UPDATE ON AQUACULTURE: SMALL-SCALE FRESHWATER FISH CULTURE IN SOUTH ASIA

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Introduction

This paper discusses the systems and approaches to improve utilization of inland water resources in South Asia through freshwater fish culture. Improved fish culture technologies are available in the region, but the use of improved methods in the existing water resources has been slow to develop. With increasing demand, static or declining natural catches of fish, and the pressing need for more rapid production of food, increased production of fish in South Asia needs to be expedited.

By the year 2000 a projected world population of 6.1 billion people will, according to 1980 levels of consumption, require an additional 19 million metric tons of fish. If one adds to this, income growths of 2.8 percent in industrial countries and 4.5 percent in developing countries, the increased demand for fish by the year 2000 would be about 30 million metric tons (Shilo and Sarig 1989). In the past increased demand was met through increased harvests from the oceans, and from inland capture fisheries, particularly in the countries of South Asia. However, the capture landings have leveled off, and in some countries, even declined. Future fish landings from capture fisheries are likely to remain constant or decline, creating the need for an alternative source of supply such as aquaculture.

While significant increases in aquaculture production in many countries of Asia have occurred, real prices of most fish products have risen steadily over the past decade and in some countries, more rapidly than other agricultural products. This indicates a growth rate of demand in excess of the local supplies. The countries of South Asia, in particular, have a low level of resource utilization with a high potential. They are now focusing aquaculture efforts on increasing the production of export oriented, high value shrimp products and the lower valued finfish such as carp and tilapia. However, with populations increasing at 2 to 2.5 percent annually in South Asia, the need to improve the use of existing water resources through more intensive culture systems is increasingly apparent.

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Fish Supply and Demand Situation

The Food and Agriculture Organization of the United Nations (FAO) forecasts that the total world demand for fish by the year 2000 will be 100 to 110 million tons (FAO 1990). This would be up from about 70 million tons in the mid-1980s. Trade in fish products expanded from US$1.3 billion in 1960 to over US$22 billion in 1986. With population increases in much of Asia, the pressures for an increased fish supply will be one of the highest in the world.

One example where rapid population growth is fueling an increasing demand for fish is Bangladesh, where the growth rate is between 2.3 and 2.5 percent a year. In Bangladesh, fish accounts for over 80 percent of the animal protein intake among the population, and fish is second only to rice in the diet of the poor. To maintain existing levels of fish consumption, the current estimated supply will have to be increased from around 830,000 metric tons to nearly 1.3 million metric tons by the year 2005.

Many Asian countries, in the past, depended heavily on open inland access fisheries and marine fishery for the bulk of the household supply. However, these traditional sources can no longer provide adequate output. The marine capture fisheries in South Asia are being exploited at, or beyond, maximum sustainable yields. The mechanisms for expansion, such as open water stocking of the inland capture fisheries, are still largely unproven. Quite often there has been no incentive to prevent overexploitation of the open access fishery, as the attitude of "living for today" prevails.

The open inland access fisheries, which include the large rivers, lakes, reservoirs, and floodplains, have had their potential reduced by environmental degradation, the continued improvement of capture fishing techniques, increasing competition for scarce surface water, and the development of improved flood control and drainage schemes. Another factor that leads to overexploitation is the entry of the unemployed into the fishery. These factors, along with the rapid increase in populations in Asia, and the continued strong demand for quality fish and shrimp, will generate the interest in, and need for, aquaculture as an alternative means of increasing fish production.

