. Feeding 2-3 times daily	High energy imported feeds
Production	0.75 t ha^{-1} $crop^{-1}$	1.5 t ha^{-1} $crop^{-1}$	4-5 t ha^{-1} $crop^{-1}$

Source: CMFRI, 1997a

paddy cultivation was found to be 180 labour days $crop^{-1}ha^{-1}$ compared to shrimp farming where 2 crops are harvested and labour requirement is 600 labour days crop $^{-1}ha^{-1}$ (Rao and Ravichandran, 2001). Ancillary industries like hatcheries, feed mills, processing and ice plants have also generated employment opportunities and boosted the rural economy (Table 22).

Table 22. Growth of ancillary industries in Nellore district, Andhra Pradesh

Ancillary industries	1990-91	1992-93	1994-95	1996-97	Total capacity (annual)	Employment generated
Hatcheries (Shrimps & Prawns)	0	4	30	33	2380 million PL	1650
Processing Plants	0	3	6	8	24000 mt	NA
Feed mills	0	13	14	14	78000 mt	840
Ice Plants	8	14	22	24	285 mt	400

Source : Rao and Krishnan, 2000

Crab farming/fattening

Fig. 11. Mud crab fattening

In view of the widespread disease problems in shrimp farming during the nineties, farmers looked for alternate, more disease resistant and economically important commercial fish species. Live mud crabs (*Scylla serrata*, *S. tranquebarica)* being a much sought export commodity, mud crab fattening was considered the best alternative (Fig. 11). Seed stock consist of freshly moulted crabs (water crabs) of 550 g which are stocked in small brackishwater ponds at a stocking density of 1 m^{-2} or in individual cages for a period of 3-4 weeks while being fed thrice daily with trash fish @ 5-10% their biomass. Selective harvesting is done according to size, growth and demand and the venture is profitable because of low operating costs and fast turnover (Table 23). Mono-culture (with single size and multiple size stocking) and poly-culture with milkfish and mullets are being carried out on a small scale, as the seed supply is still mainly from the wild. Experiments on breeding and seed production of *S. tranquebarica* have shown 20% survival rate from egg to first instar stage and attempts are on to improve the survival rate for an economically viable hatchery technology. Until this is achieved, it would be preferable to popularize mud crab fattening compared to mud crab farming.

Table 23. Economics of three systems of culture of *Scylla tranquebarica*

Culture Method	Monoculture	Polyculture	Fattening
Culture period (days)	120	138	30
Expenditure			
Production (t)	0.78	1.14	0.56
Income (Rs.)	1572000	2612000	122850
Net profit/crop (Rs.)	113340	212800	66650

Source: ICAR, 2000

Clam culture

Package of clam culture practices has been developed for the blood clam *Anadara granosa* and *Paphia malabarica*, where production on 40 t ha^{-1} 6 months^{-1} and 15-25 t ha^{-1} 4-5 months^{-1} have been achieved in field trials. Induced spawning and larval rearing upto settlement of spat has been perfected for clams like *Paphia malabarica*, *Meretrix meretrix* and *Marcia opima*. In hatcheries, spawning is effected by thermal shocks. The larvae settle between 7 and 17 days after spawning and attain a length of 2-3 mm in 2 months when they are ready to be transferred to nurseries for further growth. Nursery rearing is carried out in box type cages made of fine velon screen suspended from racks in shallow calm waters. In 6-8 weeks the planted spats attain 10 mm size and are ready to be shifted to grow-out fields. Baby clams are scattered in the farming area at 1000- 2000 numbers m^{-2} and harvest is possible in 4-5 months with a production of 14-25 t crop^{-1}.

Finfish culture

Marine finfish culture in the country is still at its infancy. Attempts are being made to develop suitable hatchery and farming technology for the mullets (*Mugil cephalus*, *Liza macrolepis*, *Valamugil seheli*), groupers (*Epinepheleus tauvina*), seabass (*Lates calcarifer*), milkfish (*Chanos chanos*) and pearlspot (*Etroplus suratensis*). The Central Institute of Brackishwater Aquaculture (CIBA) has developed an indigenous hatchery technology for seabass using captive broodstock which were stocked in large RCC tanks (12 x 6 x 2 m) with 70-80% water exchange daily. Maturation process was accelerated using LHRH hormone injection and larvae were maintained with rotifers and *Artemia* nauplii. Cooked and minced fish meat is used for nursery rearing and survival rate upto 14% in larval rearing phase and 84% in the nursery phase has been recorded.

Rajiv Gandhi Centre for Aquaculture of the MPEDA is promoting seabass cage culture in earthern ponds of 1.5 m water depth. Knotless net cages 2 m x 2 m x 1.5 m have been used with a production of 120 kg per cage with a projected production of 12 t fish ha^{-1} using about 100 cages. At present, imported pellet feed is used along with farm made feed. Culture of seabass in saline water ponds is found to be viable and this can be popularized. However import substitution with indigenous scientific farm-made fish feed has to be achieved before the technology can be effectively adopted by small-scale fishermen (Anon., 2002 a).

The potential brackish water species which can be farmed are enlisted in Table 24 alongwith status of technological development of each of them.

Table 24. Candidate species for brackishwater aquaculture in India

Species	Hatchery Techniques	Rearing Techniques
Fishes		
Mugil cephalus, Liza parsia, L. macrolepis, Valamugil seheli, Chanos chanos, Etroplus suratensis	X	X
Lates calcarifer	XX	XX
Crustaceans		
Penaeus monodon, P. indicus	XXX	XXX
Scylla tranquebarica, S. serrata	X	XXX
Molluscs		
Perna viridis, P. indica, Crassostrea madrasensis, Anadara granosa, Meretrix meretrix, M. casta and *Paphia malabarica*	XXX	XXX

x=Techniques under development xx = Techniques developed xxx = Techniques developed and commercialised

Source: CMFRI, 1997a

Indigenous shrimp feed technology

A simple technology for on-farm production of the eco-friendly and scientifically formulated shrimp feed *Mahima* (Fig. 12) using low cost and locally available ingredients such as mantis shrimp, prawn waste, soyabean and coconut oil cake with a nutritive value (% dry matter basis) of crude protein 35-42%, crude fat 3-5%, crude fibre 3-1.5%, ash 12 –16%, moisture 8-12% and acid insoluble ash 0.82 – 2% has been developed and has become popular in many improved-extensive shrimp culture farms (CMFRI, 1995). The beneficiaries are small-scale fish farmers and rural fisherwomen who have taken up *Mahima* production in small scale units on a commercial basis. Composition of *Mahima* shrimp feed (%) for two formulations, based on availability of ingredients, are given in Table 25.

Fig. 12. Preparation of *Mahima* feed

While extensive farming methods are sustainable and produce little waste, intensive operations discharge effluents carrying nitrogenous excretory waste, uneaten food, residues of chemicals and drugs that cause damage to the ecosystem. The quality of effluent water from different systems of shrimp farming in India (Table 26) is generally believed to be good without any serious impact on biodiversity (Kutty 2001). The Ministry of Agriculture (GOI) has prescribed standards for shrimp farm waste water (Table 27)

Table 25. Composition % of shrimp feed *Mahima* I and II

Ingredients	%
MAHIMA I	
Soyabean flour	20
Rice bran	20
Mantis shrimp meal	10
Prawn head meal	15
Coconut oil cake	12
Wheat flour	20
Sardine oil	1
Vitamin-mineral pre-mix	2
MAHIMA II	
Shrimp head meal	32.5
Clam meal	32.5
Tapioca flour	15
Corn flour	12
Molasses	2
Vegetable oil & sardine oil (1:1)	4
Vitamin-mineral pre-mix	2

which is in the interest of the farmers to adhere to ensure sustainable production system. The MPEDA is also extending assistance for setting up effluent treatment units in shrimp farms of 5 ha or more water area, either for a single farm or a group of farms. Conversion of mangroves and agricultural lands is also a serious reason for conflicts arising out of competitive utilisation of limited natural resources, although such practices are minimal (Rao and Ravichandran, 2001) and mainly fallow and unproductive agricultural lands have been converted. There are also reports of salinization of ground water and agricultural land through seepage from aquaculture ponds. Wild seed capture which was rampant before establishment of hatcheries and the blocking of access to sea by large farms that caused conflict with the capture fisheries sector, have been resolved to a large extent now.

Table 26. Quality of effluent water from different systems of shrimp farming in India

Parameter	Extensive	Semi-intensive	Intensive
Phosphate P ($mg^{-1}L$)	0.05	0.12	0.11
Nitrate – N ($mg^{-1}L$)	0.15	0.04	0.22
NH_3 – N ($mg^{-1}L$)	0.007	0.02	0.013
Hydrogen sulphide ($mg^{-1}L$)	0.02	BDL*	BDL*

*Below detection level Source : Varghese, 2001

Table 27. Standards for shrimp farm waste water

Parameter	Guidelines issued by MoA** Coastal marinewaters	Creeks	Standards for Discharge of pollutants* in marine coastal areas
pH	6.0 – 8.5	6.0 –8.5	5.5 – 9.0
Suspended solids (mg l^{-1})	100	100	100
Dissolved oxygen (mg l^{-1})	not less than 3	not less than 3	-
Free ammonia (as NH_3 -N) (mg l^{-1})	1.0	0.5	5
Biochemical Oxygen Demand- BOD (5 days @ 20°C) (mg l^{-1})	50	20	100
Chemical Oxygen Demand-COD (mg l^{-1})	100	75	250
Dissolved phosphate (as P) (mg l^{-1} max)	0.4	0.2	-
Total nitrogen (as N) (mg l^{-1})	2.0	2.0	-

* Gazette Notification G.S.R. No. 422 (E) dated May19, 1993, General Standards for discharge of environmental pollutants Part-A: Effluents

** Ministry of Agriculture

Cost and returns for shrimp production

Table 28 compiles some of the available empirical evidences concerning the economics of shrimp culture under different systems of production and management. Viswakumar (1992) analysed the economics of shrimp production in Andhra Pradesh under different systems of production and feed regimes. Under extensive systems with supplementary feeding, shrimp farming yielded a net return of Rs 30,000 ha^{-1} $year^{-1}$, while under improved extensive and semi-intensive systems of production the per ha net income was estimated to be Rs 0.09 and 0.13 million respectively. Usha Rani *et al.* (1993) and Krishnan *et al.* (1995) also reported similar results. The studies from Tamil Nadu by Jayaraman *et al.* (1993) reported much higher profitability for shrimp farming under different systems of production, compared to that in Andhra Pradesh. The semi-intensive system, was highly profitable than the extensive system.

