8.4 Role of freshwater fish seed supply in rural aquaculture

Sunil N. Siriwardena
Institute of Aquaculture, University of Stirling, Stirling FK9 4LA
United Kingdom
Sns1@stir.ac.uk; Sunil.siriwardena@hotmail.com

Siriwardena, S. N. 2007. Role of freshwater fish seed supply in rural aquaculture, pp. 563–579. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. *FAO Fisheries Technical Paper.* No. 501. Rome, FAO. 2007. 628p.

ABSTRACT

As a critical basic input for successful aquaculture, fish seed supply plays an important role in providing a food and an income source to contribute to the Millennium Development Goals. It is expected that this important role will continue to meet the projected aquaculture production to 2020. Therefore, this review focusses on the role of fish seed supply in providing food and livelihoods in the rural sector, demand of fish seed supply and constraints in meeting the demand and some of the interventions in fish seed supply for rural aquaculture.

Reliable statistics do not exist concerning rural households involved in fish seed supply. Nevertheless, its role as a livelihood is reflected in the number of rural households involved in small-scale freshwater aquaculture. Decentralization of fish seed production has offered small farmer-operated hatcheries and fry nursing in rural areas significant income levels for rural households. Break-up of production cycle into breeding and nursing is partly triggered by limited availability of land and the involved cost of accommodating nursery facilities in the hatchery premises. Fish seed production and supply also play a critical role in stock enhancement and culture-based fisheries of natural water bodies. Among the species, carps maintain leading rank in terms of quantity in fish seed supply. Examples exist of small indigenous species with high nutritive value which makes an important dietary component in rural households and that seed production of such fish species for rural aquaculture can make an important nutritional contribution.

In recent years, there has been a general trend in rural aquaculture shifting from extensive traditional fish seed supply practices to more intensely managed systems using new technologies. If the pond-based fish seed production continues, the increase in land area requirement is considerable to meet the projected aquaculture production to 2020. To ease the pressure on land in the expansion of fish seed and aquaculture production, optimal use of paddy fields for rice-fish culture has been suggested as an alternate to pond culture practices. This includes stocking brood fish and encouraging the spawning and incubation of eggs in rice fields and direct stocking of fertilized eggs or fry. Decentralized fish seed production mechanisms such as local and small-scale household hatcheries, hapa nursing and trading networks and on-farm breeding have proven to be good catalysts for fish seed supply for rural aquaculture. Therefore, it is essential to provide continued institutional support, particularly in areas that lack good infrastructure, to enable rural poor to enter into 'spawning' and 'nursing' networks. Fish seed supply is an essential component of a value chain and its growth as an agribusiness will largely depend on private farmers. Governments have an important role in setting the right framework conditions, building the required infrastructure and capacity and promoting fair local market.

INTRODUCTION

Food security, rural development and poverty alleviation are closely linked. Aquatic products represent an important component of the food of the Asian rural sector and the various types of aquaculture form an important component within farming systems development that can contribute to the alleviation of food insecurity, malnutrition and poverty through the provision of food of high nutritional value, income and employment generation. Specific examples of aquaculture activities that have positive impacts on the rural poor include breeding of fish, fry nursing and the development of nursing and trading networks, integration of fish farming with rice crops in floodplains, raising fry and fingerlings in enclosed or semi-enclosed water bodies for both sale and home consumption and sustaining and restoring aquatic biodiversity through appropriate management methods.

Availability of technology, demand for fish seed and low cost breeding and seed production systems offer opportunities for rural poor people to enter into the fish seed supply chain. With increasing concern on decentralizing fish seed supply, small farmers in rural areas have the opportunities to participate in fish seed supply and even to produce their own fish seed without conventional hatcheries (Edwards, 2000). Farmers in the highland valleys of Viet Nam and Lao PDR have traditionally spawned fish (e.g. common carp in paddy fields); such systems are also common in more developed areas in Indonesia and China. Small carps and tilapias can be bred locally in ponds or simple net hapas, which not only reduces costs and improve quality by avoiding long distance transportation, but also provides employment and income. Such systems have been developed in Bangladesh, Cambodia and Lao PDR where they have had a powerful multiplier effect (Edwards, 2000).

In 2003, total fish production reached 83.73 million tonnes of which freshwater fish culture production was 22.14 million tonnes (FAO, 2005), representing about 26.44 percent of the total fisheries production in Asia. Aquaculture is the fastest growing sub-sector of agriculture; Asia is the largest aquaculture producer in the world. In a short period of 43 years, freshwater aquaculture production increased from 0.721 million tonnes in 1960 to 22.14 million tonnes in 2003, a growth of 2 971 percent. This is a very significant contribution to Asian food fish supply. This impressive growth of freshwater aquaculture production implicates the important role played by fish seed production and supply. It is expected that this contribution will continue to meet the projected aquaculture production target to 2020. Therefore, this review focusses on the following: (i) role of fish seed supply in providing food and livelihoods in the rural sector, (ii) the projected demand of fish seed supply and constraints in meeting the demand and (iii) some interventions in fish seed supply for rural aquaculture.

ROLE OF FRESHWATER FISH SEED SUPPLY IN RURAL AQUACULTURE

Contribution of rural aquaculture to Millennium Development Goals (MGDs)

As a critical basic input for successful aquaculture production, fish seed supply plays an important role in providing a food and an income source. As a food producing sector, the most immediately apparent contribution that aquaculture can make to the achievement of the Millenium Development Goals (MDG) is as a contributor to the eradication of poverty and hunger, outlined in Goal One of the Eight MDGsof the United Nations Millenium Declaration adopted by 189 nations in 2000. In this context, fish seed supply for rural aquaculture may relieve hunger directly through the provision of food, or indirectly by providing a source of employment and income generation for food purchase. The alleviation of poverty and hunger go hand in hand and alleviating poverty may, to a certain degree, reduce hunger, as in many cases, hunger arises not as a result of lack of food availability, but rather as a result of lack of access or ability to purchase it.

At the beginning of the new millennium, the number of hungry people in the world stands at 826 million, of which 514 million (62.2 percent) are in Asia (FAO, 2000a). Rural areas in South Asia, housing more than 70 percent of populations, have high concentrations of hungry people. This means that nearly half the South Asian population suffers from malnutrition (Gill *et al.,* 2003). Diets in many rural areas in the region rely on rice as the predominant form of carbohydrate and for a significant amount of protein. This rice diet is deficient in the essential amino acid, lysine and although animal meat protein has higher lysine content than rice it is only about three quarter of the concentration in fish (Garrow and James, 1993). Aquaculture's contribution to improved nutrition lies in the production of a high quality, affordable source of animal protein, particularly for the rural poor. Food fish represent the most important source of animal protein for many developing countries and low income food deficit countries (LIFDCs) including China. In this regard, fish seed supply and the ability of aquaculture to meet the demand are most critical in countries where the population is dependent upon fish.