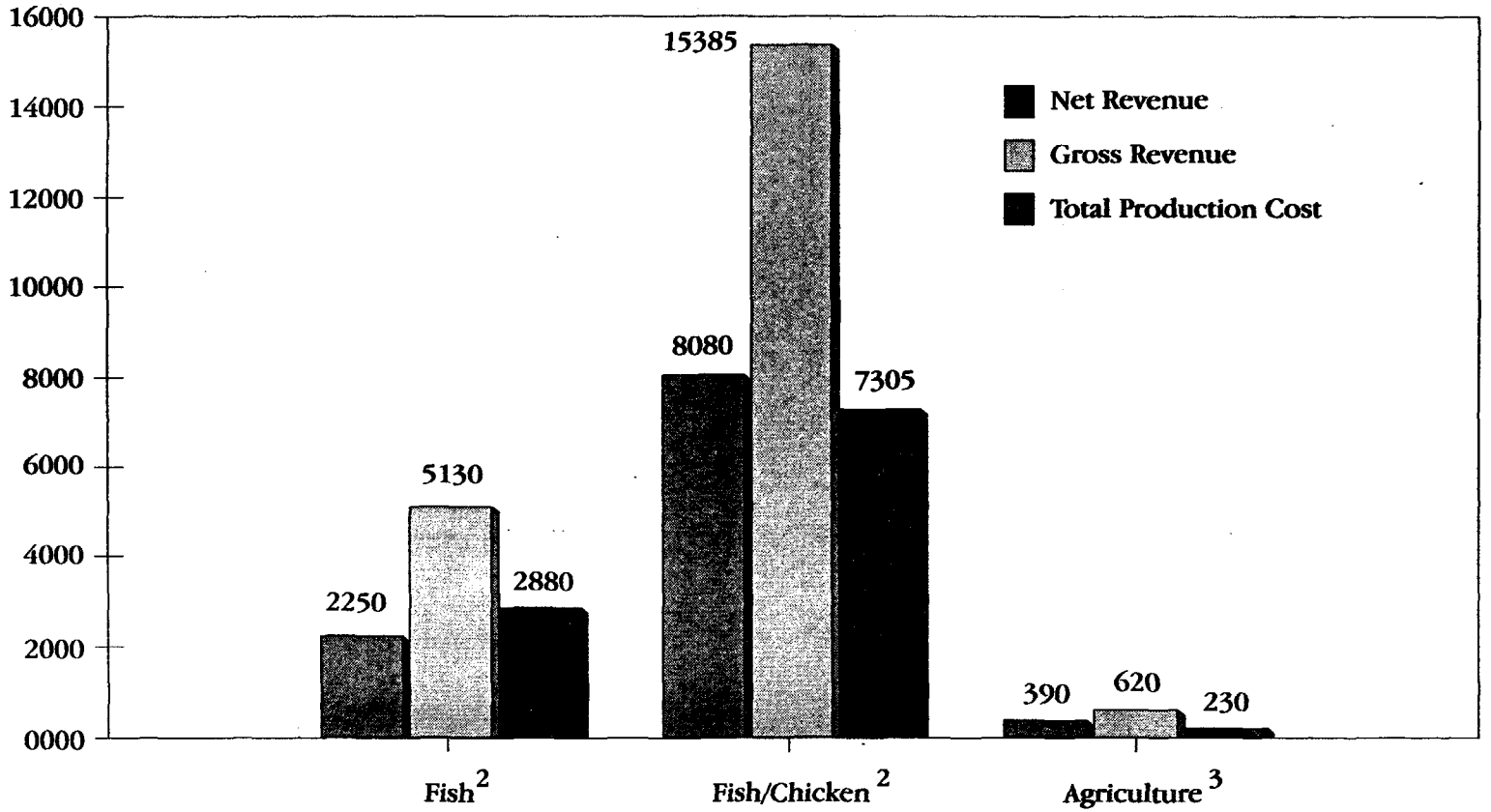
Comparative Advantages

The culture of fish has an advantage over the husbandry of other vertebrates because fish use less metabolic energy for movement and thermal maintenance. Fish are more efficient converters of food to flesh than most other land vertebrates. Dry food to wet weight of animal flesh gained for various vertebrates are as follows: fish 1.5:1 or less; cattle about 10:1; pigs about 4:1; and chickens 2.5:1 (Shang 1981). Therefore, production costs for fish are generally lower than that for beef, poultry, and swine. Yields of pond-produced fish in Asia under semi-intensive culture can be as high as 5,000 kilograms to 10,000 kilograms a hectare a year, compared to cattle production, which would yield only 500 kilograms to 700 kilograms a year on the same area.

In India, according to Sinha and Srivastava (1991), the return from aquaculture can be up to fifteen times higher than traditional agriculture. In Bangladesh, the financial gains from aquaculture can be up to thirteen times higher than that for agriculture, for fish only systems and up to thirty times higher in integrated fish and chicken systems (see figures 1 and 2).

Figure 1. Production Costs and Returns for Aquaculture and Agriculture in Bangladesh [1]

U.S. $/Hectare



1. Based on 1 hectare of land area for 12 months.

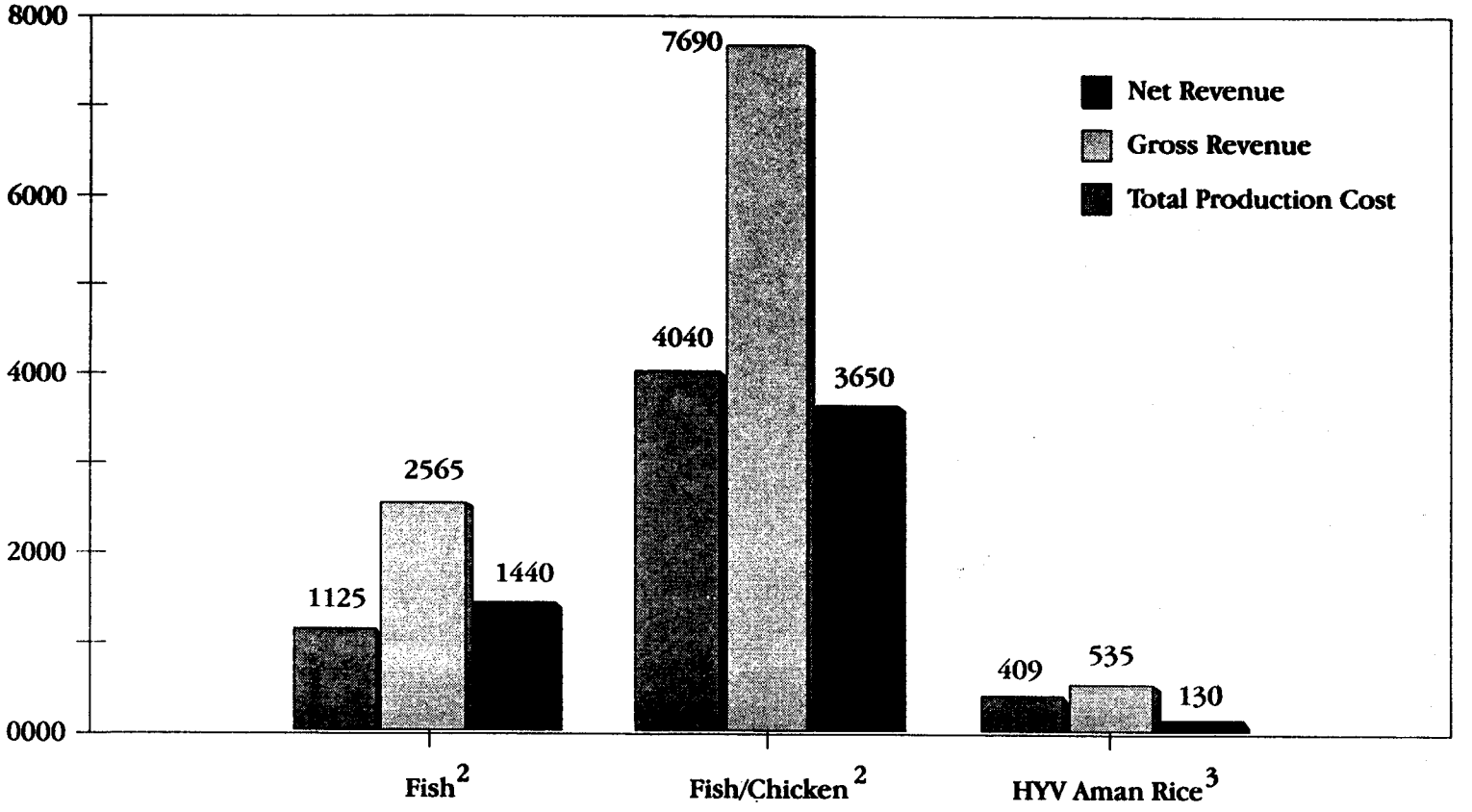
2. Actual field results of semi-intensive carp polyculture with laying chickens in rural Bangladesh ponds. Aquaculture Extension Project (1991).