The profitability under semi-intensive method was considered so high that an entrepreneur could realise his investment in two years. If bumper harvests are realised from three crops in a year, the investment could possibly be realised within a year depending on the level of investment, technology and prices.

Although semi-intensive shrimp farming is highly profitable, it is considered risky as well, because of overstocking and disease problems. Many companies raised equity for shrimp farming and there was a time when shares of such companies were high. However, shrimp farming and the share market suffered serious setbacks and the corporate companies involved in shrimp farming are not successful now.

Table 28. Economics of shrimp farming in India

References/ Culture practice	Yield (t ha^{-1} crop^{-1})	Total income (Rs 000)	Total cost (Rs 000)	Net income (Rs 000)
Viswakumar (1992)				
Supplementary feeding	0.30	24.92	13.60	11.33
Pellet feeding	1.00	83.08	49.09	33.99
Semi-intensive	3.90	260.95	187.69	73.26
Usha Rani *et al.* (1993)				
Small Farms	0.95	34.12	26.57	7.55
Large Farms	1.23	41.06	25.66	15.40
All Farms	1.16	40.46	26.27	14.19
Jayaraman *et al.* (1994)				
Tiger shrimp	1.00	73.63	31.94	41.69
White Shrimp	1.00	56.64	27.41	29.23
Krishnan *et al.* (1995)				
Extensive	1.00	37.38	5.05	32.33
Improved Extensive	2.00	74.75	26.35	48.40
Semi-intensive	4.00	149.50	63.54	85.97
Bhatta (1999)				
Goa	1.419	55.20	10.31	44.89
Kundapur	1.088	24.98	4.45	20.53
Saju *et al.* (1999)				
P. indicus (Stocking density)				
50,000/ha	0.787	29.90	14.03	15.87
50,000-60,000/ ha	0.991	37.65	17.70	19.95
Above 60,000/ha	1.22	46.35	18.47	27.88
P. monodon (Stocking density)				
30,000/ha	0.973	29.90	14.03	15.87
30,001 to 40,000/ha	1.14	37.65	17.70	15.85
Above 40,000/ha	1.335	46.35	18.47	27.88

It is believed that if a disease incidence was anticipated, the best option would be to go for improved extensive farming, as it is less risky yet adequately profitable. In a case study on the economics of improved shrimp extensive system of farming in Vedaranyam in Nagapattinam district, Jayaraman *et al.* (1993) reported a net farm income in the range of Rs 0.13 to 0.27 million ha^{-1} year^{-1}. The findings of Bhatta (2000) and Saju *et al.* (1999) were also on the similar lines.

Swamidas and Satyanarayana (2000) estimated the input-output ratio for different brackishwater shrimp farming methods of small, medium and large farms in the coastal states. In Andhra Pradesh average input output ratio under traditional system of farming is better compared to that in other states (Table 29). In semi-intensive system of farming West Bengal has an edge over others, with an input output ratio of 1:1.34.

Table 29. Input- output ratios on different groups of holdings in relation to brackishwater aquaculture technology

State	Traditional Method				Semi-intensive Method			
	Small	Medium	Large	Average	Small	Medium	Large	Average
West Bengal	1:1.5	1:1.4	1:1.3	1:1.4	1:1.20	1:1.32	1:1.50	1:1.34
Gujarat	1:1.6	1:1.5	1:1.4	1:1.5	1:1.38	1:1.28	1:1.06	1:1.24
Kerala	1:1.7	1:1.8	1:1.6	1:1.7	1:1.05	1:1.40	1:1.45	1:1.30
Andhra Pradesh	1:1.6	1:2.1	1:1.7	1:1.8	1:1.70	1:1.20	1:1.35	1:1.24
Average	1:1.6	1:1.7	1:1.5	1:1.6	1:1.20	1:1.30	1:1.34	1:1.28

Source: Swamidas and Satyanarayana, 2000

There is not much variation in the input-output ratio across different categories of holdings. On an average, medium sized farms are more efficient under traditional system of farming, while for semi-intensive system large farms are marginally better. On the whole, the traditional method is better compared to the semi-intensive method.

Capture Fisheries

Boat classification and characteristics

The fishing boats used throughout the country are indigenous, non-mechanized and locally built, except for mechanized boat introduced in some part of India (Biswas, 1996). They have been designed to suit local conditions.

The simplest and most primitive types of boat used for fishing in inland waters are the rafts and *dongas*, operated in calm waters. In the larger rivers and estuaries where there is strong current and tidal movements, sturdier planks built boat are used.

Raft

The types of rafts and various materials used for their construction are:

i. Inflated buffalo skins tied together and used by fishermen in the upper reaches of the river Ganges.

ii. Banana stems or shoal bundles tied to form a floating platform in ponds, and calm waters of West Bengal, Tanjore district in Tamil Nadu.

iii. Earthen pots tied together to support a light platform of bamboo as in the river Ganges near Patna, Gaya and in the river Cauvery.

iv. The coracle, a shallow framework of wicker covered with a well-stretched cowhide, commonly used in the rivers Cauvery and Tungabhadra, and in Mettur Dam.

Boat

The different types of boats, alongwith material used for construction and area of operation (Figs. 13 and 14), are mentioned below.

Dug out boat

Hollowing out the butt and stem of the palm tree makes a simple form of dug- out boat. It is commonly used in West Bengal for angling and cast net fishing in inundated calm waters. Similar but sturdier dug-outs known as *Vallam* are used in the backwaters and estuaries of Kerala.

Plank built boat

The plank built boats are of various types and are used for fishing in rivers with strong currents and tides, and in the larger backwaters and lakes for operation of large nets. Small riverine and estuarine crafts, known as *dinghis* are employed extensively in West Bengal for operation of purse nets and dip nets.

In the Chilka Lake and the river Mahanadi, flat bottom plank built boats, known as *Nava* are in use.

Dinghi* and *Nauka

These are carvel boats of Orissa and West Bengal. *Naukas*, which are well designed and constructed up to a size of 13 m x 3 m x 2 m are quite spacious and are used for a variety of purposes including fishing operations.

These *dinghis* have narrow tapering bows and sterns and have no keels. Larger boats of this type are used for operating larger nets. The boat (*Chhadni nauka*) used for operating larger drift nets, are as large as 18 m. long and 3 m wide.

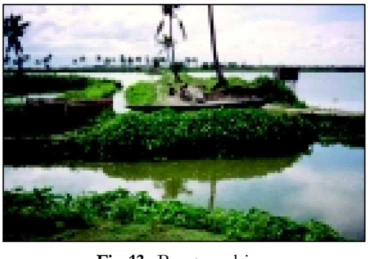

Fig. 13. Boat making

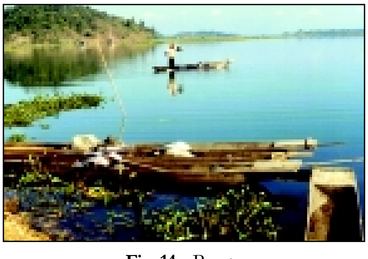

Fig. 14. Boats

Musula Boat

It is a non–rigid boat constructed with planks sewn together with coir rope, but without frames or ribs, so as to withstand the severe knocking of the surfs. These are upto 9 m in length, but many are smaller.

There are various patterns of boats, e.g. *Bar boat* in Orissa and *Padava* in Andhra Pradesh. A variant with ribs inside has been developed in the area between Kakinada and Machalipatnam in Andhra Pradesh.

Coracle

These are dominant in the reservoirs of south India. These are large wide mouthed (4 m diameter) circular flat bottom basket. Coracles are generally used for operation of gill nets, shore seines and long lines.

Dug out canoes

These are made from large logs of wood by scooping out the inner part, the keel portion being thicker than the sides. These are mainly used in Kerala and Karnataka. The large dug outs (*Vanchi, Odams*) are 10-12 m long and are used for operating a variety of nets. The smaller dugouts known as *thonies* are generally used for gill nets, drift fishing and for seining. Mango wood is mostly used for these canoes. The dug out canoes (*Shoe dhoni*) of Andhra Pradesh are made out of palm tree trunks. These are used in the backwaters and estuaries. These canoes are well maintained using indigenous preservations like cashew nut oil, fish body and liver oil, etc.

Built up boats

The best constructed, indigenous boats are seen on the western part of the country. The built up boats in many places have been reported to last for 40 to 50 years with periodical repairs and replacements.

