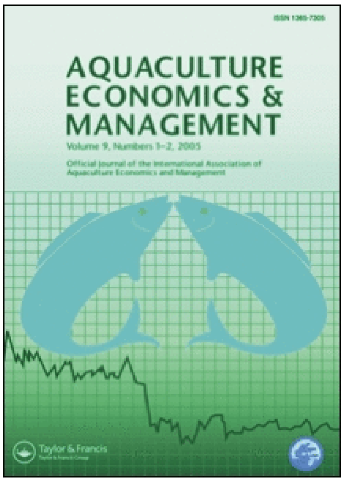

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INLAND AQUACULTURE IN INDIA: PAST TREND, PRESENT STATUS AND FUTURE PROSPECTS

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INLAND AQUACULTURE IN INDIA: PAST TREND, PRESENT STATUS AND FUTURE PROSPECTS

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□ *In India, inland aquaculture has emerged as a fast-growing enterprise and a viable alternative to the declining capture fisheries. The present paper is an attempt to assess Indian inland aquaculture with respect to its resource base, output trends, systems and activities, yield gaps, adoption and impact on aquaculturists, economics, returns to inputs, investment needs, and future prospects. The paper is largely based on existing literature and observations made as part of an ICAR-WorldFish demand supply project. Indian aquaculture is primarily limited to inland sector and carp-oriented; for that reason, this activity received special attention. Freshwater aquaculture observed tremendous growth in the past 15 years, but immense scope still exists for horizontal expansion and increases in productivity (vertical expansion). This is evidenced by the fact that the average farm fish yield is only one-third of that achieved in farm trials. The difference was mainly due to much higher input use in on-farm trials. Most of the aquaculturists were practicing extensive aquaculture, but aquaculturists with semi-intensive operations benefited most from adoption of technology. The benefit:cost ratios for different systems of aquaculture varied between 1.22 to 1.86. The return to capital was much higher than the return to labor, due to the low labor input. The semi-intensive aquaculture system would receive the greatest return from projected macrolevel investments, followed by extensive and intensive systems. Dedicated efforts are needed to meet the demand for quality fish seed and feed in order to achieve the desired 45% increase in area and greater than 50% increase in productivity. Based on the observations, activities designed to foster inland aquacultural development in India are recommended.*

Keywords inland aquaculture, resource, production, technologies, yield gap, economics, investment need, future prospects, India

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INTRODUCTION

The importance of the fisheries sector in India is demonstrated by the fact that it employs more than five million people (Anon, 2000), contributes to food and nutritional security and employment, supports livelihoods, and raises the socioeconomic status of poor fishing communities. During the past half-century, Indian fish production registered excellent growth, from a meager 0.75 m t in 1950 to 6.3 m t in 2002 (Anon, 2000; Katiha et al., 2003). The industry contributes nearly INR 200 trillion to the national economy, forming 1.4% of national gross domestic product (GDP) and 5.4% of agricultural GDP (Anon, 2000). The sector is one of the major contributors to foreign exports.

During the past two decades, the inland fisheries in India, which include both capture and culture fisheries, have registered tremendous growth and change. Until the mid-1980s, capture fisheries were major source of inland fish production. But since then, fish production from natural waterways, such as rivers and lakes, has trended downwards, primarily due to a proliferation of water control structures, indiscriminate fishing, and habitat degradation (Katiha, 2000). Diminishing resources, the energy crisis and the resultant high cost of fishing have led to an increased realization of the potential for and versatility of aquaculture as a viable and cost effective alternative to capture fisheries (Ayyappan & Jena, 2001; Ayyappan, 2004; Jana & Jena, 2004; Pillai & Katiha, 2004).

With the importance of inland aquaculture in India in mind, the present paper provides an insight into aspects of the country's inland aquacultural resources, production practices and trends, and future prospects. The sector includes both fresh and brackish waters. Based on the observations, recommendations are made about how to further develop inland aquaculture sector in India.

Data Sources and Methodology

The present study is based on literature searches and analysis of secondary and primary data gathered under ICAR-WorldFish demand supply project. The data on the resources, production levels, activities and systems, potential, investment needs, future prospects, and requirements of aquaculture came either from the literature or from other secondary sources. The observations on yield gaps (IRRI, 1979), economics, and returns to inputs were based on analysis of primary information and on the responses of researchers and aquaculturists gathered during the project. The level of adoption of technology is low (< 33%), medium (33% to 66%), and high (>66%) as per methodology of Bhaumik et al. (1992). The returns to various inputs/factors of production have been computed on the basis of their shares in costs/investment.

RESULTS AND DISCUSSION

Potential Area Suitable for Aquaculture

Freshwater

By virtue of its geographical situation in the monsoon belt, India is endowed with good rainfall. As a consequence, it has extensive potential aquacultural area in the form of ponds and tanks. These water bodies are distributed throughout almost all the states of India (Table 1). These bodies cover an area of over 2.388 million hectare(s), with the largest areas being in the state of Andhra Pradesh (0.52 m hectare(s)), followed by Karnataka (0.41 m hectare(s)) and West Bengal (0.276 m hectare(s)). These three states account for about 50.5% of India's aquacultural waters.