3. Total farm production cost and return projections from annual farm budget summaries which includes the production of rice, jute, vegetables and fruits.

Source: Data from: Agriculture wing of the Bangladesh Water Development Board (1988).

Figure 2. Production Costs and Returns for Aquaculture and Agriculture in Bangladesh [1]

U.S. $/Hectare



1. Based on 1 hectare of land area for 6 months.
2. Actual field results of semi-intensive carp polyculture with laying chickens in rural Bangladesh ponds. Aquaculture Extension Project, Department of Fisheries (1991).
3. Production costs and returns for one crop of HYV Aman Rice.

Source: Adapted from World Bank Fisheries Sector Review (1991).

Status

Major Technological Advances in Aquaculture

Due to the development of induced breeding technologies, India and Bangladesh, along with other countries in Asia, have been able to expand their production of fish seed and meet the rising demands. Bangladesh has increased its hatchery produced seed from near zero in the late-1970s to more than 3 billion in the late-1980s (see figure 3). Prior to 1980, Bangladesh produced virtually no fish seed from hatcheries and producers were dependent on the supply from the rivers. But the river sources were unreliable, and it was not until the hatcheries increased that a dependable supply of fish seed could be ensured. India increased its hatchery produced seed from 1 billion in 1980 to 9.3 billion in 1987-88 (Sinha and Srivastava 1991). These increases have been possible through induced breeding. Almost 90 percent of the Chinese carps cultured in China are produced from hatcheries (Thia-Eng 1986).

Regional and countrywide improvements to polyculture models, multiharvest plans, and integrated farming programs have led to increased yield in the region. The major technological advances in aquaculture have included induced breeding of fish, shrimp breeding, maturation and larval rearing, aeration aquaculture, advances in integrated farming, improved multiple harvesting and stocking technologies, multispecies culture improvements, and sex reversal and hormone manipulation techniques, particularly with **tilapia**.