Various types of built up boats are:

- Bassien type- locally called *macus* has a broad hull, pointed bow and straight keel. Machua type boats are used for the operation of large nets in the estuaries of Gujarat.
- Satpati type- popularly called *galhat* has a medium pointed bow broad beam, straight keel and high gunwale.
- Broach type- flat bottomed and used in inshore and estuarine waters.
- *Batchary* and *chot* type- fishing boats from West Bengal mostly operated in Hooghly estuary.

All timber structures are smeared with oil and natural resin preparations as preservatives. The wooden hull below water is protected with indigenous preservations like fish oils, cashew oil and coal tar.

Gear and major fish species caught

The prevalent fishing gear in middle and upper stretches of Ganga river system, their classification, local name, period of operation, preferred river condition and probable catch (Seth and Katiha, 2002) are summarised in Table 30.

Drag net

The drag nets are of two types, with and without pockets. *Chanta* is the most common form with pocket and *Mahajal, Chaundhi, Ghanali* and *Dodandi* are 'without pocket'. Figs. 15 and 16 present dragnet and its operation.

Chanta is operated mainly after monsoon during the receding phase of flood in the river zones, where water remains turbid with moderate current. The probable catch includes medium sized carps and catfishes. Its catching efficiency is very high.

Mahajal, a dominant net of earlier years is now used with lesser frequency. The preferred river conditions for the operation of this net are clear water with clean sandy bottom and slow current. Catch consists of large sized

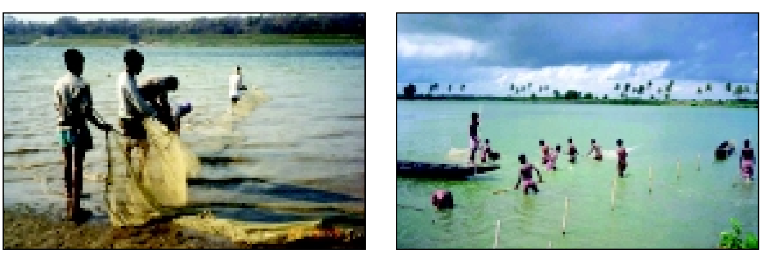

Fig. 15. Spreading of drag net

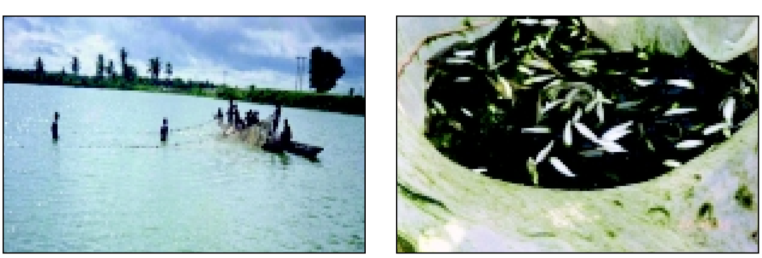

Fig. 16. Operation of drag net and fish catch in river Ganga

carps, catfishes, featherbacks, *viz.*, *Aorichthys seenghala* (Sykes), *A. aor* (Ham.), *Bagarius bagarius* (Ham.), *Notopterus notopterus* (Pallas), *Notopterus chitala* (Ham.) and other miscellaneous fishes.

Operation of *Chaundhi* starts by the onset of winter and continues till the river receives monsoon floods. Fishing by *Chaundhi* is occasionally during pre- and post-monsoon months, depending upon the availability of catfishes in the fishing sites. The net is primarily used for encircling the fishes, which are later removed with the help of a trap called *Kuriar*. Because of heavy sinkers, its operation on muddy bottom with sludge is avoided. *Cirrhinus mrigala* (Ham.), *A. seenghala, A. aor, Wallago attu* (Sceneider), *Rita rita* (Ham.) and other bottom feeding fishes are caught with this net.

During the pre- and post-monsoon months when the river remains turbid with mild current, *Ghanali* is preferred for fishing of medium sized miscellaneous fishes like *Coitor spp., Gudusia chapra* (Ham.), *Setipinna phasa* (Ham.), *Chela* spp., minor carps, etc.

Dodandi is operated rarely. It is used mostly during summer in feeble current with clear water. Mainly medium sized miscellaneous fishes like *G. chapra, S. phasa, Chela* spp., minor carps, *Aspidoparia morar* (Ham.), *Eutropichthys vacha, Clupisoma garua* (Ham.), *Mugil* spp., etc., constitute the catch.

Gill nets

Another important gear, the gill net is more prevalent than drag nets, indicating preference for lower energy gears. These nets are made up of synthetic woven material and generally has a footrope. Local fishers refer these nets as *current jal*, when foot-rope is removed and the net is allowed to drift with current.

Phasla is the most common gillnet and has greater variation in dimension and mesh size. It is mostly operated in clear stagnant water for fishing of medium to large sized major carps, minor carps, *E. vacha, C. garua*, *Aorichthys* spp., etc.

The operation of *Gochail* starts with the monsoon when the river water becomes turbid and have fast current. It is used until the river is not overflooded, to catch large size major carps, *Aorichthys* spp., *W. attu, B. bagarius*, etc.

During summer, *Ranga jal* is the most preferred gear for fishing in and around the nesting sites of *Aorichthys* spp. This area is characterised by mild current, shallow depth and sandy riverbed (Seth, 1997). The *Ranga jal* is an improvement over gill net. The traditional gill net (*phasla*) has been modified to suit such riverine conditions. The modifications include reduction in spacing of low weight sinkers folded over the footrope. It facilitates swift drifting of the net over sandy riverbed without getting curved or folded within the sinkers. It also reduces the escape of bottom dwelling fishes. It is successfully used for fishing of *Aorichthys* spp. Although *Ranga jal* is operated through the year except during monsoon, it is recognised as a pre-monsoon net.

A purse net, *Kamel*, is primarily the gear for pre-monsoon and early winter months. It is mainly used for *Hilsa ilisha*, but is becoming rare now.

Others

Hook and line (*Jor*), cast net (Fig. 17) (*Bhanwar jal*), and dip net (Figure 18) are operated round the year; while scoop net (*Jali*) during post- monsoon and winter months. The operation of traps (Fig. 19-21) is generally from winter to summer months, except *Kuriar*, which is common in post-monsoon and winter, and *Kohni* during monsoon months. The catch of these gears has been summarised in Table 30. The trap *Gopal jal* is exclusively utilised for fishing *Aorichthys* spp.

The prevalent gears can be classified under seven categories. The construction and operation of most of these nets were described by Saxena (1965, 1988). In recent years, the major change is that the nets are woven and fabricated by synthetic materials instead of cotton as in the past. It is primarily due to easier handling, lower energy requirements and better fishing efficiency. A variety of gears prevalent in sixties to early eighties has become less common nowadays. The rare operation of purse net namely *Kamel* is

Fig. 17. Cast net and its operation

Table 30. Fishing gears prevalent in the Ganga river system with period of operation and catch composition

S.No.	Type of gear	Local name	Period of operation	River conditions	Probable catch
A.	Drag net				
1.	With pocket	Chanta	After monsoon	Mild current, turbid water, receding flood phase	Medium sized carps, *Aorichthys* spp., *Wallago attu, Rita rita, Channa* spp.
2.	Without pocket	Mahajal	Through the year, except monsoon months	Clear water with clean sandy Bottom	Large sized carps, *Aorichthys* spp. *Notopterus Chitala, Bagarius bagarius*, other misc. catch
		Chaundhi	Winter till river recieves freshets	Clean sandy bottom without sludge, clear water	*C. mrigala, Wallago attu, Rita rita, B. bagarius*, Medium sized misc. fishes
		Ghanali	Pre and post monsoon	Turbid water with mild current, even sandy bottom	*Coiter spp.; Gadusia chapra; Setipiraphasa*; *Chela spp.;* minor carps, etc.
		Dodandi	Mostly summer months	Feeble current, clear water	Medium sized misc. fishes *G. chapra; S. phasa; Chela* spp.; minor carps, *Astridopaira morar, Eutopichthys vacha; Clupisoma garua, Mugil* spp. etc.
B.	Gill net	Gochail	Monsoon months, except in heavy floods	Fast current , turbid water	Large sized fishes, major carps, *W.attu, B. bagarius;* etc.
		Ranga	Through the year except in monsoon, mostly in pre- monsoon though	Mild current with clean sandy river bottom	
		Phasla	Through the year except in monsoon	Slow current, clear stagnant water	Medium to large sized major carps, minor carps, *E. vacha; C. garua, Aorichthys* spp.
C.	Purse net	Kamel	Pre-monsoon and early winter through	Fast current, Clear water	Medium and large sized major carps, minor carps, *Hilsa ilisha, Aorichthys* spp. and *Rita rita*
D.	Hook & Line	Jor	Through the year, mainly in monsoon	Fast current with turbid water	*Aorichthys* spp. *E. vacha; C. garua, W.attu, R.rita*
E.	Cast net	Bhanwar jal	Round the year		Small sized mixed catch, occasionally large sized fishes
F.	Scoop net	Jali	Post monsoon and winter	Clear to turbid water with mild current	Juveniles of carps and catfishes, small sized misc. fishes, shrimp, *Mugil* spp.
G.	Trap	Kuriar	Post monsoon and winter	Clear water and sandy bottom	Large sized carps, *Aorichthys* spp.; *B. bagarius*.
		Gopal Jal	Summer	Clear water and sandy bottom	Exclusively used for *Aorichthys seenghala* and *Aorichthys aor.*
		Sirki	Summer	Clear waters at river turnings	Shrimp, *Mugil* spp. small miscellaneous fishes

Source: Seth and Katiha, 2002

an example of shift in fishing practices. It was very common during the sixties, when hilsa formed major fisheries. The drag net, *Mahajal* has been gradually replaced by gill nets, e.g. *Ranga jal*. The trap *Gopal jal*, which has been a common net of the upper stretch of Ganga river system is now used extensively in the middle stretch also. The chronological investigations revealed that the period of operation of most of the gears is delayed by 45-60 days during a year when compared with the period of operation during past decades. The probable reason may be the changing hydrography of the river.