TABLE 1 Inland Aquacultural Water Bodies in India

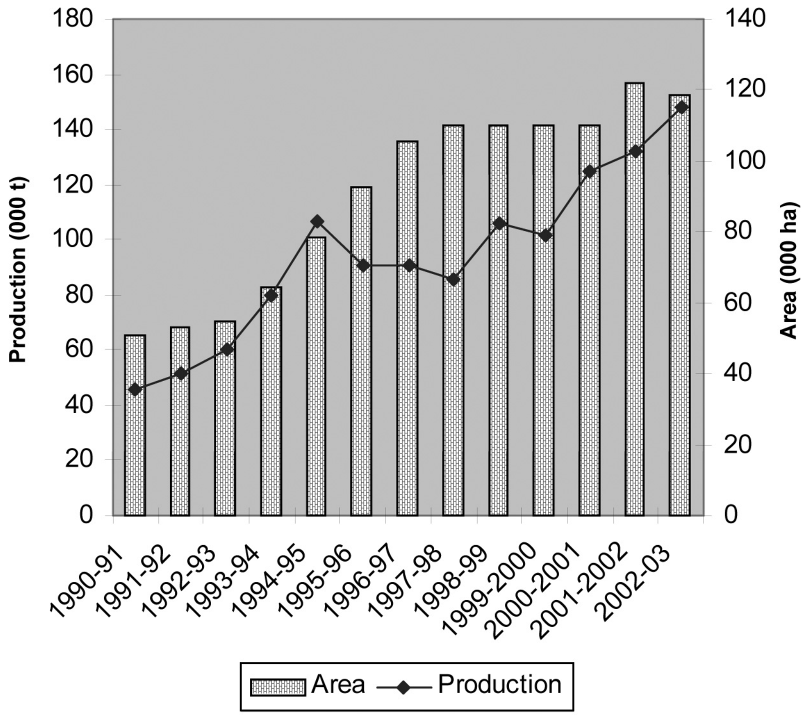
State	Total area of aquacultural water bodies ('000 000 ha)	Area as % of all aquacultural water bodies in India	Area covered by FFDA ('000 ha)	% of state aquacultural water bodies covered by FFDA	Production on FFDA adopted farms (t)	Yield on FFDA adopted farms (kg/ha/year)
Andhra Pradesh	0.517	(21.65)	13.72	2.65	26,074	1,900
Arunachal Pradesh	0.001	(0.04)	0.16	16.40	180	1,098
Assam	0.023	(0.96)	3.44	14.97	6,368	1,850
Bihar	0.095	(3.98)	22.31	23.49	47,527	2,130
Goa	0.003	(0.13)	N.A.	N.A.	N.A.	N.A.
Gujarat	0.071	(2.97)	30.93	43.57	34,027	1,100
Haryana	0.010	(0.42)	18.57	185.70	65,005	3,501
Himachal Pradesh	0.001	(0.04)	0.26	26.30	658	2,502
Jammu & Kashmir	0.017	(0.71)	1.56	9.15	2,022	1,300
Karnataka	0.414	(17.34)	21.70	5.24	31,898	1,470
Kerala	0.030	(1.26)	4.00	13.34	7,202	1,800
Madhya Pradesh	0.119	(4.98)	54.96	46.19	86,292	1,570
Maharastra	0.050	(2.09)	11.31	22.63	6,109	540
Manipur	0.005	(0.21)	1.79	35.82	2,507	1,400
Meghalaya	0.002	(0.08)	0.03	1.25	18	720
Mizoram	0.002	(0.08)	0.15	7.30	219	1,500
Nagaland	0.050	(2.09)	1.16	2.33	1,163	1,000
Orissa	0.114	(4.77)	39.84	34.95	75,698	1,900
Punjab	0.007	(0.29)	12.15	173.57	49,628	4,085
Rajasthan	0.180	(7.54)	4.17	2.32	7,211	1,730
Sikkim	N.A.	N.A.	0.06	N.A.	196	3,500
Tamil Nadu	0.224	(9.38)	12.15	1.76	16,521	1,360
Tripura	0.012	(0.50)	3.33	27.78	6,666	2,000
Uttar Pradesh	0.162	(6.78)	69.21	42.72	138,410	2,000
West Bengal	0.276	(11.56)	98.78	35.79	296,349	3,000
Pondicherry	N.A.	N.A.	0.07	N.A.	75	1,119
Other	0.003	(0.13)	N.A.	N.A.	N.A.	N.A.
Total	2.388	(100.00)	425.82	14.93	908,023	2,135

Source: Anon (1996a, 1996b); Sinha and Katiha (2002).

Despite immense efforts to increase the size of the industry, only 0.8 million hectare(s) have been brought under scientific fish culture. In the early 1970s, Fish Farmers Development Agency (FFDA) was set up with World Bank assistance to promote the adoption of modern aquacultural techniques and thereby increase fish production. The agency has adopted over half of the 0.8 million hectare(s) dedicated to scientific fish culture. The greatest penetration of FFDA into the sector has been in the states of Punjab and Haryana. In those states cropping density is more than one, as is evidenced by the fact that, in those states, the cropped area is greater than the actual area. The influence of FFDA in these states is reflected in terms of high productivity. The national average productivity from FFDA-supported ponds has increased from 50 kg/hectare(s)/year in 1974–75 to about 2,135 kg/hectare(s)/year in 1994–95 (Katiha, 2000) and 2,270 kg/hectare(s)/year in 2003–04 (Anon, 2004). The production from these FFDA ponds; however, is restricted mainly to three species of Indian major carps (*Catla catla* (*Catla*), *Labeo rohita* (*Rohu*), and *Cirrhinus mrigala* (*Mrigal*) with three exotic species (*Hypophthalmichthys molitrix* (Silver carp), *Ctenopharyngodon idella* (Grass carp), and *Cyprinus carpio* (Common carp)) through polyculture of either only Indian or combination of Indian and exotic carps. Yet much effort is needed to harness the potential of unexploited water bodies. During the government's Ninth Five-Year Plan, the stress for fisheries was on increasing the ability of FFDA to assist fish farmers for adopting various improved means of aquaculture. The plan also focused on the expansion of prawn farming and the establishment of medium-sized fish feeding units (Anon, 1996a).

Brackishwater

The potential area of Indian coast brackishwater farming has been estimated at 1.19 million hectare(s), of which only 13.14% (0.157 m hectare(s)) is so used. However, there has been phenomenal growth of the sector, especially in shrimp farming, during last one decade, with area coverage increased from 65,000 hectare(s) in 1990–91 to 152,000 hectare(s) in 2002–03. The area covered in different maritime states for shrimp farming during the period is presented in Figure 1. Andhra Pradesh is the leading state followed by West Bengal, Kerala, Orissa, Karnataka, and Tamil Nadu. The area covered by shrimp farms in the coastal regulatory zone (CRZ) along the entire coastline has remained almost the same from 1997–98 to 2000–01. This was due to the ban imposed by the Supreme Court of India in December, 1996 for construction of new farms in the CRZ. The ban permitted shrimp farming only for new farms following traditional cultural practices (extensive/modified extensive). In order to ensure the implementation of this directive of the court, Aquaculture Authority of India was set up.



Source: Anon (2001, 2002) and Jose (2003)

FIGURE 1 Area covered and production under shrimp aquaculture in India.

Past Trends

Freshwater

Over the past 15 years, annual inland aquacultural fish production has increased from 0.51 to 2.38 m t; while during the same period, inland capture fisheries production has declined from over 0.59 to 0.40 m t (Anon, 1996a, 1996b; Gopakumar et al., 1999; Anon, 2000). The contribution of aquaculture in inland fish production has increased sharply from 46.36% in 1984 to 85.65% in 2002–03 (Table 2). This increase is primarily due to the tremendous rise in output from freshwater aquaculture (from 0.3 to 2.0 m t). Further, the share of freshwater aquaculture in total inland fish production during the same period has also increased from 27.95% to 71.84%. Despite this increase, the sector possesses scope for further increases in inland fish production by way of horizontal expansion and higher productivity per unit area.

In India, aquaculture production has moved from being a highly traditional activity to being a well-developed industry (Ayyappan, 2000). With a rich resource base in both water bodies and fish species, investments in the sector are trending upwards. Over the last 15 years, there was a

TABLE 2 Inland Fish Production in India ('000t)

Type of fisheries	1984–85	1989–90	1994–95	2002–03
Capture	591.74 (53.64)	396.50 (28.28)	334.03 (15.93)	500.00 (15.67)
Aquaculture	511.50 (46.36)	1005.50 (71.72)	1762.70 (84.07)	2690.00 (84.33)
Fresh water	308.30 ((27.95))	779.40 ((55.59))	1392.30 ((66.40))	2100.00 ((65.83))
Brackish water	203.20 ((18.41))	226.10 ((16.13))	370.40 ((17.67))	590.00 ((18.50))
Total inland fish production	1103.20	1402.00	2096.70	3190.00

(Katiha & Bhatta, 2002 and Dehardrai, 2004).