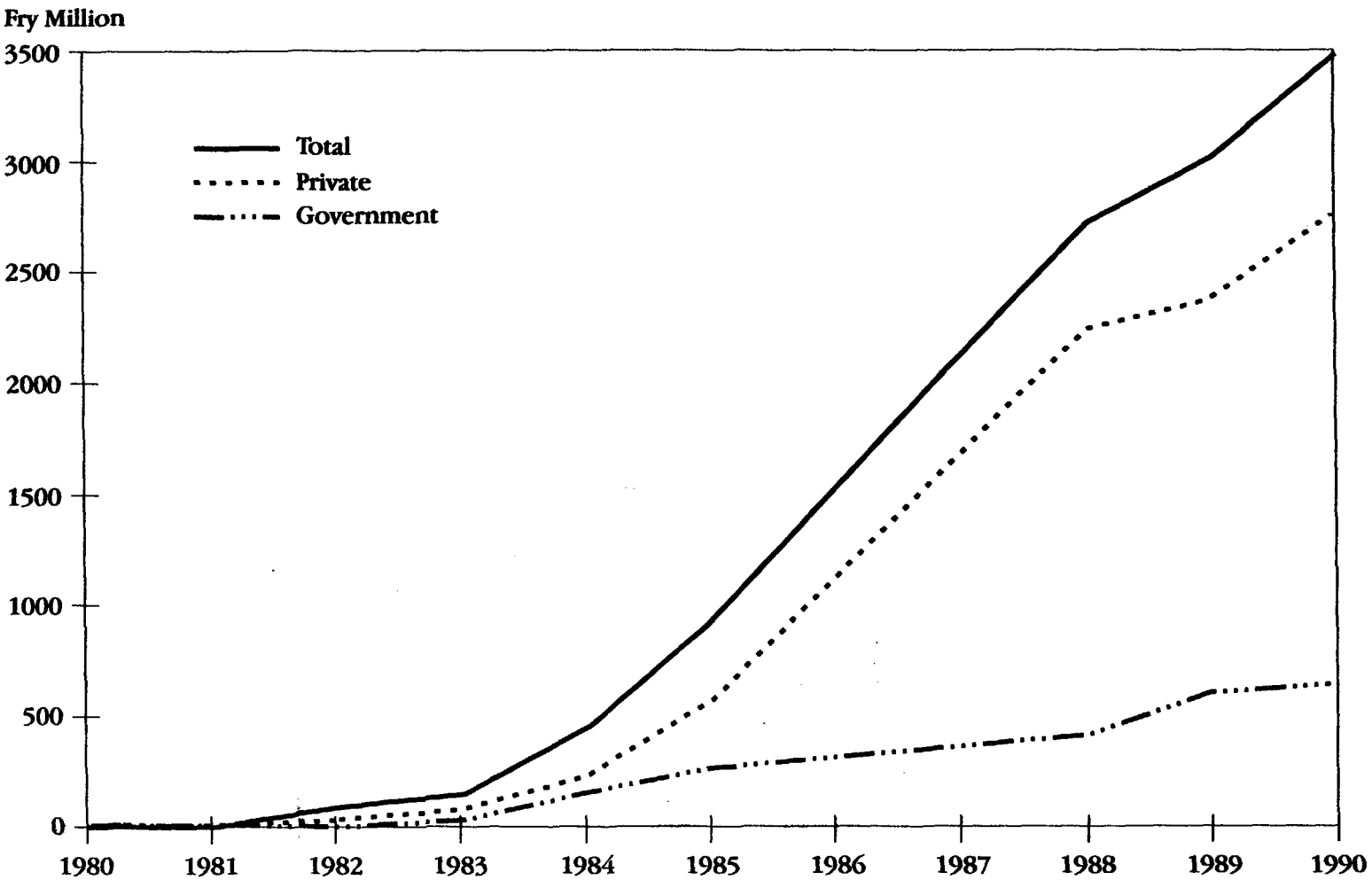
Current Production

According to 1988 estimates of the FAO, the value of global aquaculture production was about US$22.5 billion (FAO 1990). This includes all freshwater and marine species of fish, shrimp, other crustaceans (mollusks, oysters, mussels), seaweeds, and other aquatic plants, which total more than 14 million metric tons. This represents an increase of more than 9 million tons since 1973 (Pillay 1990).

China's aquaculture harvests far exceed that of other countries. In 1988, China harvested about US$7.95 billion worth of aquaculture products, while the total for the United States was US$609 million. Carps dominate the world production over other species groups, with Asia leading production.

Despite the advances in techniques and increases in production, there are substantial areas, particularly in South Asia, that lag behind in aquaculture development. Current levels of production from freshwater aquaculture are still low in countries such as India, Bangladesh, and Pakistan. In these countries most of the fish production takes place in the extensive category, with limited semi-intensive culture, and virtually no intensive culture. China, Thailand, and Taiwan (China) have intensified steadily and have achieved widespread higher yieldsaunit area. China maintains high yields on a large scale over large resource areas.

Figure 3. Estimated Total Hatchery Produced Fish Fry in Bangladesh, 1980-90



Source: Adapted from Department of Fisheries estimates in kilograms of fish hatchlings.
One kilogram of hatchery produced hatchlings has been estimated at 400,000 individuals.

Future Potential

The overexploitation of existing open access fishery resources, coupled with environmental changes and degradation, will limit future supplies of fish from this traditional source. If yields can be increased, aquaculture may be able to meet the future demands for fish in South Asia.

Yield Potentials

In South Asia, existing pond water resources are not fully utilized for aquaculture. Only a small percentage is being used for semi-intensive culture. With semi-intensive techniques, existing traditional methods producing 800 kilograms to 1,000 kilograms a hectare a year, can be made to yield 5,000 kilograms to 10,000 kilograms a hectare a year. The trend for the future will have to be the improved utilization of existing resources through more intensive culture.

Potential production from India is estimated at 4.5 million tons a year while present levels are at 1.3 million tons (Sinha and Srivastava 1991). In Bangladesh, if semi-intensive aquaculture were applied, the potential yield could be as high as 0.7 million tons a year to 1.4 million tons a year in existing water bodies alone. The current estimated production in inland culture fishery is only 0.18 million tons a year (Department of Fisheries 1990).