Clearly aquaculture has the potential to contribute to achieve one of the goals of MDG as a source of high quality food source, rich in essential micronutrients, (b) rural development and poverty alleviation. Aquaculture can also reduce vulnerability of rural households to shocks and seasonal/annual variability through diversification/ income smoothing.

Fish seed supply as a livelihood

Most of the freshwater aquaculture production in the region comes from small-scale operations in the rural areas. Projects in Lao PDR and Cambodia over the past few years demonstrate that a focus on the participation of poor groups in aquaculture can make significant contributions to improve rural livelihoods. Frequently, rural poor will readily enter into aquaculture if the basic constraints of reliable fingerling supply can be overcome (Philips, 2002).

Reliable statistics on rural households involved in fish seed supply is scarce as small-scale and dispersed production data do not appear in official statistics. Nevertheless, its role in aquaculture is reflected in the amount of households involved in small-scale freshwater aquaculture. At the household level, freshwater aquaculture is becoming more important and throughout much of the Mekong basin, particularly in poor and fish deficit areas away from major wild fisheries, a fact not usually captured in official statistics (Phillips, 2002). In Northeast Thailand, for example, 170 000-200 000, or 6.5–7.6 percent of the 2.6 million rural households are involved in small-scale aquaculture. In Lao PDR, although the annual production of 5 000 tonnes seems quite low, 55 200 rural households, representing 8.3 percent of rural households engaged in some form of aquaculture (Phillips, 2002). In China, in 1997, 3.29 million people against 1.53 million, in the rural sector were involved full-time in aquaculture recording a 115 percent increase (Zhiwen, 1999). Mazid (1999) reported that around 73 percent of rural households are involved in polyculture of major Indian and Chinese major carps and exotic species in ponds, the most dominant aquaculture practice in Bangladesh.

In Viet Nam, culture of fish and shrimp in ponds contribute about 30-70 percent to total household income, although the proportion of pond area is smaller than the land area for agriculture (Luu, 1999; FAO, 2000). The majority of farmers in China are engaged in fish farming as their primary source of income. In Indonesia, FAO reported that about 78 percent of farming households cultivate fish in small ponds of less than

500 m^2 and aquaculture is the main source of income for 66 percent of the households that cultivate fish in paddy fields and ponds (FAO, 2000b).

The income structure shows that the average annual gross household income of the Chinese farmers (about US$17 000) is the highest, followed by the Thai farmers (about US$11 000). In China, the average gross incomes of state-owned, collective and co-operative farmers are US$149 135, US$184 963 and US$53 179, respectively, in China. In general, the gross household income of fish farmers is above the national average income in China. The contribution of fish culture to total household income is as high as 80 percent in India and as low as 15 percent in Bangladesh. The contribution of carp farming to total income in India varies considerably between the states. It is only 15 percent in Orissa and 95 percent in Andhra Pradesh.

Decentralized fish seed production which brought fish breeding and fry nursing and trading networks to rural areas provided opportunities for rural households to enter into aquaculture. Small farmer operated hatcheries and fry nursing operators procured seed from government or private hatcheries. Even though some assets are needed to invest in aquaculture production, poor landless people can become involved and benefit from well-targeted aquaculture interventions. For example, in Lao PDR, landless poor people who did not have access to ponds were involved in a successful and sustainable fish nursing network (Lithdamlong, Meusch and Taylor, 2002). Promotion of decentralized fish seed production and networking offers other advantages – income generation in rural areas, better distribution of income, higher rate of survival of fish to fingerling stage, spread of aquaculture-related activities into a wider area of the country and easier access to fingerlings for aquaculture and stock enhancement purposes (De Silva and FungeSmith, 2005). Fry nursing for fingerling production in rural areas is popular (e.g. Lao PDR) because it requires little investment or risk and profits are made quickly (Phillips, 2002). Once fingerlings are produced, they are transferred to adjoining ponds for on-growing. If farmers are close to a market income can be easily generated from raising fish. In Bangladesh, Hossain and Humayon (2001) reported that carp spawning to fry rearing generated higher net returns (TK124 895 = US$1 874.4) than that of fry to fingerling rearing (TK96 660 = US$1 450), respectively. In contrary, fry fingerling rearing showed a higher cost benefit ratio (4.71) than that of spawn to fry rearing and spawn production in India (Katiha, 2001). Nevertheless, both fry nursing and fingerling rearing bring significant income for rural households.

In most Asian countries, backyard hatcheries are common, particularly for the production of Chinese and Indian major carp fry. Backyard hatcheries are generally effective, not capital intensive and are managed by at most, two persons (De Silva and FungeSmith, 2005). In Orissa, India, for example, community-based carp hatcheries are successfully run by village women (Radheyshyam, 2001). These community-based hatcheries enable poor women who do not have pond resources to be engaged in fish-related activities, providing them with additional household income (De Silva and FungeSmith, 2005). Women in rural Southern India engage in carp breeding, fry nursing, carp polyculture, breeding of catfish and freshwater prawns in backyard hatcheries, ornamental fish breeding and culture, culture of *Spirulina* and *Azolla*, net making and mending and feed preparation for carps and prawns (Shaleesha and Stanley, 2000). Women earn a supplementary income from these activities and increase the family income considerably. For example raising carp seed in a pond of 0.1 ha over a period of 15-20 days will provide a net income of US$119 (Shaleesa and Stanley, 2000). Such hatcheries tend to contribute significantly to rural aquaculture development and indirectly, to poverty alleviation in rural communities.