Figures in single parentheses represent percentage of total inland fish production, while figures in double parentheses represent percentage of inland aquaculture.

five-and-half-fold increase in freshwater aquaculture fish production. Appropriate technologies, financial investments, and entrepreneurial enthusiasm primarily account for this situation. The success stories of carp polyculture on a commercial scale culture started in the Kolleru lake basin in Andhra Pradesh in the mid-1980s, and were replicated in Punjab, Haryana, Uttar Pradesh, and elsewhere (Gopakumar et al., 1999). Aquaculture in Kolleru lake basin started during the 1980s at an extensive level and gradually spread to other areas in the Krishna-Godavari delta region (Sarangi et al., 2004). The inundated paddy fields of the region were converted into dugout ponds ranging between 1–40 hectare(s) area. The farming in this area is basically of two types, seed farming and grow-out farming. Many of the farmers with larger holdings were having seed rearing facilities to an extent of 10% of the farm area. These rearing facilities are utilised for growing fish seed collected from local hatchery up to 50–100 g over period of 8–10 months. These stunted fingerlings from the seed farmers are procured by the grow-out farmers for pond production.

Generally, two species of Indian major carp viz., rohu (*Labeo rohita*) and catla (*Catla catla*) are stocked @ 10,000 stunted fingerlings per hectare(s) with species ratio of 9:1. Some farmers often stock a snakehead species, *Channa striatus* @ 500 fishes/hectare(s) mainly to control trash fishes and aquatic insects. Organic manuring in the form of poultry manure @ 8–10 t/hectare(s) is mostly used, of which 50% is the initial loading dose and the rest are applied at equal monthly splits. When cattle dung is applied, 20–25 t/hectare(s) of cow dung is mixed with SSP @ 10–25 kg/t and applied in splits. Fertilisers such as urea, SSP, and DAP are also applied @ 200–500 kg/hectare(s) in monthly/fortnightly installments. Feeding up to 1 month is done with groundnut oil cake (GNOC) alone, followed by deoiled rice bran (DORB) and GNOC mixture at a 1:1 ratio for another 1 month and later exclusively with deoiled rice bran. Cotton seed, sunflowers, and soybean, cereals such as broken rice, pearl millet, and maize are the other common feed ingredients used by the farmers. Feeding is done daily at

5%, which decreased to 1% with progress of culture. Fishes are cultivated for 9–12 months, within which catla attains 1.5 to 2.0 kg, whereas rohu grows to 1.0–1.5 kg with 80–95% survival. Under this practice, the yield of fish ranges from 6–8 t/crop. The farmers adopt phased harvesting, which starts from the 8th month onwards.

Brackishwater

The contribution of the brackishwater sector is confined mainly to aquaculture of shrimps as the share of cultures of other fishes and capture fisheries is insignificant. The national shrimp culture output was estimated at 115,320 t during 2002–03 (Figure 1). The tiger shrimp (*P. monodon*) constitutes the major share of production, followed by white shrimp (*P. indicus*), and banana shrimp (*P. merguensis*). There was a steady rise in the production of cultured shrimp between 1990–91 (35,500 t) and 1994–95 (82,850 t); thereafter, it dropped until 1997–98 (66,870 t) before picking up again in 1998–99 (82,630 t). Since then, the production has increased annually. This is mainly due to the adoption of improved culture practices, particularly of disease control practices, as well as horizontal expansion of the industry. The increasing output clearly indicates the potential of the sector for increasing shrimp production and productivity in India.

AQUACULTURE SYSTEMS AND ACTIVITIES

Freshwater

Existing freshwater aquaculture activities can be categorised into fish seed production and the production of table-size fish or grow-out. Technologies differ according to the type of fish, and some are discussed briefly next.

Hatchery and Seed Production

Hatchery activities for fish breeding and seed production may be categorised as (i) induced breeding of Indian major carps (*Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*), minor carps (*C. reba*, *L. bata*, and *Puntius sarana*) and Chinese carps and strain development of Indian major, minor, and Chinese carps; (ii) intensive rearing of seed of these carps; (iii) breeding and seed production of air-breathing catfishes (*Clarias batrachus* and *Heteropeustes fossilis*); (iv) breeding and seed production of giant freshwater prawns (*Macrobrachium rosenbergii*); and, (v) breeding and seed production of ornamental fish (*Colisa* sp.).

Grow-out

Current freshwater grow-out systems may be classified into (i) polyculture of Indian major carps or Indian major and exotic carps together (composite carp culture) mentioned previously; (ii) mono- and polyculture of air-breathing fishes (*Clarias batrachus* and *Heteropeustes fossilis)* mentioned in breeding; (iii) mono- and polyculture of freshwater prawns (*Macrobrachium rosenbergii*); and, (iv) fish farming with Indian major and exotic carps integrated with the production of rice, cattle, pigs, ducks, and poultry.

Polyculture of Indian major carps or of Indian and exotic carps together can further be classified into (a) low input or fertilizer-based systems; (b) medium input or fertilizer- and feed-based systems; (c) high input or intensive feed and aeration-based system; (d) sewage-fed water-based systems; and, (e) aquatic-weed-based system.

Brackishwater

Hatchery and Seed Production

The hatchery technologies are developed for penaeid shrimps *Penaeus indicus* and *P. monodon. P. indicus* and *P. semisulcatus* are also induced bred successfully. Further, the seed of *P. monodon* has also been produced. Among fishes, induced breeding of mullets (Abraham et al., 1995, 1999), breeding and seed production of sea bass, *Lates calcarifer* (Thirunavukarasu et al., 1997) and breeding of grouper, *Epinephelus tauvina* have been successful. Further, captive brood stock of mud crab *Scylla serrata* and *S. tranquebarica* has been developed (Srinivasagam et al., 2000).

Grow-out

Shrimp (*Penaeus indicus* and *P. monodon)* farming is the most important sector of the brackishwater aquaculture in India. The other practices are (i) mud crab fattening, (ii) edible oyster farming, (iii) mussel farming, (iv) clam culture, and (v) finfish farming.

Aqua Feeds

Aqua feeds have been developed primarily for shrimp culture. "Mahima" shrimp feed was developed by Central Marine Fisheries Research Institute, Cochin, India, using low-cost indigenous ingredients. The composition and water stability of the feed are specified to meet the nutritional requirements of post larvae, juvenile, and adult shrimp. This simple feed formula is suitable for on-farm production (Sridhar & Srinath, 1998).

YIELD GAPS IN FRESH WATER AQUACULTURE

Freshwater aquaculture in India is carp oriented. The joint share of three Indian major carps and three exotic carps in freshwater aquaculture production is over 90% (Katiha & Bhatta, 2002). Keeping this fact in mind, yield gap analysis has been done for carp culture technology to estimate the difference between the yield obtained in experimental stations and on farm experiments (Gap I) and the difference between the maximum yield obtained in farm experiments and the average farm yield (Gap II) (IRRI, 1979). These were estimated for fish grow out, both in terms of yield and input use.

The gap estimates are presented in Table 3. In India, fish yields at experimental and farm trials were 8.0 t/hectare(s)/year and 5.5 t/hectare(s)/year, respectively, making gap I 2.50 t/hectare(s)/year. The actual farm average was 1.93 t/hectare(s)/year with a range of 0.3 to 9 t/hectare(s)/year, making gap II 3.57 t/hectare(s)/year. The actual fish yield was only about a quarter of the yield at experimental station, and about one third of the yield from farm trials. To identify the factors responsible for these yield gaps, the difference between recommended and actual farm input use was analysed. This gap was positive for all of the inputs except stocking rate (seed number per hectare(s)). The higher stocking rate at the farm level resulted from the smaller average size and comparatively low percentage of desired species in seed stock. These factors also led to higher mortality of fish seed stocked.