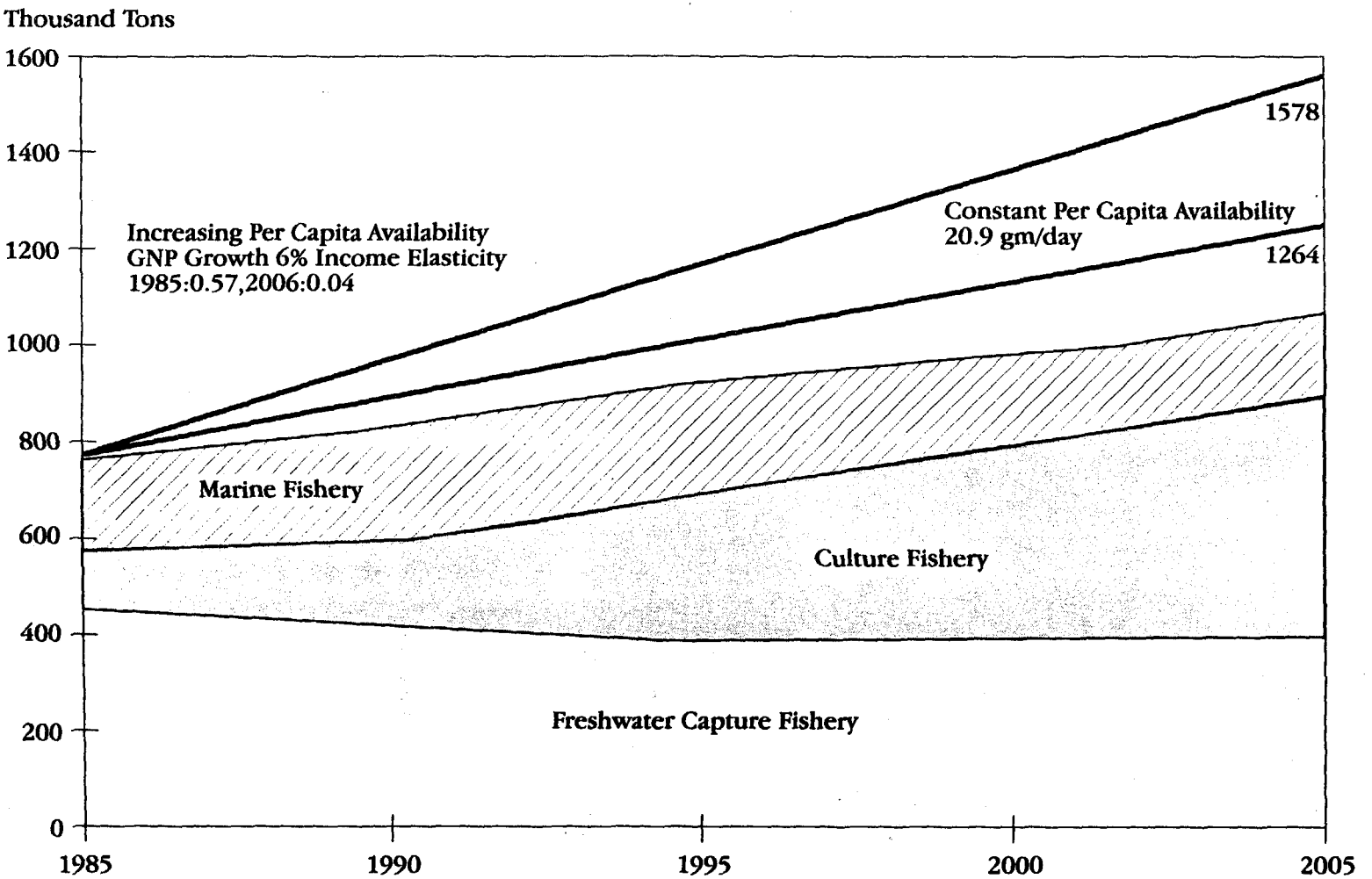
In Asia alone, the total area used for aquaculture is estimated to be about 2.4 million hectares. According to Shang (1981), this estimate, plus other undeveloped coastal lands suitable for culture of fish, may be as much as 30 million hectares. India has water areas suitable for controlled freshwater aquaculture of more than 1.6 million hectares, and Bangladesh from 250,000 to possibly more than 400,000 hectares. In Bangladesh, much of this has a very low opportunity cost. Figure 4 shows the impact of increased yields from semi-intensive aquaculture on the total fishery production of Bangladesh. This figure demonstrates the need for an even more rapid expansion of semi-intensive aquaculture to keep up with the future demand.

Income and Employment Generation

Aquaculture is labor intensive and, at all stages, generates employment. An example of this is multiharvesting, which improves the yield and income and increases the labor requirement. Fish feed production should be encouraged instead of the use of prepared fish feeds, which require less labor and more cost. The production of duckweed, for instance, which requires more labor at lower costs should also be encouraged. Increasing employment and the use of labor for aquaculture intensification is of particular significance in those countries where the opportunity cost for labor is low.

Aquaculture has the potential to be an important generator of income and employment in the rural areas of many Asian countries. Shang (1981) estimated that the production of 4 metric tons of fish provides one full-time job and an income adequate for a family. In Bangladesh, the net income derived from the production of 1,000 kilograms of fish a year can support a family of up to eight people. Stated in another way, the net income derived from aquaculture in 0.2 hectares of water surface area, is adequate to support a family in some developing countries.

Figure 4. Demand for and Production of Fish in Bangladesh Medium Scenario for Pond Aquaculture[1]



1. Increasing production of fish through semi-intensive fish culture in 40 percent of the existing pond resources.

Approaches to Future Development

To achieve rapid growth in aquaculture, substantial investments are required. In Bangladesh, a total investment of from US$250 million to US$500 million (simply for operation inputs) would be required to upgrade pond culture of carp from its current level of 800 kilograms to 1,000 kilograms a hectare a year to 5,000 kilograms a hectare a year. Returns can be as high as two to three times that invested as seen on figures 1 and 2, and when existing pond resources are used, there is virtually no opportunity cost. In addition to the actual investments in the culture activity, investments in disseminating the technology would be required.

Through aquaculture, it is possible for very small and poor farmers to earn high incomes from a very small resource. Future efforts of development should be directed toward helping such farmers achieve profitability and, in ensuring the success of each, to attract others. The unique advantages of aquaculture over other land and water uses have been demonstrated. Aquaculture is an economic activity which is not limited only to those with adequate funds for investment. It is well-suited to those rural individuals who lack capital and who can be motivated to earn a sustainable income. In South Asia, there are substantial opportunities for the widespread involvement of small, poor to marginal farmers, to greatly increase their incomes through aquaculture.

Opportunities also exist for medium- and large-scale farmers, both in freshwater fish culture and brackish water culture of shrimp. Opportunities exist for commercial scale production of both fish seed and tablefish. Coastal shrimp culture still offers opportunities, but operations need to be kept extensive to semi-intensive with more emphasis on lower costsakilogram of product.