Most of the inland open waters or capture fisheries resources are under open access, with some exceptions of their leasing and auction for fisheries

Fig. 18. Dip net in operation

Fig. 19. Traps

Fig. 20. Traps and drag nets

Fig. 21. Traps in operation in floodplains of Assam

operations to co-operatives and private contractors. Inland capture fishery is basically recognised as small-scale fisheries. The commercial fishery is now coming up for the culture-based fisheries in general and for small reservoirs in particular. These waters are mostly leased out or auctioned for fisheries operations and offer immense potential for fisheries enhancements, and in turn, increase in fish production and productivity.

Considering different types of fishing regimes, the results of riverine ecosystem (Sinha and Katiha, 2002) are presented for open access, co-operatives and private fishing regimes (Table 31).

Table 31. Fishing assets and catch per unit effort in riverine fisheries under different management regimes

Item	Regime		
	Common property	Private	Co-operative
Fishing asset			
Per cent of fishers with type of gears			
Gill net	67.06	56.27	57.14
Drag net	18.14	32.23	17.14
Cast net	7.78	5.02	2.86
Hook and line	24.37	21.73	34.20
Other	6.59	5.62	20.00
Per cent of fishers with own boat	79.64	62.13	25.00
Hired labour (Mandays/ Year)	—	96.28	—
Annual fishing effort (Mandays/Year)	281.82	293.24	147.63
Catch per unit effort			
Per family (kg/year)	1431.67	780.02	376.46
Per day (kg)	5.08	2.66	2.55

Source: Sinha and Katiha, 2002

The fishing assets under open access and co-operatives are either owned or shared by the fishers; while in the case of private regime these belonged to fishers (may also be financed by contractor) or provided by private contractor.

Most prevalent gears under all the regimes are gill nets followed by hook and lines in the open access and co-operatives (Table 31). For private regime it is the drag net due to fishing operations by hired professional parties, which generally use this type of net. The highest percentage of crafts was owned under open access followed by private and co-operatives. The area of operation was limited for co-operative and private regimes, while it was not so in the case of open access. To avail this facility of fishing, the fishers prefer to have their own fisheries requisites. It increased their degree of freedom for fishing, which influenced their returns. In the case of co-operatives, the member fishers have limited area of operation and have greater association, thus preferred to share the requisites, particularly the boats. In the private regime, the remuneration is low, and so, fishers do not want to share their catch, which would reduce their income. It led them to prefer their own boats and gears. Further, the contractor also provided them finance to purchase the inputs. In case of co-operatives and open access, credit support from any institution was very rare.

In the Ganga river system, 76% of the fishers has gill nets (Table 32) followed by drag nets (9%). The study of mesh size of gill nets indicated that nearly 28% nets are of 0.5-1 cm mesh, 17% are 0-0.5 cm and 11% are 1-1.5 cm (Table 33)

Table 32. Use of gears

Gear type	Per cent
Small drag net	9.38
Large drag net	1.76
Gill net	76.53
Cast net	2.79
Bag net	1.21
Traps	1.96
Scoop net	4.76
Shooting net	0.1
Others	1.52

Source: Preliminary results under AP-CESS funded project on ' Techno- socioeconomic status of fisheries of River Ganga'

Table 33. Distribution of gill nets by mesh size

Mesh size (cm)	Per cent
0-0.5	17.1
0.5-1.0	27.7
1.0-1.5	10.8
1.5-2.0	8.0
2.0-3.0	8.8
3.0-4.0	9.8
4.0-5.0	8.5
5.0-10.0	9.3

Source: Preliminary results under AP-CESS funded project on ' Techno- socioeconomic status of fisheries of River Ganga'

Catch per unit effort

The annual fishing effort was highest in the private regime (293 days) followed by open access (281 days) and co-operative (147 days); while annual and per day catch was maximum for open access (1432 and 5.08 kg) followed by private (780 and 2.66 kg) and co-operative (376 and 2.55 kg). These observations may be attributed to the intensity of fishing or the fishing effort under different regimes. Fluctuations and height of water level and the fish stock present in the river affected the effort and catch in a year.

Fishing effort may be for fishing with their own fishing requisite and effort as fishing labour, i.e. fishing as a sharer with others. The average annual fishing effort was 260.29 days (Table 34). The maximum fishing days was in autumn and summer followed by pre and post –monsoon. The percentage distribution of fishers according to annual level of fishing effort (Table 35) was maximum for the fishers fishing between 3-6 months per year (38%), followed by 37% with fishing effort between 1-3 month.

Table 34. Seasonal involvement in river fishing and fishing labour

Activity	Period					
	Pre-monsoon (31 days)	Monsoon (61 days)	Post monsoon (61 days)	Winter (90 days)	Autumn Summer 122 days	Annual 365 days
River fishing	15.50	18.93	25.47	31.83	61.15	152.89
% of total	50.0	31.0	41.8	35.4	50.1	41.9
Fishing labour	9.16	10.50	19.61	27.39	40.74	107.41
% of total	29.5	17.2	32.2	30.4	33.4	29.4
Total	24.66	29.43	45.09	59.22	101.89	260.29
% of total	79.55	48.25	73.91	65.80	83.52	71.31

Source: Preliminary results under AP-CESS funded project on ' Techno- socioeconomic status of fisheries of River Ganga'

Table 35. Level of fishing efort

(In %)

Level of Involvement(Month)	River fishing	Fishing labour
< 1	3.7	10.1
1-3	18.8	37.7
3-6	42.6	38.1
>6	34.9	14.1

Source: Preliminary results under AP-CESS funded project on ' Techno- socioeconomic status of fisheries of River Ganga'

The catch composition in different seasons indicated that clupeids were dominant (32.3%) in most of the seasons, followed by large catfishes (16.0).

Cost and returns in capture fisheries

The cost structure is almost similar for open access and private regimes, while it is very low for co-operatives (Table 37). The lower cost for co-operatives may be due to lower fishing effort and sharing of inputs.

Table 36. Season-wise species composition (%) in riverine catch

Species	Pre-monsoon	Monsoon	Post Monsoon	Winter	Autumn Summer	Annual
Major carps	13.9	6.7	16.0	11.2	3.1	2.4
Minor carps	9.2	10.1	4.7	4.8	5.1	0.8
Large catfish	12.7	13.6	20.5	18.7	9.6	16.0
Small catfish	13.5	21.3	16.9	18.3	10.4	4.8
Hilsa		0.5	0.4	0.1		
Garua&*Vacha*	6.4	5.6	15.4	16.9	28.5	32.3
Bagarius	3.7	3.1	5.1	2.1	1.1	3.0
Others	40.6	39.1	21.1	27.9	42.2	40.7

Source: Preliminary results under APCESS funded project on ' Techno- socioeconomic status of fishes of River Ganga'

Table 37. Cost and returns in riverine fisheries under different management regimes

Item	Regime		
	Common property	Private	Co-operative
Costs (Rs)			
Fixed cost (per year)	2907.31	3017.17	1451.48
Variable cost (per year)	1712.21	1737.39	285.43
Total cost	4619.52	4754.56	1736.91
Returns (Rs)			
Price received (kg)	24.09	18.79	34.82
Gross returns (per year)	34488.93	14656.58	13108.34
Net returns (per year)	29869.41	9902.02	11371.43
Net returns (Rs/per kg)	20.86	12.69	30.21
Input output ratio	7.49	2.90	7.55

Source: Sinha and Katiha, 2002

The per kg price received by the fishers may be recognised as the indicator of impact of these management regimes and fishing rights on the fishers' income. These estimates favour the co-operative regime the most followed by open access. The lowest values for these estimates were under the private regime. The co-operatives directly dispose the catch in local market or at nearby town. The members of the society themselves perform the marketing functions, eliminating all the market intermediaries, and received much better prices. In open access, the catches are auctioned in the wholesale markets and fishermen receive the auction price after deduction of wholesaler's commission. In private regime, the contractor distribute the catch in term of fixed rate/ loyalty per kg, so, the fishers are deprived of the benefits of market price.

The gross and net annual and per day returns were maximum for open access regime followed by co-operative and private, but the net income per kg of catch favoured co-operatives the most followed by open access, and the least for the private regime. The input output ratios also indicated the superiority of co-operatives and open access regimes over the private as their value for these ratios were more than 2.5 times of the estimated ratio for private regime. It depicted the working efficiency and extent of remuneration of fish catch for different management regimes and revealed that privatization of the fishing rights in riverine fisheries would accelerate the process of social disequilibrium to broaden the income inequalities. It would further push the downtrodden down and uplift the economically fluent fish traders.