The level of other inputs used in general practice were much lower than the levels used in farm trials; the use of oil cake in practice was only 2% of the level used in the farm trials, while the equivalent figure for inorganic fertilizer was 51%. These levels were only 1% and 35%, respectively, of the levels used at experimental stations. At most of the farms, aquacultural practices followed were extensive when compared with the intensive and semi-intensive practices used in the experimental station and farm trials. The yield and input use gaps may be attributed primarily to financial constraints and to problems relating to technology access, technology transfer, diversification,

TABLE 3 Gaps in Fish Yield and Input Use for Carp Polyculture Technology in India

	Experimental station#	Estimated onfarm trials#	Actual farm average@	Gap I	Gap II
Yield (kg/ha)	8,000	5,500	1,932.41 (333–8,991)	2,500	3,567.59
Input use					
A. Seed (no./ha)	10,000	7,500	19,334.18	2,500	–11,834.18
B. Lime (kg/ha)	1,000	750	153.44	250	596.56
C. Organic Fertilizers (kg/ha)	20,000	16,500	4,523.31	3,500	11,976.69
D. Inorganic Fertilizers (kg/ha)	500	350	177.02	150	172.98
E. Feed (kg/ha)*					
i. Rice bran	15,880	10,917.5	1,081.91	4,962.5	9,835.59
ii. Oil cake	15,880	10,917.5	167.35	4,962.5	10,750.15
iii. Formulated feed	12,880	8,855	0.00	4,025	8,855.00

#Based on data collected from Central Institute of Freshwater Aquaculture, Bhubaneswar.
@Based on a survey conducted under ICAR-WorldFish supply demand project.
*Jena et al. (1998).

technology adoption, and socioeconomic issues. Awareness of technology, especially management technology, is extremely low at the grass root levels, except in the states of Andhra Pradesh, Punjab, and Haryana. Poor extension services are also contributing to these gaps. Lack of knowledge regarding fish diseases and their control poses problems in controlling fish mortality.

The other limiting factors for farmers are lack of knowledge about monitoring of soil and water parameters, about feed composition and its nutritional value, and about different package of practices such as pond preparation, fertilization, stocking, feeding, and health care. Property regimes, input supply, harvesting, output disposal, high interest rates for credit, poaching, etc. were also identified as constraints limiting the realization of potential, and of technology diversification and technology adoption. Most of the ponds are either community village/government ponds or privately owned. These waters have mostly open access with multiple uses for drinking water, agriculture, and allied activities and day-to-day requirements. It reduces degree of freedom for applying the recommended levels of inputs, which ultimately results in low yield.

The states/owners have different policies in terms of lease amount, lease period, and selection of lessee. For example, in some states the ponds will be leased out for one year only to fisher community. Such policies restrict the adoption of scientific cultural practices, such as pond preparation, etc. due to short period of lease. In this short period the benefits of these practices could not be realized. The fisher lessees are mostly very poor and may not follow the scientific cultural package of practices. These observations emphasize on support systems for credit, technological access, supervision, monitoring, and fish catch disposal and marketing.

ADOPTION AND IMPACT OF THE PROCESSES

As stated earlier, Indian freshwater aquaculture is carp oriented. The characteristics of water resources, constraints in adoption and the impact of processes (hatchery, seed production, and carp polyculture) on aquaculturists were analysed at different levels of input use and technological adoption (Table 4) and are discussed next. A similar exercise has been done for brackishwater aquaculture. The level of adoption is determined (Bhaumik et al., 1992). The low level of adoption is up to 33%, medium 34% to 66%, and high, above 66%.

Freshwater

Hatchery and Seed Production

These operations produce fish seed for use in stocking ponds for grow out. The first activity is induced breeding for production of spawn. It is a

TABLE 4 Adoption of Freshwater Aquaculture Systems and their Impact on Rural Development*

System	Characteristics	Level of adoption	Constraint(s)	Impact
Seed production				
Induced breeding of carps	Capital intensive; hatcheries mostly under private government agencies; low risk; high market demand; high profit	High	High technical expertise; finance; infrastructure facilities	High
Carp fry rearing	Small private/government ponds; low investment; high profit; moderate risk; high market demand	High	High technical expertise; infrastructure facilities	High
Carp fingerling rearing	Small private/government ponds; moderate investment; low profit; moderate risk; high market demand	Moderate	Low availability of water bodies; low B:C ratio	High
Carp polyculture				
Low input or fertilizer-based system	Small holding; community ponds; low investment; open access	Very low	Inability to privatize returns	Low
Medium input or fertiliser and feed-based system	Medium and large ponds; private; moderate to high investments; low risk; high production and profit	High	Input scarcity; limited access to infrastructure facilities; low Remuneration	Very high
High input or intensive feed and aeration-based system	Medium-sized pond; very high investment; private holding; high risk; high productivity; good market access	Moderate (the input use is higher than recommended for few practices)	Financial; low B:C ratio; low ecological sustainability; high risk	Moderate

*Based on the responses of scientists from CIFA, Bhubaneswar and CIFRI, Barrackpore, and from aquaculturists contacted during the project.

capital-intensive activity, requiring high technical expertise, considerable finance and infrastructural facilities, and is mostly done by private or government agencies. The rate at which these operations are adopted by local farmers and their impact on aquaculture productivity and returns are very high due to high market demand and profits and the need for heavy investment. Hatchery production of spawn in the country is however confined to carps only. There are over 430 eco-hatcheries in the country, both under private and public sector. These satisfy the seed demand of freshwater aquaculture and able to replace the natural riverine spawn collection since last three decades. Further, 35 freshwater prawn (*Macrobrachium rosenbergii*) hatcheries are established mainly in the state of Andhra Pradesh, Tamil Nadu, and Kerala producing over 200 million of postlarvae. However, the country is yet to establish any commercial hatchery for catfishes in spite of the fact that the technology of seed production has already perfected.

The second activity is production of fry from spawn. This activity is generally conducted in small ponds, by private or government agencies. It requires only low levels of investment and carries a moderate risk. However, it requires high technical expertise and sophisticated infrastructure. The adoption rate and impact of this activity is high due to high market demand for fry. The present production level of carp fry in the country is to the tune of 18,500 million. The states of West Bengal and Assam are producing the bulk.

The last activity is the raising of stocking material for grow out that is, fingerlings. As is the case with other seed production activities, this activity is performed by either private or government agencies, in small ponds, with moderate investments. The low availability of ponds for this activity and the low benefit to cost ratio associated with it are two major constraints that result in only moderate adoption of the activity. But, the high demand for carp fingerlings for aquaculture and culture-based fisheries leads to high impact.