Future aquaculture development can alleviate poverty and promote the development of rural areas. Aquaculture can increase employment alternatives, particularly for women; producing more fish for local consumption (that is, improving nutritional standards); raising the net incomes of rural communities; increasing opportunities for foreign exchange earnings; supplementing or replacing capture fishery catches where environmental degradation or overfishing have depleted stocks; and effectively utilizing fallow land and water resources.

Small-Scale Aquaculture and Poverty Alleviation

Small-scale aquaculture can substantially increase the household income of a family in Bangladesh from 6 percent of the total family income to 38 percent in one year of fish culture. The percentage of income from the relatively small pond area of 0.1 hectare can double if the fish operation is integrated with chicken-rearing. In most areas of South Asia, a farming family can be supported by the returns from aquaculture from 0.2 hectare of water.

In general, small-scale aquaculture operations provide more employmentaunit of capital invested than larger farms (Pillay 1990). One direction for developing countries could be the promotion of small-scale aquaculture projects for poor farmers. Working with people below the poverty line can be successful when they can be assured of a constant supply of inputs, financial assistance and technical guidance. In Bangladesh, studies show that poor farmers adopt the activity rapidly, are generally more committed to the constant care required, produce fish at higher yield levels than wealthier neighbors, and repay loans more regularly. Strategies should be followed that build a permanent, sustainable framework around the small farmer, within which he can prosper through hard work with the help of appropriate technology.

Credit

Access to credit needs to be ensured in order to reach the large numbers of rural poor who are unable to finance the costs of getting started in aquaculture. In Bangladesh, to go from extensive to semi-intensive culture in the existing pond resources, would require between US$250 million to US$500 million annually for investment, just to cover the running costs (DANIDA 1987). The current institutional lending for fisheries and aquaculture is in the range of US$3 to US$4 million (World Bank 1991).

In studies conducted as a part of the Aquaculture Extension Project in Bangladesh, more than 50 percent of the pond owners state that lack of financing is the greatest constraint to their involvement in aquaculture, and less than 2 percent have access to credit for that purpose (DANIDA 1987). The general experience with credit for small-scale aquaculture and fisheries programs in India and Bangladesh has been rather negative in terms of loan disbursements, utilization, and loan recovery (DANIDA 1987). Among the factors responsible for this, the more important ones are:

- Reluctance on the part of financial institutions to disburse loans without the borrower providing **immovable assets as primary collateral**, which is not possible for the majority of small-scale fish farmers in the region.

- Existing gift and grant character of loan programs where capital subsidy components, subsidized interest rates, and the "writing off" of fisheries loans has resulted in the deterioration of loan repayment motivation and discipline.

- Social interference in the selection of borrowers by locally elected bodies, which often results in people receiving loans who are neither able nor willing to use the loans for the intended purpose.

- Ineffective technical extension services.

- Lack of trained branch level staff for appraisal of loan applications and loan supervision.

- Complicated procedures and requirements for obtaining a loan, which often keeps those who most need it away.

In Bangladesh, institutional credit disbursements to the fisheries sector have declined when they should be growing with the demand (DANIDA 1987). This has been primarily attributable to the above factors. Credit programs with small fish farmers can be successful through efficient selection of the loan recipients, improved loan supervision, and the waiving of collateral. Credit provided through nongovernmental organizations (NGOs) is another way of improving the delivery to the target population.

Extension Approaches

Fish yields must be raised and the transfer of the technology accelerated. The technology must be demonstrated successfully and widely. Extension services are needed to support aquaculture development through the creation of public awareness, transfer of appropriate technology, development of support services, provision of support to private hatcheries, and greater access to credit. Farmers must be assured of the reliability of the support services and the availability of these services into the future. Programs should stress the profitability with no subsidies, because the economic returns from aquaculture are great and can be achieved within a relatively short period of time.

As an alternative to government intervention, NGOs can be effective in motivating target producers to improve aquaculture practices. Some NGOs in the region have been able to improve the fish producer's access to credit, fish seed, technology, markets, and the water resource itself. They have been most effective in transmitting an extension message and following through with motivation and supervision to small-scale producers. NGOs should be supported and given training on all the technical aspects of aquaculture.

In Bangladesh, over 90 percent of the pond resources are underused for fish production. In an attempt to increase aquaculture within the private sector (where the ownership of virtually all this resource lies), a DANIDA-financed aquaculture extension project has developed a model for increasing fish production on an areawide basis (DANIDA 1987). This is a public sector program directed at establishing true supports to the private sector with accessible credit, practical, directed, technical guidance, and high-yielding fish and integrated fish and poultry production models, which brings net returns in one year of US$2,800 to US$7,000 a hectare over that invested.

The goal of the program is to create sustainable aquaculture development with small-scale, poor to marginal, private pond operators through the extension and promotion of a simple low-cost aquaculture production system. The program uses experienced and well-trained rural aquaculture entrepreneurs as extension agents. Project support goes to the private sector at all levels, from the primary producers of hatchery seed through to fingerling growout for stocking into terminal tablefish production ponds. The project has been able to establish sustainable rapid increases in aquaculture production in target areas of Bangladesh by (a) supporting the private sector technically and financially at all levels; (b) facilitating marketing and establishing linkages between each of the producers and their markets; and (c) extending a production system with high yields and low costs.