Role of fish seed in stock enhancement culture based-capture fisheries

Fish seed supply plays a critical role in stock enhancement and culture-based fisheries of natural water bodies such as floodplains, lakes and reservoirs and small water bodies. Culture-based fisheries differs from stock enhancement that stocking of small water bodies undertaken on a regular basis; a person or a group of persons and/or an organization will have property rights to the stock (De Silva and FungeSmith, 2005). The objectives of stock enhancement or culture-based fisheries programmes are to increase fish production, provide employment opportunities and enhance the food fish supplies to the population living around natural water bodies. The source of stocks for enhancement may be derived from capture, but more typically are obtained from hatchery operations. In certain countries, e.g. China, the practice of culture-based capture fisheries includes under aquaculture. In Asia, significant stock enhancements of floodplains are restricted to Bangladesh and Myanmar, while stock enhancement of man-made lakes or reservoirs are practiced in many countries (e.g. Bangladesh, India, Indonesia, Myanmar, China, Sri Lanka). Floodplain fisheries in both countries are important not only from a fisheries production viewpoint, but also socio-economically, sustaining the livelihoods of large numbers of rural people (De Silva and FungeSmith, 2005).

However, the floodplain stock enhancement programmes have resulted in an increased number of private hatcheries operated by local entrepreneurs, rather than increased employment of the poor (De Silva and FungeSmith, 2005). Comparing costs and returns in stock enhancement of floodplains and small water bodies under Third and Fourth Fisheries and Oxbow Lake Projects in Bangladesh, Hambrey (2003) reported that overall, costs are likely to be lower and returns higher for smaller closed or near closed water bodies than for the larger floodplain systems. Protection of stocked fish will be easier. Production will be more consistent from year to year. Fishing/harvesting will be undertaken over a smaller area and catch per unit effort is likely to be higher. Management committees will tend to be simple with more convergent interests and correspondingly lower transaction and management costs.

SPECIES DIVERSITY AND FISH SEED DEMAND

Species diversity and trends in freshwater fish seed production

Freshwater omnivorous and herbivorous fish have been important food fish for developing countries in Asia. Of the recorded 75 species in aquaculture production reported to FAO, low value species, i.e. carps and barbs, continue to be the most popular species group in Asia (Table 8.4.1), In terms of quantity nine of the top 10 species, are carps (Table 8.4.2). This indicates the most popular fish species diversity in demand for seed production. The low value species, carps and tilapias together contributes more than 80 percent to the total freshwater fish production (excluding aquatic plants) in most of the leading aquaculture producing countries in Asia (Table 8.4.1). One of the attributing factors to this major share in aquaculture production is fish to be cultured should be lower in the food chain as this will allow rural farmers to use more readily available feeds, and because it is more ecologically efficient.

Silver carp, grass carp, common carp, bighead carp and crucian carp maintains the leading ranks both in terms of quantity and value (Tables 8.4.2 and 8.4.3). Catla, mrigal and black carp lost ranks within first 10 in terms of value of production. Among carps, crucian carp recorded the highest growth both in terms of quantity and value for the eight-year period from 1995 to 2003. Despite the concerns on environmental impacts, Black carp recorded the second highest growth in terms of quantity, mainly due to its economic value.

Common carp is the dominant freshwater species in Indonesia accounting for almost 46.2 percent of total freshwater aquaculture production in 2003 (FAO, 2005). Indonesia is the world's third largest producer of common carp after China and the USSR. Other freshwater species in Indonesia are tilapia, Nile carp, and Java barb. In the Philippines, of total freshwater aquaculture production in 2003, tilapia and other cichlids were the major species accounted for 78 percent, (FAO, 2005). Although

TABLE 8.4.1

Contribution of low value species to total freshwater aquaculture production in leading aquaculture countries in Asia

Country	Species contribution (million tonnes)							
	Carps and other cyprinids		Tilapia and other cichlids		Total* freshwater fish production		Percentage contribution of carps and tilapia to total freshwater production	
Year	1995	2003	1995	2003	1995	2003	1995	2003
China	8.3	13.64	0.355	0.879	9.35	17.04	92.1	85.15
India	1.211	1.882	NR	NR	1.58	2.066	76.6	91.1
Indonesia	0.192	0.255	0.045	0.091	0.28	0.478	84.6	72.4
Philippines	0.003	0.009	0.077	0.12	0.098	0.154	82.0	84.00
Bangladesh	0.198	0.617	NR	NR	0.271	0.756	73.1	82.0
Thailand	0.034	0.06	0.076	0.097	0.193	0.283	57.0	55.5
Viet Nam	NR	NR	NR	NR	0.296	0.548	-	-
Cambodia	0.0078	0.016	0.00023	0.0005	0.0087	0.0178	92.0	92.8
Total					12.07	20.80		
Asia total	10.133	16.798	0.579	1.259	12.545	22.14	85.4	81.6

Source: FAO (2005); *Excluding aquatic plants; NR – Not reported

TABLE 8.4.2

Trends in species contribution to freshwater aquaculture production in quantity (tonnes)

Common name	Species name	Year		Percentage growth	Percentage growth/yr
		1995	2003		
Silver carp	*Hypophthalmichthys molitrix*	2 539 405	3 768 240	48.4	6.05
Grass carp	*Ctenopharyngodon idella*	2 103 875	3 591 492	70.7	8.84
Common carp	*Cyprinus carpio*	1 643 008	3 009 868	83.2	10.4
Bighead carp	*Hypophthalmichthys nobilis*	1 249 910	1 923 740	54	6.75
Crucian carp	*Carassius carassius*	537 555	1 792 501	233.5	29.2
Nile tilapia	*Oreochromis niloticus*	485513 (3.87 %)	1116805 (5.0 %)	130	16.25
Roho	*Labeo rohita*	542 364	713 267	31.5	3.9
Catla	*Catla catla*	447 834	566 051	26.4	3.3
Mrigal carp	*Cirrhinus mrigala*	420 958	514 662	22.26	2.78
Black carp	*Mylopharyngodon piceus*	104 152	270 279	159.5	19.93
Total		**10 074 574 (80 %)**	**17 266 875 (78 %)**		
Freshwater fish nei		1 277 298 (11.25 % of the total production)	3 220 696 (15.72 %)	152.12	19.0
Total		**11 351 872 (90.5 %)**	**20 487 571 (92.5 %)**		
Other species of importance					
Snakehead	*Channa spp.*	558	32 279	5 685	710
Thai silver barb	*Puntius gonionotus*	32 230	56 979	77.0	9.6
Tilapia nei		64 331	120 162	87.0	10.9
White amur bream	*Parabramis pekinensis*	335 034	524 927	56.7	7.1

statistics show that milkfish (*Chanos chanos*) and carps are available, milkfish is not widely cultured in freshwater environments (WorldFish Centre, 2002). Production of milkfish in freshwater environments is decreasing at an average annual rate of 2 percent. Carps, on the other hand, are considered newcomers in the Philippines (WorldFish Centre, 2002). Although the production of carp is not even 1 percent that of tilapia, it expanded at an average annual growth rate of 55 percent during 1993-1997