Grow-out

Carp polyculture is conducted at three levels. The first is a low input or fertilizer-based system, practiced mostly in small community ponds, with multiple uses and open access, which requires only low levels of investment. The level of adoption and impact are also very low due to the fact that mostly such aquaculture practice is in community village ponds with multiple uses. These are utilised as common pool resources and it is difficult to adopt all cultural practices recommended in the technology. Further, privatization of aquaculture activity in general and the returns from it in particular is constrained by management and property regimes for these water bodies. At the second level the aquaculture system is a medium input or fertilizer- and feed-based system. This system is prevalent in medium-sized to large-sized private ponds with moderate-to-high investments. The levels of adoption and impact are high, despite problems

TABLE 5 Adoption of Brackishwater Aquaculture Practices: A Cross-Case Analysis

Aquaculture system	Characteristics	Level of adoption	Constraint(s)	Extension support
Shrimp farming				
High-tech corporate farming	Large holdings; high investment and risk taking capabilities; high production and profit; direct access to market	Over-use of practices	Social and ecological disturbances	Do not prefer
Semi-intensive and improved traditional	Medium holdings; medium investment and risk taking capabilities	High	Scarcity of seed and feed	Benefited most
Small subsistence including traditional marine aquaculture	Low investment and production; open access; easily managed; different scales of production; institutional	Low Low	Financial Lack of laws for use of open waters	Often bypassed
Post harvest system				
Factory processing	Standard practices and international laws; regulations; direct access to export	High	Financial	Mostly benefited
Small-scale processing	Unorganized, low investment capabilities	Low	Financial; inadequate infrastructure	Inadequate

Source: Srinath (2000).

of scarcity of quality input, limited access to infrastructures and low remuneration. Most of the commercial farms of the country fall under this category. The last system prevalent in carp polyculture is a high input or intensive feed and aeration-based system. This aquacultural practice is generally followed in medium-sized private ponds with high investments by agencies with risk-bearing ability. These agencies generally use the inputs higher than recommended levels, therefore, the adoption level is very high. It leads to high risk, low ecological sustainability, and low benefit:cost ratios. The impact in this case is moderate.

Brackishwater

The most important brackishwater aquaculture operation is shrimp culture. It is also practiced at three scales, namely, subsistence-oriented traditional farming by small and marginal farmers, semi-intensive farming in the small-scale sector, and high tech, intensive farming by corporate bodies (Srinath, 2000). As has been discussed, the country produces 115, 320 t of shrimp from about 152,000 hectare(s) water area. A lion's share of the total production comes from Andhra (51%) followed by West Bengal (25%) and Orissa (9%).

The experiences of adoption of shrimp culture systems are summarized in Table 5. The high-tech farming operations are guided by the objectives of immediate profits and short-term gains rather than the sustainability of the system. High tech farming relies mainly on imported technological inputs. The publicly funded extension system that relies on local resources, with emphasis on long-term gains and sustainable systems, rarely finds a place in this sector. The farmers operating big- or medium-scale farms under paddy-cum-shrimp farming systems generally practice selective farming of a single species, as well as supplementary stocking and feeding. These farmers, with their information-seeking tendencies, try to avail themselves of technical inputs, and most of the extension and development opportunities, as a result all the developmental efforts are diverted towards them. But, the scarcity of hatchery seeds, social resistance to wild seed collection, faulty use of farming practices and improper investment decisions limit their output—often resulting in economic losses. Small and marginal holdings often face resource constraints and have less opportunity for development.

ECONOMICS OF DIFFERENT PROCESSES

Freshwater

Seed Production

The process of fish seed production has three stages—namely, spawn, fry, and fingerlings. The estimated costs, returns and profits associated with

TABLE 6 Economics of Carp Seed Production (per ha)

Item	Nursery (INR)	Rearing (INR)
Fixed cost	5,000	15,000
Lease value (per crop for nursery and per/year for rearing)		
Variable cost		
Pond preparation		
Predatory and weed fish clearance	7,500	7,500
Insect control	1,000	
Fertilizer	7,500	4,000
Seed (Spawn, 3,000,000), fry 0.2 million	15,000	12,000
Supplementary feed	4,500	24,000
Labour charges	5,000	12,000
Miscellaneous	2,000	3,000
Total cost	47,500	79,500
Returns (Survival rate 40%)	72,000	
Returns (Survival rate 75%)		105,000
Profits	24,500	25,500

Source: Katiha et al. (2003).

raising fry from spawn and with growing fry to fingerling stage are presented in Table 6. In the case of raising fry from spawn, 3–4 crops may be produced in a year, leading to an output of 3.6 to 4.8 million fry. The major components of the operating costs are the seed and the lease costs. The benefit:cost ratio has been calculated as 1.52 for nursery management. At the stage of rearing fry to fingerling, the costs of feed, the lease and seed are the major costs. The average number of fingerlings produced is 0.15 million per hectare(s) and the benefit:cost ratio has been calculated at 1.32.

Grow-out

The cost structure, returns and benefit:cost ratios for different aquacultural systems are presented in Table 7. The cost constituents were the annual cost of leasing the water body, the costs of organic manure and inorganic fertiliser, seed, feed, management, and harvesting. The specific costs related to particular systems included expenses on birds/animals in integrated fish culture, the cost of paddy cultivation in paddy-cum-fish culture, the construction of pens in pen culture, etc. Feed was the most important cost component, accounting for more than 50% of the total cost. The lease value varied according to the fertility, and the property and management regimes of the water body. The cost of inputs fluctuated according to the required intensity of their use across different systems. The greatest cost was for high-input carp culture (INR 0.31 million), primarily due to high feed costs. The lowest cost was for low-input carp polyculture (INR 41 925), which lacks major inputs. The net profit per hectare(s) ranged between INR 16 462 for paddy-cum-fish culture to INR 0.14 million for prawn culture. The benefit:cost ratio was greatest for prawn culture

TABLE 7 Costs and Returns for Different Freshwater Aquaculture Grow-out Systems (INR/ha)

	Carp Polyculture			Sewage fed fish culture			Integrated							
	Low input/ fertilizer-base	Medium input/ fertilizer and feed based	High input/ intensive feed and aeration base	Without additional feed	With additional feed	Weed-based fish culture	Duck	Poultry	Pig	Paddy	Pen fish culture	Air-breathing fish culture	Prawn culture	Carp and prawn culture
Costs														
Lease value/year	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	5000	2000	10 000	10 000	10 000
Pond preparation	7500	7500	7500	7500	7500	7500	7500	7500	7500	2000	7500	7500	7500	7500
Fertilizers and lime	10 000	7500	7500	2500	2500	2500	2500	2500	2500	2500	7500	7500	7500	7500
Fingerlings (Seed)	3500	7000	20 000	7000	7000	3500	3500	3500	3500	3500	7000	20 000	30 000	15 000
Birds/animals							3600	4000	4500					
Paddy										7500				
Pen											30 000			
Feed (birds/ animals)							10 000	50 000	7500					
Fish feed		60 000	200 000		30 000						20 000	80 000	60 000	50 000
Sewage cost				7500	7500									
Labour (management, weed collection harvesting)	5000	15 000	30 000	10 000	15 000	20 000	15 000	15 000	15 000	15 000	15 000	30 000	30 000	15 000
Miscellaneous	3000	5000	10 000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Interest	2925	8400	21 375	3712.5	6337.5	3637.5	4282.5	7312.5	4162.5	3037.5	7050	12 000	11 250	8250
Total cost	41 925	120 400	306 375	53 212.5	90 837.5	52 137.5	61 382.5	10 4812.5	59 662.5	43 537.5	101 050	172 000	161 250	118 250
Fish yield (t)	2.5	6	12.5	3	5	3	3	3	3	1	4	4	1.5	3
Other							Meat 0.2 t Eggs 8000	Meat 0.5 t Eggs 28 000	Meat 1.6 t	5 t				0.5 t
Returns														
Fish/prawn	75 000	180 000	375 000	90000	150 000	90 000	90 000	90 000	90 000	30 000	120 000	240 000	300 000	90 000
Others							20 000	58 000	6400	30 000				100 000
Gross returns	75 000	180 000	375 000	90000	150 000	90 000	110 000	148 000	96 400	60 000	120 000	240 000	300 000	190 000
Profits	33 075	59 600	68 625	36787.5	59 162.5	37 862.5	48 617.5	43 187.5	36 737.5	16 462.5	18 950	68 000	138 750	71 750
B:C ratio	1.79	1.50	1.22	1.69	1.65	1.73	1.79	1.41	1.62	1.38	1.19	1.40	1.86	1.61

Source: Katiha et al. (2003).