Research

Research emphasis in the future should come from the bottom up, and not top down. Often scientists have not been able to respond quickly enough to meet the immediate needs of the industry. In many instances, there has been little communication between the farmer and the researcher. Adaptive research should be conducted in the production of artificial feeds, using local ingredients and increasing the use of plant instead of animal proteins. Research on grow-out operations to improve existing knowledge of optimal carrying capacities under various types of feeding and water management regimes is also important. There is a need for research into selective breeding, in order to ensure constant, future supply of quality fish seed. Efforts should be made to increase regional

cooperation in Asia, with the pooling of knowledge and information to cut the costs of research and development for any single country.

Production and Resource Utilization Considerations

Concentration in the future should be on the following areas of aquaculture:

- Culture of species low on the food chain that can be produced in large quantities at lower costs.
- Continued development of lower cost, more efficient culture systems.
- Continued promotion of integrated approaches using fish with livestock, fish with agriculture.
- The use of relatively cheap, energy rich supplementary feeds, and the use of duckweed and other vegetation as a direct feed.
- Increased recycling of agricultural and livestock wastes.
- Localized production of feedstuffs to increase employment and allow higher returns on the investment.
- The use of multiharvesting techniques to increase outputs and improve marketing potential by spreading the harvest over time.

Approaches in the future should work toward the full integration of the aquaculture operation with livestock rearing and agriculture. The use of a wider variety of fish species, which feed on a wider variety of planktonic organisms and the higher plants, should be encouraged. The best approach for the developing countries of South Asia is in the use of low-cost systems, fueled by agriculture and livestock by-products, and with readily available, but, at present unused vegetation, coupled with multistocking and harvest culture systems.

Where tubewells and reservoirs have been constructed for irrigation agriculture, the opportunity exists for high-density, high-yielding pond aquaculture systems. With the assured supply of water, the risks in intensifying the culture system are reduced while the yields of fish can be multiplied as the farmer increases his stock density, feeding, and water inputs.

Concentration for the near term should be, initially, on better utilization and development of existing areas and potential. According to Shang (1981), it costs seven times more to construct new ponds in Indonesia than to improve the existing ponds from an extensive to intensive kind of farming. In Bangladesh, the cost difference is four to five times. Many of the existing pond resources also have opportunity costs which are very low and there is substantial existing resource where the opportunity cost is at or near zero.

Involvement of Women in Aquaculture

In Aquaculture Development Programs in Bangladesh, studies show that women working on homestead aquaculture achieve higher fish yieldsaunit of water area than male operators in the same areas. Women are successfully producing tablefish at rates of over 5 tons a hectare a year. They are also rarely delinquent on their loan repayments. Family owned pond water resources tend to be near the homestead, providing the opportunity for women to undertake aquaculture while still carrying on with normal household activities. Women's involvement also frees family men to pursue other avenues of income generation.

Aquaculture and the Environment

Negative impacts of aquaculture development have occurred, and are still occurring, through unplanned development of coastal mangrove areas for shrimp culture in the region. Destruction of the mangrove in Bangladesh, for example, has taken place despite the fact that extreme acidic soils lie below, causing difficulty in the culture of shrimp. In other parts of the country, there are thousands of hectares of land which do not require clearing and have suitable soils for high levels of production. The lack of adequate planning in aquaculture development and the absence of regulatory management have allowed development to proceed in areas where conflicts and future environmental impacts abound. In the future, areas other than valuable mangrove forests, which act as nursery areas for juvenile wild marine shrimp, should be developed.

Positive uses of aquaculture in mitigating fish losses from engineering interventions also have occurred in the region. One example where aquaculture was used successfully to mitigate fish losses due to an engineering intervention was in the Chandpur Irrigation and Flood Control Scheme in Bangladesh. The movement of fish into and out of a 210 square mile area, originally rich in aquatic life, was impeded by the construction of water control dikes around the entire area. To reduce the loss of fish into the area and the potential loss of livelihoods to fishermen, a fish hatchery was constructed to supply fish seed to make up for the loss caused by the engineering intervention. Fish landings of carps and shrimp did decline due to the closure but then increased to above preclosure figures in the case of fish. The increase was a direct result of the hatchery produced seed of more than 100 million annually, and an improved extension program in the area that led to an increase in semi-intensive fish culture. Private sector hatchery development in the area resulted from this investment.

Other potentially positive impacts of aquaculture on the environment have been the continued development of hatcheries and the intensification of pond aquaculture in Bangladesh and India. The increase in hatchery supplied seed has probably kept natural seed collection in rivers from intensifying, thereby promoting the potential of natural wild fish survival. Intensification of pond aquaculture has provided more opportunities for employment from the increased harvest of cultured fish to landless fishermen. To some degree, this will have a reducing effect on fishing pressure in the open access fishery.

Public and Private Sector Role

There are many examples where large public sector projects have failed to achieve their goals. In some cases they have become a burden to the countries through the unproductive use of large numbers of employees and the high cost of maintaining a large, often unproductive, infrastructure. The most productive areas of public sector intervention lie in research and development, modernized extension interventions, and policy support to the private sector.

The public sector has had an impact on the industry in the area of hatchery or seed production through demonstration. To a large extent the production of fish seed from hatcheries was started in the public sector and now, for example, in Bangladesh has been almost completely taken over by the private sector. The development of hatcheries for carp is a good example of where public sector investment was needed in the beginning to start off an activity, but where after the initial development, the private sector was able to take over and expand production. In most of Asia, nurseries have been in the hands of the private sector for some time. Currently, in most of Asia, and particularly in India and Bangladesh, the private sector has assumed the major role in carp aquaculture. This includes the hatchery, nursery, transport, on-growing phases, and of course, the marketing and is achieving significant returns at each level.

