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RAINBOW TROUT (*ONCORHYNCHUS MYKISS*) CULTURE IN THE HIMALAYAN KINGDOM OF NEPAL

A SUCCESS STORY

APAARI

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Foreword

One of the main objectives of the Asia-Pacific Association of Agricultural Research Institutions (APAARI) is to disseminate significant achievements of member NARS in different fields of agriculture through informative Success Stories. Pursuant to this objective APAARI has published and widely distributed so far 24 success stories on important aspects related to agricultural research for development in the Asia-Pacific region. In fishery sector, being so vital for economy of resource poor people and important from the point of view of nutritional security, APAARI has published so far three Success Stories. These were:

i) Tilapia Farming in the Philippines
ii) Bivalve Mariculture in India
iii) Farming of Carrageenophytes in the Philippines

Most of above Success Stories are related to Marine fishery. On the contrary, globally significant advances have taken place in inland aquaculture. In this context, APAARI decided to bring out this Success Story on Rainbow Trout, ***Oncorhynchus mykiss***, which has successfully been experimented and promoted for commercial production by the Nepal Agricultural Research Council (NARC) in the land-locked mountainous kingdom of Nepal, where per capita fish consumption is presently very low and the people residing in highly terrains do need good source of protein rich diet through diversification of agriculture. Hence, the species of cold water fish, Rainbow Trout, was identified for research and development in Nepal and for this purpose, the research collaboration was sought from JICA, Japan. It has now successfully reached to a harvest level, both in the government and private sectors. Rainbow Trout has considerable scope for expansion in Nepal and could become an important export earning commodity in near future.

In this publication, details concerning research and development on Rainbow Trout, a valuable cold water fish have been presented. APAARI, therefore, hopes that this publication will be able to catalyze other NARS for its introduction and production in similarly placed cold climate and get benefited. I congratulate the authors for having presented all available information on this subject for the benefit of others interested in trout fish farming. It is our expectation that the readers would find this publication both interesting as well as useful.

R.S. Paroda
Executive Secretary
APAARI

24 February, 2005

I. Introduction

Nepal is a Himalayan Kingdom situated at an altitude varying from 60 m in the south to 8,848 m in the north and is physio-graphically and agro-ecologically very diverse. It is one of the richest countries in the world, possessing about 2.27% of the world water resource (CBS 2003); approximately 5% of the total area of the country is occupied by different freshwater aquatic habitats (Bhandari 1992). Out of 818,500 ha total water surface area, there are about 6,000 rivers and rivulets flowing from north to south totaling about 45,000 km in length and covering an estimated area of 395,000 ha; these rivers and rivulets comprise about 48% of the total water resources (FDD 1998). Thus aquaculture in Nepal depends entirely on the exploitation of inland water bodies e.g. rivers, streams, lakes, reservoirs and ponds. Pond fish culture is the important part of aquaculture. The major species used are warm water carps, namely, Rohu (*Labeo rohita*), Bhakur (*Catla catla*) and Naini (*Cirrhina mrigala*) including exotic carps; common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), and grass carp (*Ctenopharyngodon idella*); these are under commercial culture mainly in the southern Terai plain. Cage culture of these species has also been promoted in some lakes and reservoirs in the hilly region. Though per capita fish consumption in Nepal is very low (1.543 kg/yr) (DoFD 2002) compared to other countries in the Asia-Pacific region and fisheries support only about 2% of the Agriculture GDP in the country (DoFD 2001), there has been a national initiative to promote/extend aquaculture in cold habitats for the mountain farming communities in order to generate income. A cold-water fish, the rainbow trout (*Oncorhynchus mykiss*) has been introduced to expand aquaculture in the hills of the country by utilizing the cold-water resources available. This success story briefly narrates the outcome of research and development efforts put forth by the national programme vis-à-vis the achievements made in trout culture in Nepal.