TABLE 8.4.3
Trends in species contribution to aquaculture production in value (US$ million)

Common name	Species name	Year		Percentage growth	Percentage growth/yr
		1995	2003		
Silver carp	*Hypophthalmichthys molitrix*	2 198.93	3 099.32	41	5.12
Grass carp	*Ctenopharyngodon idella*	1810.1	2 893.28	59.8	7.5
Common carp	*Cyprinus carpio*	1 795.45	2 464.62	37.3	4.66
Bighead carp	*Hypophthalmichthys nobilis*	1 072.63	1 649.13	53.75	6.72
Crucian carp	*Carassius carassius*	491.63	1 256.17	155.5	19.43
Mandarin fish	*Siniperca chuatsi*	371.82	1 229.06	230.55	28.82
Nile tilapia	*Oreochromis niloticus*	549.86	1 104..27	100.8	12.6
Roho	*Labeo rohita*	1 149.92	953.35	-17.1	-2.14
Japanese eel	*Anguilla japonica*	1 285.38	871.66	-32.2	-4.0
White amur bream	*Parabramis pekinensis*	403.12	603.67	49.75	6.2
Total		**11 128.84 (74.7 %)**	**16 124.53 (74 %)**		
Freshwater fish nei		1 459.64 (11.6 %)	3 042.2 (15.87 %)	108.42	13.55
Total		**12 588.5 (84.5 %)**	**19 166.73 (88.0 %)**		
Species lost ranks within first ten					
Catla	*Catla catla*	413.86	544.36	31.5	3.9
Mrigal carp	*Cirrhinus mrigala*	370.17	469.67	26.9	3.36
Black carp	*Mylopharyngodon piceus*	172.0	445.82	159.2	19.9

(Dey, Paraguas and Alam, 2001). It is thought that carp has a tremendous potential for culture in the Philippines.

Nile tilapia, catfish and Thai silver barb are the most popular freshwater species in Thailand contributing around 34.3 percent, 32.0 percent and 17.23 percent, respectively, of total freshwater aquaculture production in 2003 (FAO, 2005). These species have also expanded at average annual rates of 3.5 percent, 13.0 percent and 9.75 percent, respectively, over the period of 1995-2003. During the same period, production of common carp has increased at an average annual rate of 11.62 percent (FAO, 2005). A variety of freshwater organisms has been cultured in Viet Nam. However, the information on species-specific production is scanty (WorldFish Centre, 2002). In most cases only a qualitative indication is provided on the level of culture for each species (Lovatelli, 1997). ICLARM (1998, 2001) reported that carps (common carp, silver carp, grass carp and bighead, rohu and catla), contributed 29 percent of fish production in 1996 in the country. Other important freshwater species are tilapia, catfish and Thai silver barb.

Although high-value freshwater species such as mandarin fish in China and river eel in Indonesia are emerging as freshwater aquaculture species, their occurrence is localized (Table 8.4.4). Common carp, Chinese major carps and tilapia are the most frequently used species in aquaculture providing benefits widely in rural Asia. This trend is more likely to continue in future in the expansion of aquaculture in Asia, although markets dictate demands. Prices of high value fish and crustacean species will increase with expansion of their aquaculture as a result of increase in fish meal prices. Therefore, increase in rural aquaculture production is more likely to be favoured towards low-value species from increased number of countries joining the production process, and an expansion of the culture area, particularly in countries the aquaculture expansion is not constraint with land and water (Delgado *et al.*, 2003). Investment in the efficiency of related rural aquaculture production systems of low value species would put these commodities within the reach of more poor people.

It is worth noting that production and frequency of occurrence of "freshwater fish nei" (freshwater fish not elsewhere included in FAO production statistics), which constitutes a species assemblage, contributes a significant share to the freshwater aquaculture production both in terms of quantity and value (Tables 8.4.2 and 8.4.3). Nevertheless, leading candidate species within the assemblage is not reported. It is high time to revisit this species assemblage for any emerging species for rural aquaculture. The contribution of indigenous species within this assemblage in terms of socio-economics is of particular importance in order to influence policy directions to promote their culture.

Even though the common argument to culturing indigenous species is to minimize potential risks to the biodiversity caused by introduced alien species, some indigenous species are more profitable than exotics and may be readily adopted by rural farmers. For example, *Barbodes* (*Puntius*) in Lao PDR was readily adopted by hatchery operators and farmers when simplified hatchery techniques became available (Phillips, 2002). Examples also exist of small indigenous species with high nutritive value which makes an important dietary component in rural households. Roos, Islam and Thilsted (2003) reported that aquaculture can make an important nutritional contribution through the production of Vitamin A-dense small indigenous species. They found that the small indigenous species dominated the total fish intake in terms of amount as well as frequency of consumption, contributing 84 percent to the total fish intake among the surveyed households. In Bangladesh, by integrating Vitamin A-dense small indigenous species, such as *Amblypharyngodon mola*, (Mola carplet) with existing carp production in carp polyculture ponds, the nutritional quality of the production can be improved without any negative impact on the total fish production. This production system offers great potential for providing a valuable source of dietary Vitamin A in rural Bangladesh, if seed of *Amblypharyngodon mola* can be made available. It is estimated that, if 10 kg/yr of *Amblypharyngodon mola* are produced in each of the estimated 1.3 million ponds in Bangladesh, the annual recommended Vitamin A intake of > 2 million children would be met (Roos, Islam and Thilsted, 2003).