Culture-based Fisheries

Culture-based fisheries technologies are particularly important for large open waters. Reservoirs constitute the prime inland fishery resource of India by virtue of their vast area and huge production potential (Sugunan and Sinha, 2000). Apart from allowing quick yield enhancement at minimal capital investment and environmental cost, fisheries development of reservoirs directly benefits some of the weakest sections of the society. The benefits accrued due to increase in yield and income generation directly contributes to improve the quality of life of fishermen. Unlike the culture systems, where the profit is accrued to a single investor or a small group of investors, in reservoir fisheries, the benefits of increased yield is more equitably distributed among a large number of people, albeit as smaller shares. Thus, being a community- based development process, it has a direct bearing on the rural population.

Reservoirs exhibit wide variations in their morphometric, limno-chemical and biological characteristics making it difficult to develop a technology package that can be adopted uniformly. Nevertheless, the researches conducted by CIFRI over the last few decades have resulted in many guidelines, based on which the reservoir fishery managers can develop location-specific management norms. Such guidelines are more effective for the small reservoirs where the relationship between management and yield improvement is known to be more precise compared to the large impoundments.

Management systems

There are marked variations in the fishery management practices followed in various reservoirs within the country. Even though the Government or corporate agencies in most of the states own the reservoirs, their fishing right and exploitation system vary considerably. The fishing systems are distinguishable into the following broad categories :

a) Privately owned and managed reservoirs
b) Public water bodies
c) Community water bodies
d) Water bodies managed by the Government.

After a scrutiny of the various management practices followed in the country, it is difficult to miss a common underlying spirit of the common property norm. Majority of the Indian reservoirs are public properties where a fixed number of licensed fishers make their living. The exceptions are the small reservoirs in some states like Karnataka and Uttar Pradesh, which are auctioned to private individuals on an annual basis.

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

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

Assessment of yield potential

Several methods are in vogue to assess the fishery potential of small reservoirs deriving equations based on area, depth, catchment area and the chemical characters of soil and water. Morpho-edaphic index (MEI) has been evolved in an attempt to combine the morphometric as well as chemical parameters. Relationships between MEI and catch are based on the assumed characteristics; some sets of reservoirs possessing a certain number of limnological conditions, *i.e.* (i) the ionic composition is dominated by the carbonate- bicarbonate system, (ii) the water body is not dystrophic, (iii) the volume does not fluctuate noticeably and (iv) the temperature regime is similar. A morpho-edaphic index has been set for African lakes (Henderson and Welcomme, 1974).

MEI = Specific conductivity (μ mhos cm^{-1})/Mean depth (m). Fish yield potential (C) is calculated from the MEI as :

$C = 14.3136\ MEI^{0.4681}$

For Indian reservoirs it has been set (Sugunan *et al.*, 2002) as

$C = 3.984\ MEI^{0.6374}$

This formula can be tried to obtain a rough indication of the productivity of any reservoir within the limits between one and half and two. Asian reservoirs are known to have a lower yield potential than their African counterparts. Such equations are sufficiently precise to give an idea of the scale of investment, whether in research or developmental infrastructure, appropriate to any water body. More precision can be achieved after separate equations have been derived for different classes of reservoirs.

Enhancement

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

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

Stock enhancement

Augmenting the stock of fish has been the most common management measure that is followed in the reservoirs in most countries of the world. Ever since the reservoirs were considered as a fishery resource, it had become apparent that the original fish stock of the parent river was insufficient to support a fishery.

Augmentation of the stock is also necessary to prevent the unwanted fish to utilize the available food niches and flourish at the cost of economically important species. However, the policies and guidelines on the subject, wherever available, are often erratic and even arbitrary.

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

Fish seed production has made rapid advances in the country during the last few decades either through indigenous or imported technologies. Consequently, a number of hatcheries have come up for large-scale production of fish seed under the public and private sectors. But, despite a remarkable increase in carp seed production, the open water bodies of the country remain under-stocked, as all the seed produced in the private sector goes to the privately managed aquaculture industry. The Government hatcheries that have the responsibility to stock the public reservoirs could never produce fingerlings in the required number.

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

Selection of species for stocking

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

1. Environment suitable for maintenance, growth and reproduction.
2. Quick growing species from which highest efficiency of food utilization is obtained.

3. Based on high production of herbivorous fishes with shorter food chain is more productive and hence energy - effective.
4. Food resources of the ecosystem should be fully utilized and densest population maintained consistent with normal growth.
5. Size of the stock should be chosen with the expectation of getting the desired results.
6. Cost of stocking and managing the species must be less than the benefits derived from stocking and management.

Stocking rate

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

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

S Number of fish to be stocked (per ha)
P Natural annual potential yield of the water body
q The proportion of the yield that can come from the species in question
W Mean weight at capture
t_c Age at capture
t_o Age at stocking
-z Total mortality rate
e Constant (2.7175)

'P' can be estimated through MEI method (mentioned above) and the range of mortality rates can be found out from the estimated survival rate. The calculation of stocking rate using the formula given above, when P =

200 kg ha^{-1}, q = 1, W = 0.5 kg and t_c-t_0 is 1. The model assumes insignificant breeding by stocked population and therefore applies mainly to total cropping situations *i.e.,* those in which fish are caught below their minimum size for maturity, those whose natural reproduction does not take place and those where water body is not permanent. It shows that stocking density, which depends on the natural conditions of productivity, growth and mortality, are very sensitive to z. Because of the very large numbers of fry needed, this formula may have very limited utility in large reservoirs.

Impact of stocking in small reservoirs

The smaller water bodies have the advantage of easy monitoring and manipulation of stock. Thus, the smaller the reservoir, the better are the chances of success in the stock and recapture process. In fact, an imaginative stocking and harvesting schedule is the main theme of fisheries management in small and shallow reservoirs. The basic tenets of such a system involve:

1. Selection of right species, depending on the fish food resources available in the system.
2. Determination of a stocking density on the basis of production potential, growth and mortality rates.
3. Proper stocking and harvesting schedule including staggered stocking and harvesting, allowing maximum grow-out period, taking into account the critical water levels.
4. In case of small irrigation reservoirs with open sluices, the season of overflow and the possibilities of water level falling too low or completely drying up, are also to be taken into consideration.

Effective recapture of the stocked fishes renders the stocking more remunerative in small reservoirs, compared to the medium and larger ones. Aliyar reservoir in Tamil Nadu (Anon., 1997) is a good example for the efficacy of the management based on staggered stocking. The salient features of the management options adopted in Aliyar are:

- Stocking is limited to Indian major carps (earlier, all indigenous, slow-growing carps were stocked)
- Increasing the size at stocking to 100 mm and above.
- Reducing the stocking density to 235-300/ha (earlier rates were erratic ranging between 500-2,500/ha)
- Staggering the stocking, and
- Regulating the mesh size strictly and ban on catching the Indian major carps <1 kg in size

The above culture based fisheries management practice through stocking enhancements (Sugunan and Sinha, 2001) led to significant increase in fish production in the following reservoirs (Table 38) :

Table 38. High yields obtained in small reservoirs due to culture based fisheries with stocking enhancements

Reservoir	State	Yield (kg ha^{-1})
Aliyar	Tamil Nadu	194
Tirumoorthy	-do-	182
Meenkara	Kerala	108
Chulliar	-do-	316
Markonahalli	Karnataka	63
Gulariya	Uttar Pradesh	150
Bachhra	-do-	140
Baghla	-do-	102
Bundh Beratha	Rajasthan	94

Species enhancement

Decline of indigenous fish stocks due to habitat loss, especially caused by dam construction, is a universal phenomenon. The extent of such fish species loss is not assessed to any reliable degree in many countries. In India, all the major river basins have been affected. Introduction of economically important, fast- growing fish with a view to colonize all the diverse niches of the biotope for harvesting maximum sustainable crop is considered as species enhancement. Introduction refers to one time or repeated stocking of a species with the objective of establishing its natural populations. This widespread management practice has more relevance to larger water bodies where stocking and recapture on a sustainable basis is not feasible.

Introduction of exotics

In India, the fish transferred on trans-basin basis within the geographic boundaries of the country is not considered as exotic and so much so there are no restrictions on such species transfer. Thus, *Catla* is not regarded as exotic to Cauvery or such other peninsular rivers. This is despite the fact that the peninsular rivers have habitats and several cultivable endemic species, distinctly different from that of Ganga and Brahmaputra. The small west-flowing drainages of the western ghats, the two large west flowing drainages *viz*. Narmada and Tapti, and a number of east flowing rivers of the peninsular India have ichthyofauna different from the Ganga and Brahmaputra. Catla, rohu and mrigal have been stocked in the peninsular reservoirs for many decades now, with varying results. In some of the south

Indian reservoirs, they have even established breeding populations. The introductions are mainly the Indian major carps.

There is evidence that the Gangetic major carps have affected the species diversity of peninsular cyprinids. The Indian policy on stocking the reservoirs, though not very explicit, disallows introduction of exotic species into the reservoirs. However, common carp is very popular in reservoirs of the northeast where it enjoys a favourable microclimate and a good market. Silver carp and grass carp are not normally encouraged to be stocked in Indian reservoirs, though they are stocked regularly in a few small reservoirs of Tamil Nadu and the northeast.

Selective introduction of some exotic fish species in small reservoirs, which have no connections with the rivers, or those, which dry up completely in summer, is being examined now.

Environmental enhancement

Improvement of the nutrient status of water by the selective input of fertilizers is a very common management option adopted in intensive aquaculture. However, a careful consideration of the possible impact on the environment is needed before this option is resorted to in reservoirs. It is generally believed that most of the lakes and reservoirs may have sufficient nutrient inputs and any excessive nutrient loading can lead to pollution. However, scientific knowledge to guide the safe application of this type of enhancement and the methods to reverse the environmental degradation, if any, is still inadequate.