II. IMPORTANCE OF TROUT AQUACULTURE

Rainbow trout (*Oncorhynchus mykiss*) is native to the rivers which drain into the Pacific Ocean while brown trout (*Salmo trutta*) is native to European waters. The commercial culture of trout began as early as 1853 in the United States and possibly even earlier in Europe; it was largely due to the high quality and good taste of trout flesh (Bardach et al. 1972). Various species of trout have been successfully farmed in many countries for hundreds of years and were introduced to Asia and Europe during the 19th century. Rainbow trout is now widely distributed in the freshwaters of nearly 100 countries worldwide. Its aquaculture production in 2002 was nearly double that was produced 10 years ago, three times the amount produced 20 years ago and 6 times the amount produced 30 years ago (Figure 1). Among the countries in which trout is grown, Chile has led production, followed by Norway, France, Italy and Spain (Table 1). In the Asia-Pacific region, Iran produced the most, followed by Japan and Australia. Korea and

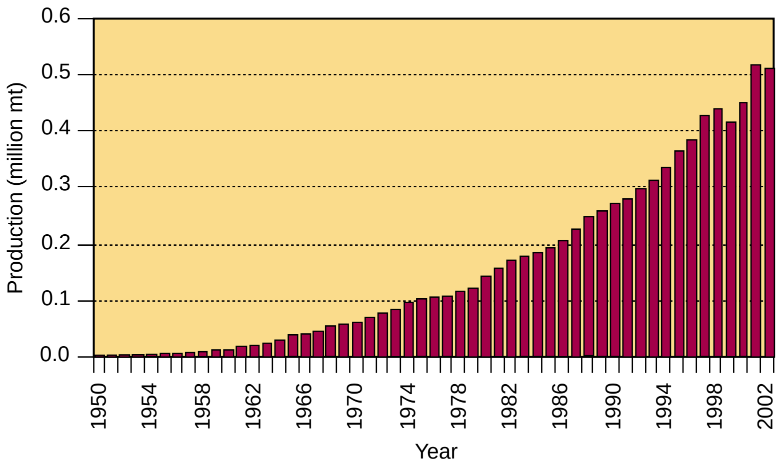

Figure 1. World aquaculture production of rainbow trout (Fishstat – FAO, 2002)

Table 1. Major rainbow trout producing countries and production (mt) in 2002 (Fishstat – FAO, 2002)

Europe and America	Production (mt)	Asia-Pacific	Production (mt)
1. Chile	111,681	1. Iran	16,026
2. Norway	83,424	2. Japan	9,681
3. France	45,348	3. Australia	5,743
4. Italy	33,770	4. Korea	2,740
5. Spain	32,442	5. Taiwan	737
6. Denmark	28,061	6. Nepal	17
7. United States	24,699		
8. Germany	24,184		
9. UK	14,330		
Others	75,779	**World Total**	508,662

Taiwan are also producing rainbow trout at lower levels. FAO database for aquaculture production does not show any production of rainbow trout in India, China, Thailand, Malaysia, Indonesia, Nepal, New Zealand, Pakistan and Sri Lanka. However, DIAS (2003) has reported that it has been introduced to these countries for various purposes. Most likely, its farming in these countries has not yet been commercialized and is still in the research and development phase.

First introduced to Japan in 1877, rainbow trout has become the third most important freshwater aquaculture species in terms of production (Yamaha 1991). Trout has a higher market value than most other fish species. However, due to the high protein content of the feed needed by trout in captivity, the cost of production is higher than that of most other fish species as well. Culturing trout both for consumption as well as recreational fishing has now become a well-established tourist industry throughout the world (Barrington 1983).

Nutritive value: Rainbow trout is low in fat and calories compared to other meats. A 3-ounce serving of cooked rainbow trout contains 130 calories, 22 g of protein, 4 g fat, 1 g saturated fat and 30 mg of Sodium (Source: Ladewig and Morat, 1995).

III. Rainbow Trout Farming in Nepal

1) Growth requirements

Rainbow trout is an exotic carnivorous sport fish which can survive in water temperatures ranging from 0 to 25°C. The optimum temperature for growth is between 16 and 18°C (Table 2), but the suitable water temperature range for feeding and growth is 13-18°C (Yamaha 1991), and 9-14°C for the spawning and hatching of eggs. The consistency of environmental conditions with regard to water temperature, volume and quality is very important for trout culture.