TABLE 8.4.4
Frequency of use of aquaculture species

Extent of use/species	Countries in Asia	Countries with significant contribution
Ubiquitous:		
Common carp	30/40	China, India, Indonesia, Myanmar, Lao PDR, Iran, Bangladesh
Silver carp	22/40	China, Bangladesh, India, Iran
Freshwater fishes nei	21/40	China, Vietnam, Bangladesh, India, Myanmar, Indonesia
Grass carp	20/40	China, India, Bangladesh
Widespread:		
Bighead carp	12/40	China, Lao PDR, Iran, Taiwan Province of China, Nepal
Nile tilapia	10/40	China, Philippines, Thailand, Indonesia, Lao PDR
Tilapia nei	10/40	Taiwan Province of China, Malaysia, Philippines
Moderate:		
Crucian carp	8/40	China, Taiwan Province of China
Limited/localized:		
Roho	5/40	India, Bangladesh, Myanmar
Mrigal	5/40	India, Bangladesh
Catla	4/40	India, Bangladesh
Black carp	2/40	China
River eel	2/40	Indonesia, Japan
White amur bream	1/40	China
Mandarin fish	1/40	China

Current and projected fish seed demand

The trend in percentage contribution of carps and tilapia to total freshwater aquaculture production in each of the leading aquaculture producing countries in Asia is more or less similar over the period of 1995 to 2003 (Table 8.4.5). Therefore, to project the fingerling requirement of carps and tilapia to achieve the projected aquaculture production to 2020, an assumption is made that there is no change in the percentage contribution of carps and tilapia to total aquaculture production after 2003 (business as usual scenario). The computed percentage contributions of carps and tilapia to total freshwater aquaculture production for selected Asian countries in Table 8.4.5 are amongst the top aquaculture producers in Asia representing more than 80 percent of the total aquaculture production in 2003, thus not compromising the representation of the sample selected.

To compute the contribution of fingerlings and brood fish of carps and tilapia and land requirement for fingerling rearing to meet the aquaculture production in 2003 and projected production to 2020 (Tables 8.4.6 and 8.4.7), the assumptions made are given in Annex 8.4.1.

There are resource constraints to meet this fingerling demand. To produce the fingerling requirement to meet the projected aquaculture production to 2020, the increase in land area requirement is considerable, particularly in China, India and Indonesia. The projected land requirement for fingerling production cannot be considered in isolation. It has to be considered in conjunction with projected grow-out area to meet 2020 target as fish seed supply is directly linked to the potential of grow-out production. When considering the cumulative effect of land requirement, the need may increase in many folds.

Although the dependency of tilapia and carp broodstock on fish meal is not as great as that of carnivorous species, fish meal is still generally the preferred protein source for use within compound aquafeeds for tilapia and carp broodstocks, because of its high nutritional quality and biological value to tilapia and carps. When fishmeal requirement for the maintenance of required broodstock to meet aquaculture production to 2020 is considered in conjunction with fishmeal requirement for grow-out, the fishmeal requirement may constrain fish seed production.

INTERVENTIONS IN FISH SEED SUPPLY IN RURAL AQUACULTURE

Traditional fish seed supply systems

In recent years, there has been a general trend in the rural aquaculture shifting from extensive traditional fish seed supply practices to more intensely managed systems using new technologies. There are a number of reasons why these changes have been taken place, but most reported changes include:

- decrease in availability/capture of wild fish seed
- increased availability of fish seed of various non-traditional culture species
- better access to information
- production for sale rather than home consumption

Traditional fish seed supply can be described as very extensive. Fish seed are obtained either collecting them from the wild or through natural spawning of fish (e.g. common carp and crucian carp) being held in ponds or paddy fields. Fish are stocked in paddy fields or ponds to collect eggs or are harvested for consumption at a later date. There is very little management other than maintaining the water level. With the intensification of culture practice, management interventions such as use of lime in nursery pond preparation and for disease control and intensifying rice-fish culture by using more species such as improved common carp, tilapia, Indian and Chinese major carps, with modifications of rice-fields with trenches or refuges have become common.

Stocking was the key element that defined most rural traditional fish seed supply systems. Other than stocking of fish, there is very little intervention on the part of the

TABLE 8.4.5
Projected aquaculture production by leading aquaculture countries in Asia

Country	Estimates						Forecast for 2020[3]		
	Production[1] 1995 (mmt)	Percentage contribution of carps and cyprinids	Percentage contribution of tilapia and other cichlids	Production[1] 2003 mmt	Percentage contribution of carps and cyprinids	Percentage contribution of tilapia and other cichlids	Production[2] (million mt)	Production of carps and cyprinids (mmt)	Production of tilapia & other cichlids (mmt)
China	9.35 (59 %)	88.7	3.4	17.04 (62 %)	80	5.15	52.255[a] (32.4) 40.747[b] (25.25)	25.96	1.67
India	1.58 (95.2 %)	76.6	NA	2.066 (93.3 %)	91.1	NA	10.744 (9.99)	9.10	-
Indonesia	0.28 (43.7 %)	68.5	16.1	0.478 (48 %)	53.4	19.0	7.355 (3.53)	1.88	0.671
Philippines	0.098 (27 %)	3.4	78.6	0.154 (33.4 %)	6.0	78.0	6.30 (2.10)	0.126	1.64
Bangladesh	0.271 (85.5 %)	73.1	NA	0.756 (88.2 %)	82.0	NA	1.340 (1.18)	0.968	-
Thailand	0.193 (34.5)	17.6	39.4	0.283 (36.6 %)	21.2	34.3	0.838 (0.306)	0.065	0.105
Viet Nam	0.296 (77.6)	NA	NA	0.548 (58.5)	NA	NA	5.175 (3.03)	-	-
Cambodia	0.0087	89.6	2.7	0.0178	90.0	2.8	NA	-	-
Total	12.07			21.34					
Asia total	12.545			22.14					

1 Freshwater fish production. (Source: FAO, 2005). Contribution to total aquaculture production is given in parenthesis.
2 Projected aquaculture production to 2020. Freshwater production is in parenthesis assuming no change in contribution of freshwater production to total production after 2003.
3 Source FAO, 2004 (a and b based on 3.5 percent and 2 percent annual aquaculture growth rate)
NA – not available

TABLE 8.4.6

Contribution of fingerlings of carps and tilapia and land requirement for fingerling rearing to meet the aquaculture production in 2003 and projected production to 2020

	Estimated fingerling production 2003 (million)		Projected fingerling requirement to 2020 (million)		Estimated pond area for fry to fingerling rearing (ha) 2003		Projected pond area for fry to fingerling rearing to 2020 (ha)	
	Carps	Tilapia	Carps	Tilapia	Carps[1]	Tilapia[2]	Carp[1]	Tilapia[2]
China	17 050	1758	32 450 (90 %)	3 340 (90 %)	76 725	3 446	146 025 (90 %)	6 546.4 (90 %)
India	2 352.5	-	11 375 (383.5 %)	-	10 586.25	-	51 187.5 (383.53 %)	-
Indonesia	318.75	182.0	2 350 (637 %)	1 342 (637.4 %)	1 434.4	357	10 575 (637.24 %)	2 630 (637 %)
Philippines	11.25	80.0	157.5 (1 300 %)	3 280 (4 000 %)	50.62	157	709 (1 300.5 %)	6 429 (3 995 %)
Bangladesh	771.25	-	1210 (57%)	-	3470	-	5445 (57%)	-
Thailand	75.0	194.0	81.25 (8.4 %)	210 (8.24 %)	337.5	380.2	366 (8.4 %)	412 (8.4 %)
Viet Nam	NA	NA	NA	NA	NA	NA	NA	NA
Cambodia	20.0	1.0	NA	NA	90.0	NA	NA	NA
Total								
Asia total	20 997.5	2518			94 489			