(1.86). For the other systems, the benefit:cost ratio ranged from 1.22 for high-input carp culture to 1.79 for low-input carp polyculture and duck-cum-fish culture.

Brackishwater

Shrimp Production

In the early 1990s, high profitability and trade liberalization policies triggered a spurt in the growth of semi-intensive shrimp farming in India. But this growth has not been subjected to the rigorous financial and economic analyses, which would have enabled the estimation of the associated costs and benefits and the formulation of sustainable policies for further development. The studies on cost and returns for shrimp production that were done were scanty and conducted at the micro-level, using small samples from scattered locations. Despite this, the evidence presented in these studies, provides some useful insights into social and sustainability issues (Jayraman & Selvaraj, 2000). Table 8 presents some of the available

TABLE 8 Economics of Shrimp Farming in India

References	Yield (t/ha/crop)	Total income (INR'000)	Total cost (INR'000)	Net income (INR'000)
Viswakumar (1992)				
Supplementary feeding	0.30	66.00	36.00	30.00
Pellet feeding	1.00	220.00	130.00	90.00
Semi-intensive	3.90	691.00	497.00	194.00
Usha Rani et al. (1993)				
Small farms	0.95	113.00	88.00	25.00
Large farms	1.23	136.00	85.00	51.00
All farms	1.16	134.00	87.00	47.00
Jayaraman et al. (1993)				
Tiger shrimp	1.00	325.00	141.00	184.00
White shrimp	1.00	250.00	121.00	129.00
Krishnan et al. (1995)				
Extensive	1.00	200.00	27.00	173.00
Improved extensive	2.00	400.00	141.00	259.00
Semi-intensive	4.00	800.00	340.00	460.00
Bhatta (1999)				
Goa	1.419	363.20	67.85	295.35
Kundapur	1.088	164.39	29.30	135.09
Saju et al. (1999)				
P. indicus (Stocking density)				
50,000/ha	0.79	196.75	92.34	104.41
50,000–60,000/ha	0.99–1.00	247.75	116.47	131.28
above 60,000/ha	1.22	305.00	121.52	183.48
P. monodon (Stocking density)				
30,000/ha	0.973	196.75	92.34	104.41
30,001 to 40, 000/ha	1.14	247.75	116.47	104.28
>40,000/ha	1.335	305.00	121.52	183.48

empirical evidence relating to the economics of shrimp culture under different systems of production and management.

Viswakumar (1992) found that, under extensive systems with supplementary feeding, shrimp farming in Andhra Pradesh yielded an annual net return of INR 30,000/hectare(s), while under improved extensive and semi-intensive systems of production the returns were estimated to be INR 90,000 and INR 194,000, respectively. Usha Rani et al. (1993) reported higher profitability on large farms than on small farms. In another case study of improved shrimp species in an extensive system of farming, Jayaraman et al. (1993) reported an annual net farm income in the range of INR 129,000 to INR 184,000 per hectare(s). (It should be noted that the area in which the Jayaraman et al. study was undertake did not suffer from the pervasive but mysterious disease outbreaks reported elsewhere, and hence the farmers were able to carry on shrimp farming profitably.) The studies by Krishnan et al. (1995) reported much higher profitability of shrimp farming compared with those by Viswakumar (1992), and showed that the semi-intensive system of shrimp farming retained its superiority over the extensive system.

With semi-intensive farming, with its high profits and ability to deliver three crops a year, the entrepreneur could recoup his investment in a couple of years. However, although semi-intensive shrimp farming is highly profitable, overstocking and disease problems make it risky. Many companies raised equity for shrimp-farming businesses on the open market, and there was a time when shares of such companies were considered attractive. However, both shrimp-farming and the share market have suffered serious setbacks in recent years and, consequently, the industry is now considered highly volatile. It is now generally agreed that, if an outbreak of disease is likely, the best and safest system is the less risky but adequately profitable improved extensive farming. The findings of Bhatta (1999) and Saju et al. (1999) were similar to those discussed previously.

Swamidas and Satyanarayana (2000) estimated the input-output ratio for different brackishwater shrimp culture operations on different sized farms across various coastal states. The study found variation across the states. In Andhra Pradesh, the average input-output ratio under traditional systems demonstrated greater productivity than that in other states (Table 9). The semi-intensive system in West Bengal had an edge over others, with an input output ratio of 1:1.34.

There is little variation in input-output ratios across different categories of holdings. In general, under traditional systems of farming, medium-sized farms were more efficient; under semi-intensive systems, large farms were marginally better. A comparison of input-output ratios in traditional farming systems across states revealed that, in West Bengal, Gujarat, and Andhra Pradesh, small farms have an edge over others, while in Kerala medium

TABLE 9 Input-Output Ratios from Different Systems of Brackishwater Aquaculture

	Traditional method				Semi-intensive method			
State	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*

(Swamidas & Satyanarayana, 2000).

farms proved better. Under semi-intensive systems, large farms in West Bengal and Kerala and small farms in Gujarat and Andhra Pradesh showed superior performance. On the whole, the traditional method performed better than the semi-intensive. This was contrary to earlier findings of profitability, but may be explained by the fact that higher investment was greater in semi-intensive systems than in traditional systems.

RETURNS TO INPUTS FOR DIFFERENT FRESHWATER AQUACULTURAL SYSTEMS

The returns to factors of production are computed as per their share in cost. The net returns and the proportions of the gross return attributed to the various inputs for different aquacultural systems are presented in Table 10. Inputs were broadly divided into two groups—capital (including fixed and variable) and labour. The systems examined were carp polyculture (three levels), integrated fish farming, air-breathing fish culture, prawn and carp, prawn culture, and pen culture systems. The per hectare(s) net returns for carp polyculture varied from INR 33,075 (low input) to INR 68,625 (high input). In comparison, sewage fed carp culture with additional feed delivered a net return of INR 59,163. For systems of integrated fish farming, per hectare(s) net returns ranged from INR 16,463 (for paddy-cum-fish culture) to INR 48,168 for (duck-cum-fish culture). Of all the systems, prawn culture delivered the highest per hectare(s) net returns (INR 138,750), followed by carp and prawn culture (INR 71,750). Net returns were generally higher for systems with higher investments. Net return as a percentage of gross return was highest for prawn culture (46.25%), followed by duck-cum-fish culture (44.20%) and low input carp culture (44.10%). It was lowest for pen culture (15.79%). In contrast to the findings for net returns, net return as a proportion of gross return was lower for systems with high investment.