Table 2. Suitable temperature ranges (°C) for trout farming

Purpose/Activities	Temperature range (°C)
Survival: can survive at the range of	0-25
Culture: normal feeding and growth	13-18
Breeding: spawning and hatching	9-14
Optimum temperature: best growth	16-18

2) Cold water resource – an ideal habitat for trout introduction

Nepal is struggling with malnutrition, largely due to a shortage of protein in the diet as a result of low income. The main objectives behind the introduction of trout farming are to encourage rural farmers/growers to produce high quality protein to be consumed and to provide an attractive income generating opportunity for the people living in the hilly region that would utilize their abundant cold-water resource. The cold-water resource consists of about 6,000 rivers and streams, most of which from the Himalayas. The rivers, made up of glacial melt water, flow down from the Himalayas bringing abundant cold water that has not yet been utilized for aquaculture. The warm water fish culture in ponds is concentrated in the Terai flat area (lowlands) where the water surface area is limited to 6,500 ha (FDD 1998). Alternative means of increasing production are limited to either increasing the productivity per unit area of the existing ponds or expanding the pond areas, which would place aquaculture in competition with other agricultural activities, especially rice cultivation. Therefore, the best option available is to explore unused water bodies such as the cold-water resources of the hilly region, where fish species like trout have great potential. People living in the hilly region have less of an opportunity to improve their economic condition due to their lack of available income-generating resources. Therefore, rainbow trout culture is very promising, as perennial cold water is available in the hilly region where there are very few other activities that could be used to generate income. In addition to providing direct benefits/job opportunities to the local people, trout farming also supports eco-tourism, making trout available for recreational sports fishing and supplying restaurants with fresh, high quality fish to be consumed by tourists.

IV. ESTABLISHING NATIONAL FARMS/CENTRES FOR TROUT RESEARCH

An attempt to culture salmonid fish in Nepal was made more than three decades ago by introducing Atlantic salmon (*Salmo salar*) and brown trout (*S. trutta*) from Kashmir, India in 1969 (Gurung and Basnet 2003). Then in 1972, another attempt was made by introducing brown trout (*S. trutta*) and sockeye salmon (*Oncorhynchus nerka*) from the United Kingdom. Unfortunately, both attempts were unsuccessful due to the lack of technical know-how. Nevertheless, the third attempt has been a success story after 50,000 eyed-eggs of rainbow trout (*Oncorhynchus mykiss*) were introduced under a technical cooperation with the Miyazaki prefecture of Japan in 1988. The eggs were kept and incubated in the Fisheries Research Centre, Godawari, located about 15 km southeast of Kathmandu at 1,525 m.

Initially the Government/national staff and the Japan Overseas Cooperation Volunteers (JOCV) carried out joint research studies in two Fisheries Research Centres located in Trishuli and Godawari. Rainbow trout has been bred and reared successfully in these centres since then. After a decade of continuous research and development efforts, a complete package of technology for the production of rainbow trout including breeding, fry nursing/rearing, and grow-out culture, and feed formulation/preparation, has been developed by Nepal Agricultural Research Council (NARC). Efforts have been made to transfer this technology into the private sector with the help of various government and non-government agencies. As a result, suitable sites have been selected (Figure 2) where there are a few private farms in each site are already in operation, and more sites have been identified in various parts of the country for further expansion.

Figure 2. Locations or sites of main trout farms in Nepal

V. PRODUCTION OF RAINBOW TROUT – A SUCCESS STORY

1) Trout research and development – national achievements

A series of research trials were conducted at the two government Fisheries Research Centres located in Trishuli and Godawari in order to develop viable production technologies. Thus it has been possible to develop a complete technology package for breeding, nursing/rearing and grow-out culture of rainbow trout, including feed formulation using locally available feed ingredients so as to make the technology more practical and cost effective. Production of rainbow trout started in 1995 on government-run farms and in 1998 on private farms. So far however, only grow-out farming has been commercialized. Breeding, incubation, larval rearing and nursing operations are carried out at the government centres to supply fingerlings to the private farms. Production data (Table 3) show that a significant increase in production volume was achieved once private farms adopted this technology.