1. Based on 90 percent carp fingerling production is in earthen ponds at a production rate of 0.2 million fingerlings /ha;
2. Based on 50 percent tilapia fingerling production is in earthen ponds at a production rate of 0.1275 million fingerlings /ha and two culture cycles per year;

Percent increase in land requirement to achieve 2020 fingerling requirement is given in parenthesis

TABLE 8.4.7

Computed contribution of broodstock to meet the computed fingerling production to meet aquaculture production in 2003 and projected production to 2020

	2003 Estimated broodstock (kg)		Projected to 2020 broodstock (kg)		Estimated fishmeal requirement in broodstock feed per year in 2003 (kg)[1]		Projected fishmeal requirement in broodstock feed to 2020 (kg)[1]	
	Carps	Tilapia	Carps	Tilapia	Carps	Tilapia	Carp	Tilapia
China	4 570 000	461 475	869 6600	876 750	4 170 000	421 000	10 839 000	800 000
India	630 500	-	304 8500	-	575 300	-	2 782 000	-
Indonesia	85 420	47 775	629 800	352 275	78 000	43 600	575 000	321 451
Philippines	3 020	21 000	42 210	861 000	2 750	19 163	38 500	785 663
Bangladesh	206 700	-	324 280	-	189 000	-	296 000	-
Thailand	20 100	51 992	21 775	55 125	8 340	47 443	20 000	5 0302
Cambodia	5 400	262.5			5 000	239		
Asia total	5 627 300	660 975						

1. Estimated from 10 percent fish meal use in broodstock feed and at 2.5 percent body weight/daily feeding regime for one year

farmer other than maintaining the water levels. There are a number of different stocking scenarios described in the traditional fish seed supply systems including:

- stocking wild caught fish seed
- stocking eggs of fish (e.g. common carp and crucian carp eggs) that are being collected from the wild
- stocking eggs collected by placing artificial or natural (water hyacinth or straws) substrate in streams
- stocking eggs collected by placing artificial substrate in household culture ponds
- stocking fingerlings nursed in rice fields or nursery ponds that are being produced by collecting of eggs
- stocking gravid adults to spawn in rice fields or household ponds

Various issues related to traditional methods for fish seed acquisition pose possible constraints. The most immediate is the reliance in many cases on wild stocks as the source of seed. Wild stocks are generally perceived as declining, a situation that could threaten the local availability of seed. This being the case, it is important to assist farmers to develop improved practices for maintaining and managing broodstocks within their culture systems.

Fish fingerling production in rice fields

Strategies for the production of fingerlings in irrigated rice fields include stocking brood fish and encouraging the spawning and incubation of eggs in rice fields. Direct stocking of fertilized eggs or fry is also practiced. The fry are directly reared in early rice fields and after they have grown to 4 to 5 cm, they can be transferred to the rice fields in mid-term production cycle to grow them to market size by the time the rice is harvested. This is the easiest and most effective way which brings maximum benefits to fishermen. Another activity that is practiced is the fish fingerling production in rice fields in rotation with rice. The ricef ield is flooded during winter months when the rice fields are idle and with little competition for irrigation water.

Barman *et al.*, (2004) observed that the majority of households supported by the CARE Greater Opportunities for Integrated Rice-Fish Production Systems (Go-INTERFISH) project in Bangladesh used either eggs or fry of common carps for stocking in their rice plots during the first winter season and a very small proportion stocked tilapia brood fish or fry. In the second winter season, the use of common carp eggs remained high but stocking of fry declined, while the use of tilapia brood fish and the direct stocking of other species as fry increased. In the third winter season, the proportion of households using eggs rather than fry of common carp increased further and the use of tilapia brood fish and fry of other species also increased. Households targeted under the latter phase of the CARE Project produced fingerlings mainly by stocking the eggs of common carp and fry of other fish species. In areas under the early phase of the CARE Project, most households used tilapia brood fish and the number of farmers using common carp eggs increased. These data suggests that with previous experience and improved availability of brood fish, farmers choose to stock common carp eggs rather than fry and over time they began to maintain both common carp and tilapia brood fish (Barman *et al.*, 2004). This tended to improve the efficiency and consistency of production and reduce investment costs.

Farmers who depended on outside sources such as local nurseries or fry traders for their fry requirement of species other than common carp and tilapia to stock in rice fields gradually increased their dependence on their own fry sources, mainly from their own grow-out ponds (Barman *et al.*, 2004). This strategy of moving fish from small ponds, which often dry up, into the irrigated rice field environment allows the farmers to improve the performance of the resources available. Once stocked in the rice field at low densities and usually low numbers, fish grew rapidly to foodfish size and were used mainly for household consumption. The practice changed the use of rice fields from nurseries to fattening of fish. Silver barb was the most commonly stocked 'other' species, showing high survival and growth performance in rice fields.

The main purpose of stocking fry into winter season rice fields was to supply adequate number of fish fingerlings for stocking in autumn season rice fields for grow-out. An important aspect of increasing the trend of stocking other species (that could not be spawned locally) in rice fields, was the increasing linkage between traders and rice field fish seed producers (Barman, Little and Johannes, 2004). By supplying seed of other species, fry traders acted as conduits of knowledge, source of markets for large fingerlings of tilapia and common carp produced in the rice fields, thus assisting in fish seed supply decentralization.

Decentralized fish seed supply

Rural aquaculture is constrained by access to fingerlings, but experience suggests that local small-scale hatcheries can have a big impact (Phillips, 2002). The Asian Institute of Technology (1997) considers that the centralized, large, government hatchery model has not been successful. It is widely accepted that decentralized fish seed production mechanisms such as local and household small-scale hatcheries, hapa nursing and trading networks and on-farm breeding have proven to be a better catalyst for rural small-scale aquaculture.