Fertility typically refers to the quantity of nutrients available, and higher fertility is usually equated with higher productivity. Primary productivity is the rate at which new organic matter is added through photosynthesis.

To a large extent, impoundment fertility is determined by the richness of nutrients. Fertilizers are less effective in soft water with total alkalinity less than 20 mg l^{-1}. Soft waters have inadequate carbon (usually in the form of carbon dioxide and bicarbonate) for good phytoplankton production. Fertilizer response, and hence productivity, can often be enhanced by applying lime to low alkalinity impounded waters.

Fertilization of reservoirs as a means to increase water productivity through abetting plankton growth has not received much attention in India. Multiple use of the water body and the resultant conflict of interest among the various water users are the main factors that prevent the use of this management option. Surprisingly, fertilization has not been resorted to even in reservoirs, which are not used for drinking water and other purposes. Documentation on fertilization of reservoirs in India is scarce.

Eutrophication is a significant problem in lakes and reservoirs. Whenever the rate of synthesis and input of organic matter exceed the rate of recycling and output, an accumulation of matter within the aquatic system occurs leading to its eventual extinction. Although variable from season to season, such considerable allochthonous energy accumulate in the reservoirs and this is either deposited thereby accelerating eutrophication, or enters the food chain in significant quantities.

Artificial eutrophication as a decisive management option was opted for the first time in Kyrdemkulai (80 ha) and Nongmahir (70 ha) reservoirs of the northeast (Sugunan and Yadava, 1991a,b) by applying poultry manure (10 t ha^{-1}), urea (40 kg ha^{-1}) and single super phosphate (20 kg ha^{-1}).

Application of lime was tried in some upland natural lakes for amelioration of excessive CO_2 and acidity at the bottom (Sreenivasan, 1971). This measure, together with the application of super phosphate in Yercaud lake, raised the pH of water from 6.2 to 7.3 and decreased the CO_2 in bottom water from 6.5 to 3.8 mg l^{-1}. There was a corresponding increase in species number and biomass of plankton. Fertilization of Vidur reservoir resulted in a marked increase in the benthic and plankton communities and doubling of the primary production rate. After two successive applications of fertilizer, significant limnological changes took place including the presence of free CO_2, and decrease in pH and dissolved oxygen at the bottom layer of water.

Hatchery Technologies

Technologies for fish breeding and seed production

Induced breeding of carps

A breakthrough in induced breeding (Fig. 22) through hypophysation (Chaudhuri and Alikunhi, 1957), was achieved during the fifties with a thrust on mass production of quality spawn in controlled environment, thereby reducing dependence on natural seed collection. Chaudhuri and Alikunhi (1957) successfully induced spawning in *Labeo rohita, Cirrhinus mrigala, C. reba, L. bata* and *Puntius sarana* by injecting them with carp pituitary extract. This technique has been adopted widely and now forms a regular part of fish culture programme in India (Jhingran, 1991).

Chinese carps have also been successfully bred in 1962 following similar techniques (Alikunhi *et al.*, 1963). The technique of induced breeding of

Fig. 22. Induced breeding of carps and eggs

carps by hypophysation has also been followed in different species by several workers. Further, the use of various synthetic formulations including Ovaprim has largely replaced the use of pituitary, and the technology has become farmer friendly. Many hatcheries are switching over from the use of pitutary gland to 'Ovaprim', due to its availability as ready to use inducing agent, good breeding response and high percentage of ovulation and fertilization, besides demanding only one injection instead of two doses.

The eco or circular hatcheries, based on the technology of induced breeding of carps with pituitary gland extract (PGE) have commercialised fish seed production of Indian and Chinese carps. Under this technology sexually mature fishes, which do not breed in captivity, are bred by PGE to spawn in ponds. Although, this technology was evolved in 1955-57, it took over two decades to popularize it in India through All India Co-ordinated Project on "Seed production and composite fish culture" and other programmes. Nowadays, the synthetic hormone 'Ovaprim' is used as a successful substitute of pituitary hormone. Ovatide and WOVA-FH are also gaining popularity.

Strain development

The rapid development of commercial fish culture in recent years has led to increased emphasis on stock improvement through genetics and genetic engineering. The continuous use of the same broodstocks over a long period has resulted inbreeding depression leading to higher deformities and low survival. Tripathy and Khan (1988) have suggested periodical replacement of broodstock from important riverine systems to overcome such problems.

Several intergeneric and interspecific hybrids were produced in the last four decades for genetic improvement. Though attempts on intergeneric hybridization with Indian Major Carps (IMC) and Chinese carps have been made, they were not successful, as their hybrids did not survive after hatching in most of these cases (Alikunhi *et al.*, 1963).

In India, sex reversal in the common carp and in tilapia (*Oreochromis mossambicus*) is reported. The genetic engineering practice, which is becoming popular during recent years is gynogenesis, polyploidy, and transgenics. Gynogenesis has been successfully induced in *L. rohita* and *C. catla* (John *et al.*, 1984) by cold and heat shocks. Sterile triploid hybrids have been produced in recent years by crossing common carp with IMC males (Khan *et al.*, 1988). Reddy *et al.* (1990) succeeded in producing triploidy and tetraploidy in rohu and catla by giving heat shocks to the fertilized eggs. Further, Reddy *et al.* (1998a) induced triploidy in the common carp and observed significantly higher rates in the triploids than the diploids. Pandian and Varadaraj (1987) produced triploids and tetraploids in tilapia by heat shock. Allotriploids and autotriploids have also been produced with the former showing higher rate of survival than the latter. Varadaraj and Pandian (1989 b, c), employing judicious combination endocrine sex reversal, selective breeding and gynogenetic techniques produced super male tilapia for the first time.

Selective breeding is a classical approach to improve fish stocks. Genetic gain obtained by this process is cumulative, which can be improved over generations by keeping the in breeding coefficient low (Reddy *et al.*, 1999). In India, selective breeding work has been taken up at the Central Institute of Freshwater Aquaculture with the rohu and work over the years has demonstrated growth increments of about 50 % over the parental stock after three generations (Reddy *et al.,* 1998b; Das Mahapatra *et al.,* 2000).

Intensive carp seed rearing

Availability of adequate quantity of carp seeds of desired species at appropriate time is one of the pre-requisites for success of aquaculture operations. The availability of standard stocking materials in time and space still remains a constraint, despite domestication of induced breeding technology and production of carp seed to the tune of over 18,500 million fry in the country. The raising of seeds in the initial stages is associated with high rates of mortality due to several management problems (Anon., 2000a). Thus, it is essential to follow standardized package of practices for higher growth and survival in intensive seed raising at higher stocking densities, to avoid hypoxic conditions and competition for food and space.

Different standardized package of practices for intensive seed production involve control of less predatory and weed fish by plant derivatives and soap-oil emulsion to control insects, organic and inorganic fertilizers for fertilization of ponds, stocking carp species for mono-culture, supplementary feeding, management of water quality, and standard methods for monitoring health-care, etc.

The technology of intensive seed production includes

- Eco or circular hatchery or collection of spawn from natural waters;
- Raising the spawn to fry in nursery ponds; and
- Rearing of fry to fingerlings in ponds.

Eco or circular hatchery

From the earthen pits to double walled *hapa* hatcheries, associated modifications have come a long way in terms of running water glass jar or circular hatcheries (Fig. 23). These eco-hatcheries have not only provided the scope to produce and handle mass quantities of eggs during hatching but to a greater extent have reduced the requirement of water and manpower.

The essential features of the eco-hatchery are:

i) Tube well or a dependable source of potable water.

ii) Overhead tank (25,000 to 30,000 liter capacity), with arrangement of continuous water supply to various hatchery components.

Fig. 23. Carp eco/circular-hatchery

iii) Circular spawning pool (8 m diameter) capable of holding the spawners and male population.

iv) Incubation pool is a circular double walled chamber of 3-m diameter. The eggs are released in the outer chamber. The water intake through floor mini pipes prevents eggs to settle down. The hatchlings are kept in the outer chambers for 72 hours.

v) Spawn collection pool is rectangular in shape. The spawn is collected in a rectangular sac like cloth called *hapa*.

Raising fry from spawn

At the pond culture substation of CIFRI, Cuttack, 1-2 million spawn ha^{-1} were stocked with satisfactory results in well manured nurseries with the provision of artificial feed (Jhingran, 1991). Over the years, the stocking rates have been increased many folds and there has also been considerable improvement in survival.

India has made remarkable progress with regard to production of carp fry, with an increase from 6321 million in 1986-87 to 18500 million at present.

Fig.24. Nursery ponds for raising fry from spawn at CIFA Bhuvaneswar

Generally the size of nursery is 0.04-0.1 ha (Fig. 24). The pond preparation includes treatment of the ponds with Mahua oil cake (MOC) atleast 15 days prior to stocking for eradication of unwanted fishes and application of lime. The fertilization includes application of groundnut oil/ mustard oil cake @ 700 kg, cow dung 200 kg and 50 kg single super phosphate ha^{-1}, after making a thick paste of the ingredients. These are applied in three doses *i.e.* 50% of the paste 3 days before stocking, 25%, 5 days after stocking and the remaining 25%, 10 days after stocking.

Fish farmers usually follow stocking density of 3-5 million spawn ha^{-1} in earthen nurseries, however the intensity can be as high as 10-20 million spawn in cemented nurseries (Jena *et al.*, 1998a). Generally monoculture is done for raising the fry.