TABLE 10 The Net Returns and Returns to Inputs for Different Aquacultural Systems

Item	Carp Polyculture			Sewage fed			Integrated							
	Low input	Medium input	High input	Without feed	With feed	Weed-based	Duck	Poultry	Pig	Paddy	Pen culture	Air-breathing	Prawn culture	Carp-prawn culture
Net returns (INR/ha)	33,075	59,600	68,625	36,788	59,163	37,863	48,618	43,188	36,738	16,463	18,950	68,000	138,750	71,750
Net returns (% of gross returns)	44.10	33.11	18.30	40.88	39.44	42.07	44.20	29.18	38.11	27.44	15.79	28.33	46.25	37.76
Fixed inputs (%)	17.23	10.22	8.37	15.24	10.89	15.15	12.98	11.70	14.69	13.40	7.54	9.17	7.08	9.61
Variable inputs (%)	32.00	48.33	65.33	32.78	39.67	20.56	29.18	48.99	31.64	34.17	64.17	50.00	36.67	44.74
Capital (%)	49.23	58.56	73.70	48.01	50.56	35.71	42.17	60.68	46.33	47.56	71.71	59.17	43.75	54.34
Labour (%)	6.67	8.33	8.00	11.11	10.00	22.22	13.64	10.14	15.56	25.00	12.50	12.50	10.00	7.89

Based on figures provided in Table 9.

Depicting the nature of the technology, the percentage of gross return accruing to capital ranged from 35.71% for weed-based fish culture to 73.70% for high input carp polyculture. Within the category of 'capital', variable inputs earned a much higher share of gross returns (20.56–65.33%) than did fixed inputs (7.08–17.23%). The share of labor varied between 6.67% for low input carp polyculture to 22.22% in the case of weed-based fish culture and 25.00% in the case of paddy-cum-fish culture.

This study is the first to analyze the returns to various inputs for freshwater aquacultural operations in India. The study revealed that, with the exceptions of high input carp polyculture, prawn culture, pen culture and air-breathing culture, investment per hectare(s) was low, and the major share of inputs are variable inputs. The study also revealed that the return to labor as a proportion of gross return was very low. Most of the labor was associated with harvesting.

INVESTMENT NEEDS FOR DOMINANT FRESHWATER AQUACULTURAL SYSTEMS

The microlevel investment needs for various systems of aquaculture, as represented by the total annual costs per hectare(s), were provided in

TABLE 11 Investment Needs of the Dominant Freshwater Aquaculture Systems (in million INR)

States	Intensive carp culture	Semi-intensive carp culture	Extensive carp culture	Total
Andhra Pradesh	612.75	1,324.40	293.48	2,230.63
Assam		144.48	12.58	157.06
Bihar		481.60	125.78	607.38
Goa			6.29	6.29
Gujarat		240.80	83.85	324.65
Haryana	153.19	48.16		201.35
Himachal Pradesh		3.61	0.84	4.45
Jammu & Kashmir		48.16	20.96	69.12
Karnataka		120.40	586.95	707.35
Kerala		24.08		24.08
Madhya Pradesh		240.80	209.63	450.43
Maharastra		120.40	83.85	204.25
Orissa		481.60	125.78	607.38
Punjab	153.19	24.08		177.27
Rajasthan		180.60	209.63	390.23
Tamil Nadu		240.80	335.40	576.20
Uttar Pradesh		1,083.60		1,083.60
West Bengal	612.75	2,408.00		3,020.75
North-east		120.40	167.70	288.10
Other		6.02		6.02
Total	1,531.88	7,341.99	2262.69	11,136.56
% of total	13.76	65.92	20.32	100.00

(Modified from Katiha & Bhatta (2002) and Katiha et al. (2003)).

Table 7. It can be seen that costs were highest for high-input carp polyculture (INR 0.3 million), followed by air-breathing fish culture (INR 0.17 million) and prawn culture (INR 0.16 million). The investment needs were lowest for low input carp polyculture (INR 0.04 million), followed by paddy-cum-fish culture (INR 0.043 million).

The levels of investment that would be needed to exploit the potential areas for intensive, semi-intensive and extensive carp culture in various states of India were estimated and are presented in Table 11. In total, investment of INR 113.37 billion would be required—66% of that in semi-intensive carp culture, 20% in extensive carp culture, and 14% in intensive carp culture. The states with the greatest potential for investment would be West Bengal, Andhra Pradesh, and Uttar Pradesh. The states with the greatest potential for investment in intensive carp culture would be Andhra Pradesh, Haryana, Punjab, and West Bengal. The potential for investment in semi-intensive and extensive aquacultural system would be spread over most states of India.

FUTURE PROSPECTS AND REQUIREMENTS

Freshwater

As mentioned above, despite immense efforts to expand the inland aquaculture in India, only one third of the potential freshwater area under ponds/tanks has been brought under scientific fish culture. Tapping the production potential would require effective and intensive adoption of available technologies, the transfer of technical know-how and the provision of material inputs. Flexibility in both areas of operation and scales of investments, compatibility of freshwater aquaculture practices with other farming systems and a high potential for eco-restoration have provided a congenial environment for the establishment of freshwater aquaculture as a viable industry. Because of its potential and its impressive annual growth rate of over 6%, the government of India is encouraging aquaculture development. As part of the national freshwater aquaculture development plan, "Operation Aqua-Gold" is looking to increase the area dedicated to aquaculture to 1.2 million hectare(s). With an average productivity of 2762 kg/hectare(s)/year, this will result in an annual yield of 3.3 m t of fish, 1.65 times the current level of freshwater aquacultural production (Gopakumar et al., 1999). Strategies to increase the area (by 45.2%) and productivity (by 50.9%) in order to reach the target output have been developed. These strategies incorporate both horizontal and vertical expansion and take into account the potential and problems of the different states.

The projected water spread area of aquaculture ponds and tanks under different production levels should reach 1.2 m hectare(s) (Table 12) in

TABLE 12 Projected Water Spread under Different Production Levels ('000 ha)

	Projected water spread under different production levels							
State	8 t/ha/year	6 t/ha/year	5 t/ha/year	3 t/ha/year	2 t/ha/year	1 t/ha/year	0.5 t/ha/year	Total
Andhra Pradesh	20		50.0	60.0		70.0		200.0
Assam			6.0	6.0	3.0			15.0
Bihar			10.0	30.0	30.0			70.0
Goa					1.5			1.5
Gujarat				20.0	20.0			40.0
Haryana	2.0	3.0	4.0					9.0
Himachal Pradesh				0.3	0.2			0.5
Jammu & Kashmir				4.0	5.0			9.0
Karnataka				10.0	20.0	50.0	70.0	150.0
Kerala			1.0	1.0				2.0
Madhya Pradesh				20.0	50.0			70.0
Maharastra				10.0	10.0	10.0		30.0
Orissa			10.0	30.0	30.0			70.0
Punjab	2.0	3.0	2.0					7.0
Rajasthan			5.0	10.0		20.0	30.0	65.0
Tamil Nadu				20.0	20.0	60.0		100.0
Uttar Pradesh			10.0	80.0				90.0
West Bengal	20.0		100.0	100.0				220.0
North-east				10.0	20.0	20.0		50.0
Other				0.5				0.5
Total	44.0	6.0	198.0	411.8	209.7	230.0	100.0	1,199.5
% of total	3.67	0.50	16.51	34.33	17.48	19.17	8.34	100.00

Source: Modified Gopakumar et al. (1999), Katiha & Bhatta (2002).

order to achieve the targeted fish production of 3.3 m t. For this purpose the aquaculture activity needs to be cover 0.37 m hectare(s) additional water area. The percentage share of area under different production levels in total projected area would be 3.67% for 8 t/hectare(s)/year, 0.50% for 6 t/hectare(s)/year, 16.51% for 5 t/hectare(s)/year, 34.33% for 3 t/hectare(s)/year, 17.48% for 2 t/hectare(s)/year, 19.17% for 1 t/hectare(s)/year, and 8.34% for 0.5 t/hectare(s)/year. It indicates that approximately 80% of the area will be under production level of 3 t/hectare(s)/year or less. It seems to be a viable option.