Break-up of production cycle into breeding and nursing is partly triggered by limited availability of land and the involved cost of accommodating nursery facilities in the hatchery premises and in turn facilitated the decentralization process of fish seed supply. Break-up of production cycle into breeding and nursing offer opportunities for poor farmers to enter into fish seed production. Hapa nursing of fry to fingerling enable landless rural poor to enter into fish seed production provided support for access rights to water bodies. Further development of hapa nursing and nursing networks will also be essential to support rural aquaculture particularly in areas that lack good infrastructure. Without local networks, seed will be transported over large distances between catchments, with an attendant risk of genetic mixing of fish stocks and spread of diseases (Phillips, 2002).

THE WAY FORWARD

Access to fry and fingerlings has been documented as a constraint to rural aquaculture. This may be one of the reasons most of the aquatic production in rural areas is dependent on wild capture fisheries. Experience in many countries in the region proved centralized fish seed production has failed to reach the rural poor. Examples of decentralization of fish seed distribution exist in countries such as Bangladesh, Lao PDR, Viet Nam and Thailand on the development of “spawning” and “nursing” networks where farmers carry out spawning fish to produce hatchlings and the nursing fry to fingerlings, respectively, to distribute among neighbouring farmers. Government and small-scale private hatcheries act as centres for such spawning and nursing networks to supply fry. Such interventions have given positive results and therefore it is essential to provide continued institutional support particularly in areas that lack good infrastructure. For such networks to be sustainable large- to medium-scale government hatcheries should focus more on broodstock management and development to cater to the needs of small-scale private hatcheries which lack facilities for proper broodstock development. It is equally important to offer opportunities for rural poor to enter into ‘spawning’ and ‘nursing’ networks. Apart from continuing need for adaptive, small-scale technological development in order for poor to go into such networks, improve access of landless poor to water resources needs to be addressed.

It was also evident that the problem is not so much on inadequacy in fish seed production, but more on the issue of actual contribution to production being much less since a great proportion goes to ‘waste’. This significant proportion of waste has often been linked to the quality of fish seed. The potential negative impacts of genetics related to broodstock management issues such as inbreeding, genetic drift, introgressive hybridization and unconscious selection have been attributed to the poor quality of seed stocks. This over focus on genetic-related issues has neglected the good practices of fry traders during fry transportation and good husbandry practices of farmers during stocking and post-stocking. Development of strong farmer-decision making management tools to assess the quality of seed before and after stocking may lead to reduce the “waste”.

In the face of increasing resistance to the introduction of exotic species to increase aquaculture diversity, the use of indigenous species may be encouraged to safeguard biodiversity as well as enhance nutritional quality of the aquaculture production. However, the use of indigenous species for aquaculture has to be accompanied by broodstock management programmes that contribute to maintaining genetic diversity. In Thailand, for example, there is some evidence of loss in genetic diversity through hatchery breeding of *Barbodes* (Phillips, 2002). Thus, while promoting fish seed production of indigenous fish is a positive move, the approach needs to be supported by effective broodstock management strategies incorporating genetic concerns and species policies that reduce the movement and mixing of genetically-different stocks and strains (Phillips, 2002).

There is a need to ease pressure on land in meeting the demand for fish seed. To ease the pressure on land in the expansion of fish seed and aquaculture production, optimal use of paddy fields for ricefish culture has been suggested as an alternate to pond culture practices. Rice is cultivated in approximately 147 million ha world wide, of which almost 90 percent lies in the Asian region (Jenkins, 2003). Compared to other forms of aquaculture, additional land and water requirements for rice-fish culture are relatively small. Fish cultured in rice fields satisfy a large portion of their feed requirement from the natural environment. China produced 650 000 tonnes of fish from rice using paddy fields (Xiezhen, 2003). This is equivalent to a fish production from 144 450 ha of pond area. It has been estimated that about 6.7 million ha of paddy fields in China have the potential to practice ricefish culture (Xiezhen, 2003). If half of this potential is developed into rice-fish culture, it is equivalent to fish production from 744 450 ha of fish ponds. Das (2002) reported that 27 250 ha of potential area available in northeast India for rice-fish culture. This resource should be considered as a means of fingerling production to ease the pressure on land and water. However, ricefish culture is not perceived particularly as a good method for growing very young fish fry to fingerling production, mainly due to low survival rates (Kangmin, 2001). Further interventions such as introducing appropriate modifications in rice field systems or conditions conducive to fry to fingerling rearing will help address the issue of land and water limitations. Additional attention should be given to the successful rice-fish system in lowland rain-fed rice as practiced in Thailand. This system is appealing due to its water saving aspects.

Clearly fish seed supply has the potential to contribute to the livelihoods of rural poor. Unfortunately, fry to fingerling rearing has received only marginal attention from researchers and governments in Asia. In many countries, the processes have evolved and adapted as a result of rural entrepreneurship, rather than through governmental encouragement and backing (De Silva and FungeSmith, 2005). Potential of increasing the diversification of fish seed supply systems present a significant agribusiness opportunity to increase livelihoods and wealth generation for all stakeholders. Fish seed supply is an essential component of a value chain and its growth as an agribusiness will largely depend on private entrepreneurs. The government has an important role in setting the right framework conditions, building the required infrastructure and capacity and promoting fair local market.

REFERENCES

Barman, B.K., Little, D.C. & Johannes, J. 2004. *Tilapia and Common carp Fingerling Production in Irrigated Rice Fields of Farmers in Northwest Bangladesh: The Adoption and Dissemination Strategies.* Working Paper 10. Institute of Aquaculture University of Stirling, WorldFish Center, Bangladesh and South Asia Office, Dhaka, Bangladesh.

De Silva, S.S. & Funge-Smith, S.J. 2005. *A review of stock enhancement practices in the inland water fisheries of Asia*. RAP Publication No. 2005/12. Bangkok, Asia-Pacific Fishery Commission. 93 pp.

Das, D.N. 2002. Fish farming in rice environments of north-eastern India. *Aquaculture Asia* 7 (2): 43–47.

Delgado, C.L., Wada, N., Rosegrant, M.W., Meijer, S. & Ahmed, M. 2003. *Fish to 2020. Supply and Demand in Changing Markets*. Washington, D.C., International Food Policy Research Institute, and Penang, WorldFish Center. 226 pp.

Dey, M.M., Paraguas, F. J. & Alam, F. Md. 2001. *Cross-country synthesis. Production, Accessibility, Marketing and Consumption Patterns of Freshwater Aquaculture Products in Asia: A Cross-Country Comparison*. FAO Fisheries Circular. No. 973. Rome, FAO. 275 pp.

Edwards, P. 2000. Aquaculture, poverty impacts and livelihoods. Natural Resource Perspectives, No. 56. (available at www.odi.org.uk).