A mixture of rice bran and oil cake at 1:1 ratio is applied as supplementary feed. Feeding is done @ 6 kg day^{-1} per million spawn for first 5 days followed by 12 kg day^{-1} per million spawn for next 10 days, in spilt doses during early morning and evening hours (Jena *et al.*, 1998b).

The fry attain a size of 25-30 mm in a rearing period of 15 days.

The survival rate which was only 10-20% during 1950-60, increased to 50-60% in the later years.

Rearing the fry to fingerling

Refinements in various hatchery systems have paved the way for a large scale seed production. However spawn and fry rearing are encountering 50-70% mortality. Thus, efficient rearing of the initial stages of fish has assumed importance. Although the need for raising the fingerling in rearing ponds is fully realized, it is usually ignored by most of the fish culturists, who normally resort to stocking the ponds directly with fry. As a result, young and delicate fry are exposed to different species of predators affecting the survival of the seed (Tripathi, 1990b).

Hora and Pillai (1962) recommended that stocking density of carp fingerlings should be between 0.25 and 0.5 million ha^{-1}. In the initial experiment on rearing of IMC fry to fingerlings, survival of 76% was obtained when the ponds were stocked at densities ranging from 62,000 to 125,000 ha^{-1} (Lakhsmanan *et al.*, 1968; Singh *et al.*, 1972). Experiment on exotic carp fry gave similar results, when ponds were stocked with 0.1-0.2 m fry ha^{-1}. Adopting water re-circulatory system through biological filters proved advantageous in rearing a large number of fry with high survival (Jhingran, *et al.*, 1979). Evaluating the performance of growth and survival of IMC and exotic carp fingerlings separately and in combinations at stocking density of 0.2 m ha^{-1}, Jena *et al.* (1998a) recorded higher growth, survival and biomass production in the combination of all six species.

Generally the size of rearing pond is 0.1-0.2 ha. The pond preparation is almost the same as that for nursery for raising fry to fingerlings. It includes MOC treatment of the ponds at least 15 days prior to stocking, eradication of unwanted fishes and application of lime. Fertilization includes application of both organic and inorganic fertilizers at conventional doses (Jena *et al.*, 1998b). The stocking density is 0.1-0.2 million fry ha^{-1}.

Rice bran and oil cake in 1:1 ratio are provided as the supplementary feed. The doses of feed over the rearing period are 8-10% of fish biomass per day in the first month, 6-8% of fish biomass per day in the second month and 3-5% of fish biomass per day in the third month.

The rearing period is two to three months untill the fingerlings attain a mean size of 100 mm in length and 10 g in weight.

Cost and returns of seed production

The process of fish seed production has three stages, namely, spawn, fry and fingerlings. For raising fry from spawn, 3-4 crops may be taken in a year leading to production of 3.6 to 4.8 million fry ha^{-1}. The major components of the operating cost are the cost of seed and lease value Table 39). The benefit cost ratio was 1.5 for nursery management. At the next stage of rearing fry to fingerling the costs incurred on feed, lease value and seed cut the major share in cost. The average number of fingerlings produced were 0.15 million ha^{-1}. The benefit cost ratio was 1.32.

Table 39. Economics of seed production (Rs ha^{-1})

Item	Nursery	Rearing
Area	1 ha	1 ha
Lease value (Rs/crop for nursery & Rs/ year for rearing)	5000	15000
Pond preparation		
Predatory and weed fish clearance	7500	7500
Insect control	1000	
Fertilisation	7500	4000
Seed(Spawn 3 million , fry 2 lakh)	15000	12000
Supplementary feed	4500	24000
Labour charges	5000	12000
Miscellaneous	2000	3000
Total cost	47500	79500
Returns (Survival rate 40%)	72000	
Returns (Survival rate 75%)		105000
Profit	24500	25500

Source: Katiha *et al.*, 2002

Breeding and seed production of catfishes, magur and singhi

The first success in induced breeding of *Clarias batrachus* in India was achieved in the mid fifties when spawning was induced using homoplastic pituitary glands. Further success has been recorded in breeding the fish using heteroplastic pituitary glands and in advancement of ovarian maturation and multiple spawning of *C. batrachus*.

The air-breathing catfishes *Clarias batrachus* (magur) and *Heteropneustes fossilis* (singhi) are well adapted to adverse ecological conditions, *viz*., water bodies with low oxygen and pH, high CO_2, H_2S, CH_4 and heavy silt with decaying vegetation, organic load, etc. These can be stocked @ 20,000-50,000 fingerlings ha^{-1}, which attain 100-200 g in 6-8 months (Anon., 2000a).

Management of brood stock

Proper care and maintenance, and provision of balanced supplemented feed play a key role in achieving successful spawning. The brood fishes are stocked generally in flow through (2 l min^{-1}) cement cisterns (3 m x 1 m x 1m) with 10-15 cm thick soil base, an inlet at the top of cistern and outlet at about 20 cm from the bottom.

Induced breeding technique

Following standardized induced breeding technique (Fig. 25) using different inducing agents like carp or catfish pituitary extract, ovaprim, HCG, LHRHa +Domperidone, etc., the species can be bred from March to September.

Fig. 25. Induced breeding of airbreathing fish

The incubation time in singhi is less than magur. Proper flow through system is used for incubating eggs to make the seed available for a longer duration in a year.

Larval rearing

The newly hatched larvae are stocked at 2,000-4,000 m^{-2} in well aerated water till air-breathing habit commences. They are fed with mixed zooplankters or *Artemia* larvae or *Tubifex* spp. with replenishment of water at least twice a day initially for a few days, followed by compounded supplementary feed. The fry are ready for rearing in earthen nursery ponds or outdoor cement cisterns (4m x 1 m x 0.5m) with soil base after 10-12 days at 100-150 m^{-2} to raise fingerlings of 4-6 cm in a month. Survival of 60% may be obtained during raising of fingerlings under optimum rearing conditions.

Breeding and seed production of giant freshwater prawn, *Macrobrachium rosenbergii*

The giant freshwater prawn *Macrobrachium rosenbergii* is the largest and fastest growing natantian in the world. The species is widely distributed in south and southeast Asia, and lives in rivers, migrating to estuaries for completion of larval cycle in the brackishwater. It has considerable demand both in domestic and foreign trade and is most suitable for aquaculture in freshwater and low saline brackishwater ecosystems. The hatchery technology has been developed and standardized for obtaining sustainable seed production. The technology offers development of aquaculture and production of premium product for export, by using the resources available in the country. The process includes the following steps:

Broodstock management

The adult prawns are maintained at 2 m^{-2} with a sex ratio of 1 male to 4 females, mainly subsisting on pelletized broodstock diet (Vardhim) with a protein and fat content of 36% and 8% respectively

Incubation and hatching

The berried prawns are kept for incubation in brackishwater at 5% salinity for hatching and at an average fecundity of 500 larvae g body weight^{-1}. The inner view of a giant prawn hatchery is given in Fig. 26.

Fig. 26. Inner view of Giant prawn *(Macrobrachium rosenbergii)* Hatchery

Larval-rearing

Larvae are reared in two phases with a high stocking density (500 l^{-1}) in the first phase for one week, followed by low stocking density (50 l^{-1}) in the second phase, till metamorphosis (20 days), at 8-12 % salinity. *Artemia* nauplii at 5-50 larvae day^{-1}, depending on larval stage are given to the early zoea, and to the advanced larvae, *Artemia* nauplii are given (during evening/night time) in combination with prepared feed (during day time).

Water quality management

Water quality is maintained with proper cleaning and water exchange on alternate days (50% for early zoea and 25% for advanced larvae) with recycled water. The survival from zoea I to zoea V is 80-90% and from zoea VI to PL is 65-75%, with average survival from zoea I to PL being 60%.

Seed collection and acclimatization

The post larvae are slowly acclimatized to freshwater and are fed on dry PL feed (Amrut, Code 1, 2 and 3). They are stocked at 5,000 PL m^{-2} with substrate (molluscan shells) and are reared for a week. These are fed as per the formulations developed by CIFA, Bhuvaneswar.

Health management

Health management has been accomplished successfully without any disease problems by adopting proper husbandry conditions and by treating saltwater and freshwater with bleaching powder (20 mg l^{-1}), berried prawns with copper sulphate (0.3 mg l^{-1}), *Artemia* cyst with bleaching powder, and nauplii with formalin as prophylactic measures.

The seeds are reared with proper food and feeding regimes and by maintaining water quality parameters and husbandry conditions at the optimum level without creating stress, ensuring high survival in the production ponds.

Brackishwater

Shrimp hatchery technology

Wild shrimp seed capture, which was rampant before the establishment of hatcheries, was a major cause for conflict with the capture fisheries sector. It has been resolved to a large extent presently through development of a hatchery technology for penaeid shrimps like *P. indicus* and *P. monodon*. In India, CMFRI (Silas *et al.* 1985) and Kerala State Fisheries Department (Alikunhi *et al.* 1980) are the pioneers in the development of penaeid prawn hatchery technology. Hatchery techniques like broodstock development, induced maturation and spawning, rearing of nauplius (6 substages), zoea (3 substages) and mysis (3 substages) and post-larval (nursery) rearing techniques have been successfully transferred to users. Broodstock either grown in farms or collected from the wild are induced to mature by unilateral eyestalk ablation and/or environmental manipulation. After spawning, the fertilized eggs pass through different larval stages to become post-larva. No feeding is required upto nauplius stage after which unicellular algae (*Chaetoceros calcitrans*), *Artemia* and microencapsulated feeds are given in appropriate doses. While zoeal stages require only unicellular algae, mysis and post-larve require *Artemia* nauplii in addition to unicellular algae.The post-larvae are reared in nursery tanks for 15 – 20 days and are offered pellet feed after which they are transferred to stocking ponds for 3-4 months. A simple mini-hatchery of 1.4 million capacity (PL per year) that can be operated even with the help of semi-skilled individuals has been established at the Mandapam Regional Centre of CMFRI in 1985. Such hatcheries would be ideal to set up for sea-ranching programmes all along the Indian coast.