In addition to more land dedicated to ponds and tanks, an increase in fish production levels would require an increase in seed and feed. The requirements are detailed in Table 13. It should be noted that, currently, the 18,500 million fry produced each year (Jana & Jena, 2004) supply both the culture and the culture-based fisheries; to reach the target production levels, almost the same amount of fry would be needed to supply just the culture fisheries alone (Katiha, 1999). The projected seed requirement could be supplied by new hatcheries in seed-deficit states and/or imported from seed-surplus states. The projected area required for brood-stock management and seed rearing is 79,950 hectare(s), about 6.7% of the projected

TABLE 13 Present and Projected Area, Fish Production and Input Requirement for Freshwater Aquaculture in India

State	Total area (m ha)	Projected water area coverage (m ha)	Present production (m t)	Projected fish production (m t)	Projected yield (t/ha/yr)	Present seed production (Million fry)	Projected seed production (Million fry)	Projected feed requirement (000 t)
Andhra Pradesh	0.517	0.2	0.18	0.66	3.3	709	3020	1170
Assam	0.023	0.015	0.03	0.054	3.6	2547.54	222	93
Bihar	0.095	0.069	0.13	0.2	2.9	332.2	860	295
Goa	0.003	0.002	0.001	0.003	1.5	0.03	15	3
Gujarat	0.071	0.04	0.04	0.1	2.5	191.17	440	130
Haryana	0.01	0.009	0.026	0.054	6	200.73	212	116
Himachal Pradesh	0.001	0.001	0.002	0.001	1	23.1	5.6	1.75
Jammu & Kashmir	0.017	0.009	0.005	0.022	2.44	12.6	98	28
Karnataka	0.414	0.15	0.07	0.155	1.03	164.34	1240	85
Kerala	0.003	0.002	0.005	0.008	4	20.26	32	14.5
Madhya Pradesh	0.119	0.07	0.07	0.16	2.29	564.34	740	190
Maharastra	0.05	0.03	0.04	0.06	2	293	320	65
Orissa	0.114	0.07	0.093	0.2	2.86	186.69	860	295
Punjab	0.007	0.007	0.026	0.044	6.29	44	172	96
Rajasthan	0.18	0.065	0.005	0.09	1.38	175	600	95
Tamil Nadu	0.224	0.1	0.08	0.16	1.6	467.43	1040	130
Uttar Pradesh	0.162	0.089	0.1	0.29	3.26	546.62	1160	460
West Bengal	0.276	0.22	0.58	0.96	4.36	8180	3800	1850
North-eastern region	0.072	0.05	0.028	0.09	1.8	334.78	520	85
Other	0.001	0.001	0.001	0.001	1	14.52	6	2.25
Total	2.358	1.199	1.512	3.312	2.76	15,007.35	15,362.6	5,204.5

(Modified Gopakumar et al. (1999)).

culture area in the country. It would need to be prepared for the purpose of providing the quality seed needed to increase aquacultural productivity.

Freshwater aquaculture is largely based on organic fertilization, but to increase productivity and fully exploit the potential of aquacultural waters, intensive use of supplementary feed would be necessary. An estimated 5.2 m t of fish feed would be required for this purpose. The feed formulations could be traditional mixtures of rice/wheat bran and groundnut/mustard oil cake. The enrichment of these mixtures with at least 30% of protein is necessary for high production systems (6–8 t/hectare(s)/yr).

Besides, these requirements special emphasis is needed on the institutional settings in terms of multiple uses, lease policy and ownership pattern, and infrastructural support for research and development, marketing, and value addition.

Brackishwater

Potential brackish water aquaculture area is widespread along maritime states of India on both the east and west coasts. This area has increased consistently from 1991 till 1996 the year of white spot viral disease outbreak. After that sustainability and environmental issues have got the prime emphasis. As a result area covered by shrimp farms in the coastal regulatory zone (CRZ) along the entire coastline has remained almost the same due to ban imposed by the Supreme Court of India in December, 1996 for construction of new farms in the CRZ. The ban permitted shrimp farming only for new farms following traditional cultural practices (extensive/modified extensive) under monitoring and supervision of Aquaculture Authority of India. After 2001, shrimp farming has gained momentum adopting modified extensive system. The major problems faced by this sector are availability of quality seed and cost-effective feed. In India large scale brackishwater farming is limited to shrimp. There exists greater scope for other fish and crab species.

Coastal zone is being used for various other activities such as agriculture salt pan, tourism, etc. Construction of large farms may affect accessibility of coastal area to other activities and leading to social conflicts. Therefore, farms of large corporate needs to be split into smaller ones.

The brackishwater sector has greater employment opportunities in coastal areas. The shrimp farming requires 600 mandays/crop/hectare(s) as compared to 180 mandays/crop/hectare(s) (Rao & Ravichandran, 2001). Moreover, in contrast to paddy cultivation, where only one crop is feasible annually, shrimp farmers can take two crops and annual labour earnings are INR 12,000 as compared to INR 7,500 in agriculture. The skilled manpower requirement for next two decades is estimated at 0.2–0.25 million.

RECOMMENDATIONS FOR AN ACTION PLAN

It seems apparent that strategies for increasing fish production from freshwater aquaculture should be directed towards horizontal and vertical growth of the industry. The National Aquacultural Development Plan also envisages expansion, intensification, and diversification of culture systems (Gopakumar et al., 1999). Subject to the suitability of culture practices for, and the productivity of, various locations, the following components hold the key to the success of these strategies.

Expansion of the area under freshwater aquaculture from 0.83 to 1.2 million hectare(s).

Intensification of aquaculture practices to harness the full production potential, without in any way affecting the soil-water ecosystem. This could increase double fish productivity.

Amendment of leasing policy to increase lease duration to over 10 years and to vary rents with productivity and the level of multiple use.

Introduction of integrated culture systems of carps, catfishes, and prawns with agriculture, animal husbandry, horticulture, and forestry. Support for the breeding and culture of ornamental fishes with potential for meeting domestic needs as well as earning foreign currency.

Decentralization of fish seed production with nursery and rearing space at block levels, and establishment of hatcheries for carps, catfishes, and freshwater prawns to ensure seed supply.

Development of fish feed based on locally available low cost plant- and animal-based materials, particularly in case of brackishwater aquaculture and training and education of farmers and entrepreneurs in relation to feed processing and dispensing. Encouragement of fisher cooperatives to play an active role in the supply of inputs, particularly the fish seed and feed.

Budgetary support for investment in research, infrastructure development, training and extension in all aspects of freshwater aquaculture.

The establishment of an adequate and reliable database, using standardized nomenclature and classification for various relevant parameters, e.g., size of pond, fish seed grades, groups of fish catch, etc. Development of the database could be by a committee of experts. The data should be collected over time and space on a continuous basis.

Development of infrastructure for both production and postharvest activities, including fish and shrimp hatcheries, aquaculture estates, feed mills and ancillary industries for the manufacture of aerators and feed dispensers, and formulations against fish diseases.

Strengthening of marketing structures, including storage facilities, ice plants, cold chains, roads, and transportation in identified aquaculture areas.

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