Table 3. Rainbow trout production (mt) in Nepal

Year	Rainbow trout production (mt) in Nepal		
	Government	Private	Total
1995/96	4.9	–	4.9
1996/97	13.5	–	13.5
1997/98	12.0	–	12.0
1998/99	11.8	0.7	12.5
1999/00	8.4	1.6	10.0
2000/01	8.0	5.0	13.0
2001/02	10.1	6.6	16.7

Source: FRC, Trishuli and FRD, Godawari (2002).

Some of the major techniques to be considered for the successful culture of rainbow trout are described.

a) Site selection

Site selection is crucial for successful trout farming. The most important factors (Table 4) to consider are the quantity and quality of water (physical and chemical properties). Availability of adequate cold water (below 20°C) throughout the year is a pre-requisite when selecting the sites. The temperature of the water can be between 10 and 20°C (Yamazaki 1991); feed consumption decreases when it rises above 20°C, resulting in the slow growth and eventual death of the cultured fish. The best growth takes place between 16 and 18°C (FRD 2001). Trout also require high levels of dissolved oxygen (DO) for survival and growth; growth decreases when this level falls below 7 ppm (Gibson's 1998). Conveniently the cold waters in Nepal normally have high DO levels. The pH of the water can range from 6.5-8.0 but the optimum range is 7.0-7.5. At higher pH levels, relatively low levels of ammonia can be dangerously toxic (Bromage and Shepherd 1990; Sedgwick 1985). Most cold waters are neutral in pH, however.

A minimum rate of 500 m^3 per day of water flow is necessary per tonne of trout produced (Stevenson 1987). Therefore, the site should have a slope of 1-3% which permits adequate water flow and helps maintain good water quality. For this reason, the hilly and mountainous regions of Nepal have been found to be well-suited for trout culture and all the established farms are located on the sloping land in these

Table 4. Factors to be considered for site selection (in order of importance)

A. Water quantity and quality	B. Other factors
1. Quantity	1. Access to road
2. Temperature (°C)	2. Safety and security
3. DO (ppm)	3. Electricity
4. pH	4. Poaching
5. Ammonia	5. Flooding/land slide

regions. Moreover, the ideal site would have easily accessible roads, available electricity, a low risk of flooding and land slides, and would be safe, secure and free of poaching.

b) Culture methods

Trout farming can be done in one of two ways, either as complete farming, breeding from eggs to adults, or as partial farming, in which grow out fish are bred from fingerlings to marketable size. The partial, or grow-out, farming needs only few grow-out ponds/raceways. However, with this type of farming the farmer has to depend on others for the quality as well as quantity of fingerlings. As trout are very sensitive to adverse conditions, there can be a high rate of mortality during transportation. On the other hand, a complete farming system, where a farmer produces fingerlings himself/herself, requires more facilities, thereby increasing the cost of production. Facilities needed for the hatchery operation would include an incubation/hatching system, additional equipment for breeding activities, feeding, nursing and holding tanks, and specialized/skilled manpower. Extra facilities for residential and service accommodations would also need to be considered.

c) Culture system

As trout require clean and cold water for survival and growth, earthen ponds are not usually suitable but can be used for low stocking density. Concrete ponds or tanks of various shapes and sizes can be used. Normally, the tanks can either be circular or rectangular but rectangular tanks (Figure 3 & 4) are preferred for the maximum use of water and their low cost of construction. Circular tanks typically range from 4 to 6 m in diameter with a depth of about 0.75 m. However, circular tanks are less suited to automated handling, grading and harvesting which have been used overseas to improve productivity (Bromage and Shepherd 1990). A water supply of 4 $L.sec^{-1}$ permits stocking densities of trout upto 20 $kg.m^{-3}$. Normally, a negative correlation between stocking density and growth has been found, though stocking density did not appear to affect growth at a density upto 25 $kg.m^{-3}$ and can be increased to 35 $kg.m^{-3}$ by increasing the water flow (Bekiroglu et al. 1995). When the water supply is reliable, permanent, stable and adequate then tanks can be constructed in a parallel fashion (Figure 3) to avoid from contaminating wastewater from one fish tank to the other tanks. But if the water source is limited then linear fashioned tanks (Figure 4) would be the best way to utilize the available water at its maximum level. This linear construction, however, needs a filter chamber to filter the polluted water from one tank before it enters another tank. Availability of land and its topography would determine the selection of the design. In most cases, a combination of linear and parallel fashions may be necessary to properly utilize the water and space available. The suitable size and depth of the tanks are 50-150 m^2 and 80-90 cm, respectively. However, depending upon the space, purpose and scale of the operation or the investment, tanks can be as small as 3.6 m^2 (Table 5).