For shrimp hatcheries, a regular supply of healthy broodstock is necessary. However, the supply of spawners from the wild is limited. Until recently, eyestalk ablation was the widely adopted to induce rapid maturation and spawning. Recently, technology has been developed to induce breed and repetitively spawn *P. indicus* and *P. semisulcatus* using environmental and nutritional manipulation strategies instead of eyestalk ablation (Pillai and Maheswarudu, 2000). Broodstock development of tiger prawn *P. monodon* from seed produced in the hatchery has also been successful (CMFRI 2000).

Hatchery input technologies

Live feed culture

Live feed availability is a critical factor in hatchery rearing operations of all commercially important finfishes, crustaceans and molluscs. While prawn and fish larvae prefer diatoms (species of *Chaetoceros* and *Skeletonema*), zooplankton like rotifers (*Brachionus* spp.) and brine shrimp, the molluscs require nannoplankton flagellates (species of *Isochrysis, Chlorella, Nanochloropsis* and *Tetraselmis*) measuring < 10 micron.

Micro-algae culture

The main aspects of micro-algae culture are the isolation of required species, identification, preparation of culture media, stock culture maintenance, mass culture and harvest and preservation of the culture. Isolation of the required species of micro algae from the wild is done followed by indoor mass culture in rectangular or cylindrical perspex tanks using inoculum from stock culture and then in bigger FRP tanks by providing sufficient sunlight. For large-scale production, out-door concrete tanks (10-25 t capacity) can be used.

Rotifer *(Brachionus* spp.) culture

This involves three stages –

Raising appropriate food organisms like *Chlorella* for the rotifers in tanks (2.2 x 1.7x 0.8 m) filled with filtered sea water and fertilized with inorganic fertilizers like ammonium sulphate, calcium superphosphate, urea and metal (Cu, Zn and Mg) mixture (@ 100, 20,5,3 g t^{-1} water respectively).

This is innoculated with *Chlorella* stock which reaches maximum density in about 20 days.

Intensive aeration and periodic harvesting are done and fresh sea water is replaced with proportionate amount of fertilizers. 3-4 cultures can be taken in one run.

Brachionus is cultured by isolating stock from stagnant water bodies using 50 –100 micron mesh nets. Mass production of rotifers is done by transferring adult rotifer along with eggs and neonates if any (@30-40 nos ml^{-1}) into a *Chlorella* medium. Baker's yeast at the rate of 1 g per million rotifers is also supplied daily.

Brine shrimp culture

Artemia is an essential live feed for the shrimp hatchery and it has been estimated that at least 35- 50 t of *Artemia* cysts would have to be imported to satisfy the demands from Indian shrimp hatcheries. Large scale indigenous brine shrimp culture is a solution. Culture of *Artemia franciscana* (North American strain) integrated with salt production has been done successfully along the Gujarat coast (Gopalakrishnan and Shenoy, 1998). An average production rate of 3.9 kg ha^{-1} $year^{-1}$ of cysts of a quality comparable to imported commercial brands marketed in India makes further refining of this technology highly desirable.

Ornamental fishes

Ornamental fishes are often called as "Living Jewels" due to their attractive looks and are considered as a resource for earning foreign exchange. Globally, there has always been an increasing demand for ornamental fish (Fig. 27).

Fig. 27. Ornamental fishes

There is an annual turnover of US$7 billion globally from aquarium fish trade. The Marine Products export Development Authority (MPEDA) has estimated that India can earn about US$ 5 billion as foreign exchange by export of aquarium fish. In spite of availability of immense natural resources, ornamental fish breeding has not taken deep roots. There are about 150 full time and 1500 part time ornamental fish breeders in the country.

There are established technologies for breeding of ornamental fishes. These are well proven scientifically and are standardised. Production model has also been well defined. By virtue of extensive scientific studies and observations, it is now possible to breed most of the aquarium fish as a house hold activity, both at rural and urban levels. Many community-based projects are seriously examining the scope of production of ornamental fish as a secondary source of income for the poorer sections of society. Some of the common freshwater ornamental fishes are given in Table 40.

The streams and rivers of the western ghats and north eastern hills are rich source of freshwater ornamental fishes. In the western ghats alone, nearly 180 species have been identified as ornamental, including the most attractive *Puntius demsonii*.

Table 40. Common freshwater ornamental fishes of India

Ambassis nama	*A. ranga*	*Puntius denisonii*
Colisa fasciata	*C. chuna*	*Puntius jerdoni*
Aplocheilus panchax	*A. blockii*	*Puntius sahyadriensis*
A. lineatus	*Puntius ticto*	*Pristolepis morginata*
P. sophore	*Botia spp.*	*Puntius fesciatus*
Nemacheilus spp.	*Notopterus notopterus*	*Puntius filamentosus*
N. chitala	*Danio spp.*	*Tetraodon travancoricus*
Nangra itchkeea	*Badis badis*	*Horabagrus brachysoma*
		Danio malabaricus

West Bengal contribute about 90% to the export of ornamental fishes of India. Most of these fishes are from wild habitats, especially from the indigenous stock of the western ghats and north eastern states (Santosh and Mandal, 2001).

The fishes from our beels with ornamental value are identified as *Ambassis nama, A. ranga, Aplocheilus panchax, Rasbora daniconius, Puntius spp, Badis badis, Botia spp, Notopterus spp.*

Captive breeding of ornamental fish

CIFRI, Barrackpore has recently standardized captive breeding and larval rearing techniques for bubble nest builders like *Colisa* sp. Adult ornamental fishes are reared in the specially designed brood fish management glass aquarium. This aquarium is of medium size (60 cm x 35 cm x 30cm) and partitioned vertically using glass sheets in the middle portion. Water level is maintained at 15 cm. Male and female fishes are stocked separately in the partitioned chamber. The fishes are fed *ad libitum* with tubifex worms daily. A constant water temperature of 29^0 C is maintained with the help of a thermostat. The rearing period is two months, usually from January to March.

For spawning, glass aquarium of 45 cm x 30 cm x 30 cm size is used. The aquarium is filled with tap water upto 15 cm in height. Ripe female with fully swollen abdomen and oozing male are introduced in the aquarium during late afternoon (4-5 pm). Thermocole pieces (6 cm x 8 cm) are provided on the water surface for bubble nest formation. The male makes a foamy bubble nest under and around the thermocole pieces by the next day. Fertilized eggs are observed in the bubble nest on the second day after bubble nest formation. The female is removed from the spawning aquarium after egg laying.

The fertilised eggs (transparent with brownish spot) are hatched within 48 hours. Initially the hatchlings appear like black dots in the bubble nest. No feed is given upto 72 hours of hatching (yolk sac larvae). The movement of hatchling starts below and around the bubble nests after 48 hours of hatching. The male shows parental care by guarding the nest as well as picking and putting the fertilised eggs whenever such eggs fall from the bubbles. As soon as the hatchlings start free movement, the male is removed from the spawning aquarium.

Rearing of hatchlings

The young ones with the yolk sac absorbed are generally called as fry. These are very delicate and should not be netted or touched. For the first few weeks, they should be fed several times in a day, but only with minute particulate matters. The hatchlings are reared in the spawning aquarium for 30 more days. Fertilised pond plankton is given as food to the hatchlings twice daily by dropping on the water surface. A total of 10 ml of fertilised plankton water is

Fig. 28. Rearing of ornamental fishes

given per feeding. Cultures of *Infusoria* sp. produced in glass jars are also an excellent food source (Shaleesha and Amalan, 2001). The hatchlings first look like silvery threads with black spot at one end. Once the young ones attain an age of four weeks, they commence feeding on larger food particles. After 30 days of rearing the hatchlings attain an average length of 20 mm and start feeding on chopped tubifex worm. Newly hatched brine shrimp eggs are ideal food for young ones of about seven days and above. However the brine shrimp cysts expensive. The rearing of ornamental fishes in aquarium is depicted in Fig. 28.

Post-harvest

Supply of fresh fish

There is a pronounced consumer preference for freshwater fish, especially carps. The ideal size for carp is 1-2.5 kg. This is either harvested from open waters on a continuous basis or periodically harvested from culture tanks. When fish is caught from open water-bodies the fishermen usually sell it directly to local retailers such as cycle traders or head loaders or in trucks if the catch is more (Fig. 29).

Fig. 29. Transportation of fish catch in truck

When it is time to harvest from a culture area the farmer informs a trader who agrees on a price and arrives on the day of harvest with a truck and ice. The fish is packed in ice and taken by the trader or commission agent of the markets.

Icing

Ice is required to cool and preserve the catch. Fish is not usually iced at the landing site. However, fish destined for distant markets is iced adequately and packed in woven wicker baskets lined with leaf mats, or in old tea chests. Icing is carried out effectively for prawns and other fishes and strict procedures are adhered to.

Canning

A little canned fish is produced locally. Information available about the consumption of this product indicates some demand in metropolitan cities.