FAO. 2000a. *The state of food insecurity in the world*. Rome, FAO. 32 pp.

FAO. 2000b. *The state of fisheries and aquaculture*. Rome, FAO. 142 pp.

FAO. 2004. *Global aquaculture outlook: an analysis of global aquaculture production forecasts to 2020*. FAO Fisheries Circular No. 1001. Rome, FAO. 49 pp.

FAO. 2005. Aquaculture production: quantities 1950-2004. FISHSTAT Plus universal software for fishery statistical time series. (available at www.fao.org).

Garrow, J.S. & James, W.P.T. (eds). 1993. *Human nutrition and dietetics*. 9th Edition. Edinburg, UK, Churchill Livingstone, Edinburgh, UK.

Gill, G. J., Farrington, J., Anderson, E., Luttrell, C., Conway, T., Saxena, N.C. & Slater, R. 2003. *Food Security and the Millennium Development Goal on Hunger in Asia*, Working Paper 231. London, Overseas Development Institute. 34pp.

Hossain, Md. M. & Humayon, N. Md. 2001. *Profile of Key Aquaculture Practices and Fishing Technologies in Bangladesh.* Unpublished report submitted to the WorldFish Center, Penang, Malaysia.

Kangmin, Li. 2001. Rice-based aquaculture in China, pp. 198-201. *In* IIRR, IDRC, FAO, NACA and ICLARM (eds). *Utilising Different Aquatic Resources for Livelihoods in Asia: A Resource Book*. International Institute of Rural Reconstruction, International Development Research Centre, Food and Agriculture Organisation of the United Nations, Network of Aquaculture Centres in Asia-Pacific and International Centre for Living Aquatic Resources Management.

Hambrey, J. 2003. *Inland Fisheries and aquaculture*. A consultancy report. Edinburg, Scotland, Nautilus Consultants. 71 pp.

ICLARM, 1998. *Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia: Final Report*. Asian Development Bank Regional Technical Assistance No. 5558, Makati City, Philippines, International Center for Living Aquatic Resources Management. 151 pp.

ICLARM, 2001. *Genetic Improvement of Carp Species in Asia*: Final Report. Asian Development Bank Regional Technical Assistance No. 5711. Penang, Malaysia, International Center for Living Aquatic Resources Management.

Jenkins, M. 2003. Prospects for biodiversity. *Science* 302: 1175–1177.

Katiha, K.P. 2001. *Profile of Key Aquaculture Practices and Fishing Technologies in India.* Unpublished report submitted to the World Fish Center, Penang, Malaysia.

Lithdamlong, D., Meusch, E. & Taylor, N.I. 2002. Promoting aquaculture by building capacity of local institutions: developing seed supply networks in the Lao PDR, pp. 155-156. *In* P. Edwards, D.C. Little & H. Demaine (eds). *Rural aquaculture.* Wallingford, UK, CABI Publishing.

Lovatelli, A. 1997. Status of aquaculture in Vietnam. *Aquaculture Asia* 2(3):18-24.

Luu, L.T. 1999. Vietnam's small-scale aquaculture for better rural livelihood. *Aquaculture Asia* 4(3):14-16.

Mazid, M.A. 1999. Developmental needs and research priorities for fisheries in Bangladesh. *In* M.V. Gupta & N. Macawaris-Ele (eds). *Priorities in Aquatic Resources Research in the Asia-Pacific Region.* ICLARM Conference Proceedings 62. 39 pp.

Phillips, M.J. 2002. *Freshwater aquaculture in the Lower Mekong Basin*. MRC Technical Paper No. 7. Mekong River Commission, Phnom Penh.

Radheyshyam, D.N. 2001. Community-based aquaculture in India - strengths, weaknesses, opportunities and threats. *Naga,* The ICLARM Quarterly 24:9-12.

Roos, N., Islam, M. & Thilsted, S.H. 2003. Small indigenous fish species in Bangladesh: contribution to vitamin A, calcium and iron intakes. The American Society for Nutritional Science *Journal of Nutrition* 133:4021-4026.

Shaleesha, A. & Stanley, V.A. 2000. Involvement of rural women in aquaculture: An innovative approach. *Naga*. The ICLARM Quarterly 23(3):13-17.

WorldFish Centre. 2002. Strategies and options for increasing and sustainable fisheries and aquaculture production to benefit poor households in Asia. Semi Annual Progress Report, 2002. (available at www.worldfishcenter.org).

Xiezhen, F. 2003. Rice-fish culture in China. *Aquaculture Asia* 8(4):44-46.

Zhiwn, S. 1999. *Rural aquaculture in China*. RAP Publication 1999/22. Rome, FAO.

ANNEX 8.4.1
Assumptions made for the computation of the contribution of fingerlings and brood fish of carps and tilapia and land requirement for fingerling rearing to meet the aquaculture production in 2003 and projected production to 2020

Assumptions made for carp species:

Average weight of females	1kg
Number of eggs/1 kg female	100 000
Fertility rate of eggs (80 percent)	80 000
Hatching rate of fertile eggs (80 percent)	64 000
Survival up to seven days (75 percent)	48 000
Survival of fry up to one month (35 percent)	16 800
Survival up to fingerlings (80 percent)	13 440

Female brood fish required to produce one million fingerlings	74.4 kg of females

Female and male brood fish (1:2) required to Produce one million fingerlings	74.4 kg females + 148.8 males

Actual broodstock required (with 20 percent resources)(74.4 + 14.88) + (148.8 + 29.76)
= 268 kg

Fry density 250 000/ha (80 percent survival)	200 000 fingerlings/ha
Average stocking rate for poly culture	5 000 fingerlings/ha
Average production	4 tonnes/ha

Assumptions made for tilapias:

To produce 1 million fry/yr	150-200 kg broodstock

With 20 percent resources, required broodstock	210kg
Tilapia fry survival	75 percent (70-80 percent)
To produce 1 million fingerlings/yr required fry	1.25 million/yr
To produce 1.25 million fry required broodstock	262.5 kg
Fry stocking densities (140 000-200 000/ha pond)	170 000/ha
Fingerling production at 75 percent fry survival	127 500/ha
To raise 1 million fingerlings required land area	7.84 ha

Stocking densities of fingerlings	10 000-20 000/ha(average 15 000/ha)
Output production	5-15 t/ha (average 7.5 t/ha)
Two culture cycles/yr	15 t/ha/yr