Some of the smaller public sector projects have been successful in serving as a catalyst, spurring the development of the industry by the private sector. Private sector initiatives and investments have been a strong force in the economic development of the sector over time, particularly in such countries as Thailand, Bangladesh, India, and Nepal. Related activities, such as hatchery production of fry, pond production of fingerlings, tablefish production, supply of inputs, or marketing of the product, have been more efficient, and the development far more rapid, in private sector hands, than in the public sector. The private sector is involved in all stages and has developed to a fairly sophisticated level in all areas of operation except the tablefish production stage, where in developing countries of the subcontinent, production methods are still primarily extensive. Some of the support required for future development of tablefish production can be seen in figure 5. To a large extent all the production related activities can be, and in many cases, are being carried out in the private sector.

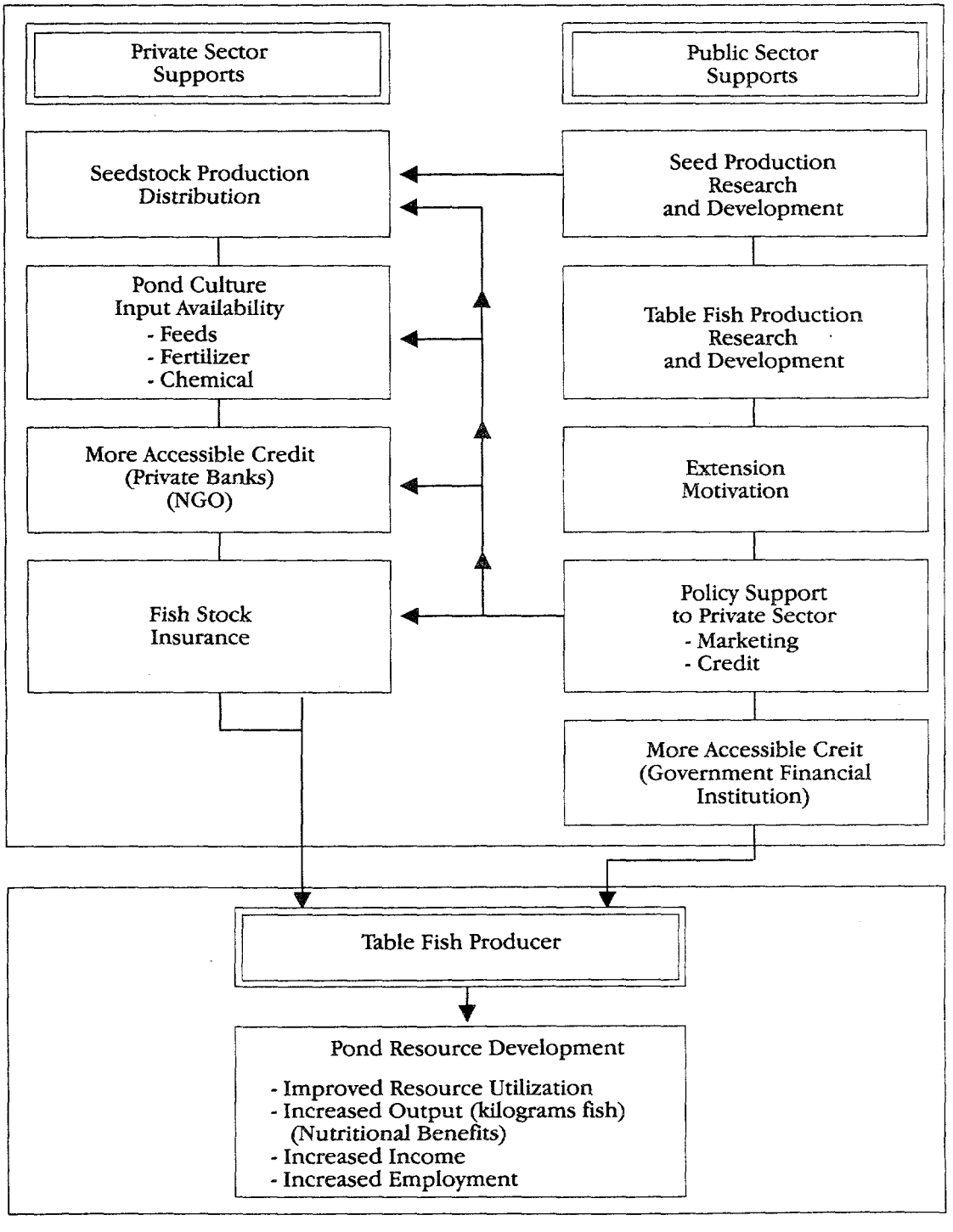
In the future, small-scale private sector operations should be supported through public sector policies. The economic development of the rural poor through such activities as aquaculture can, and should, lead to the development of individuals who will, in future, demand and seek out services rather than having to be motivated and directed through extension, as is the current situation.

Investment Opportunities

Investments in the future are to be directed toward the improvement of water resource utilization through the intensification of aquaculture, particularly semi-intensive aquaculture in ponds. Strategic investments are needed in infrastructure and institutions. The investment support should be directed toward the continued development of the private sector. Total "Area Development" approaches, which include aquaculture, are suggested.

The specific investment opportunities lie in: (a) modernization and improvement of extension and credit, which includes support to NGOs and using women and private growers as extensionists;

Figure 5. Pond Water Resource Development Supports Required for Inceasing Aquaculture Yields



(b) small private sector hatcheries; (c) tubewell and linkage of production to reservoir supplies of water; (d) critical road and rail linkages; (e) small private sector ice plants; (f) crop insurance; (g) development of trained technically skilled personnel; and (h) adaptive "on-farm" research.

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