Figure 3. Parallel type of raceway tanks for trout culture at the Fisheries Research Centre at Trishuli, Nuwakot

Figure 4. Linear type of raceway tanks for trout culture built by a farmer to fit the available landscape

Table 5. Capacity or sizes of raceway tanks used by the trout farms of Nepal

Tank no.	Owners of the trout farms in Ranipauwa, Dhading			
	Mr. Gopal Lama Area m^2	Mr. Chitra B. Lama Area m^2 (length x breadth)	Mr. Padam Lama Area m^2 (length x breadth)	Mr. Kancha Lama Area m^2 (length x breadth)
1	27.5	71.76 (10.4 x 6.9)	19.94 (10.78 x 1.85)	8.5 (4.1 x 2.08)
2	27.5	6.0 (6.0 x 1.0)	18.2 (10.0 x 1.82)	3.6 (2.8 x 1.3)
3	22.1	6.75 (5.4 x 1.25)	20.7 (10.92 x 1.90)	12.3 (4.4 x 2.8)
4	27.0	6.73 (4.4 x 1.35)	19.2 (10.38 x 1.85)	–
5	19.0	9.76 (8.0 x 1.22)	11.36 (10.82 x 1.05)	–
6	13.4	9.76 (8.0 x 1.22)	11.36 (10.82 x 1.05)	–
7	18.5	20.0 (10.0 x 2.0)	–	–
8	32.3	–	–	–
Total Area (m^2)	**187.25**	**130.78**	**100.76**	**24.4**

d) Brood fish maintenance and breeding

Trout can breed after two years and spawn upto 2,000 eggs.kg^{-1} of fish (Morrissy 1973); however, breeding activity and quality egg development depends on the quality of the feed provided as well as other management practices. Based on our experience in two research centres (Government farms; Godawari and Trishuli), the brood fish feed should contain at least 35% protein and they are normally fed at the rate of 2-3% biomass of fish once or twice daily. Rainbow trout can be bred artificially once a year from December to February and the same group of brood fish can be used twice with good results but less hatching rate compared to the first spawning group. The eggs are stripped from females and then fertilized with the milt obtained from males (Figure 5). Normally, one male can supply enough milt for the eggs of two females with a good fertilization rate. The fertilized eggs are incubated in incubation trays containing clean water supplied at 3-7 L.sec^{-1} flow rate and dissolved oxygen >7 mg.L^{-1}. Hatching takes place within 20-30 days at 9-14°C.

Figure 5. Mature female rainbow trout and milt mixing with eggs for fertilization, (Fisheries Research Centre, Trishuli, Nuwakot)

e) Nursing and rearing

The new hatchlings (0.08 g in size) take about 2 weeks to reach the swim-up stage. The swim-up stage hatchlings are provided with a starter feed containing 35-40% crude protein at the rate of 15-20% biomass at 2-hour intervals until they are 3 g in size, which takes about 10 weeks. After the fish are 3 g in size, they will be fed at 8-10% of biomass at 2 hour intervals until they become about 5 g in size. Alternatives to starter feed have also been explored for the nursing and rearing of trout larvae. Frozen raw buffalo liver feed has been proven to be one of the best alternatives, showing healthier and better growth compared to other feeds (Figure 6) (FRD 1999/2000b; 2001). Egg custard has also been found to be a potential alternative to the starter feed (Pradhan 1998). The growth of trout receiving 18.5% of fats was dynamic and faster (Parova and Rehulka 1997). Occasionally deformed alevins of rainbow trout that were produced may have been due to high water temperature during the spawning season (Basnyat and Silwal 1995/1996). Locally prepared diets for rearing trout fry and fingerlings are given in Tables 6 (Yamada et al. 1998) and 7 (Nepal et al. 1998).

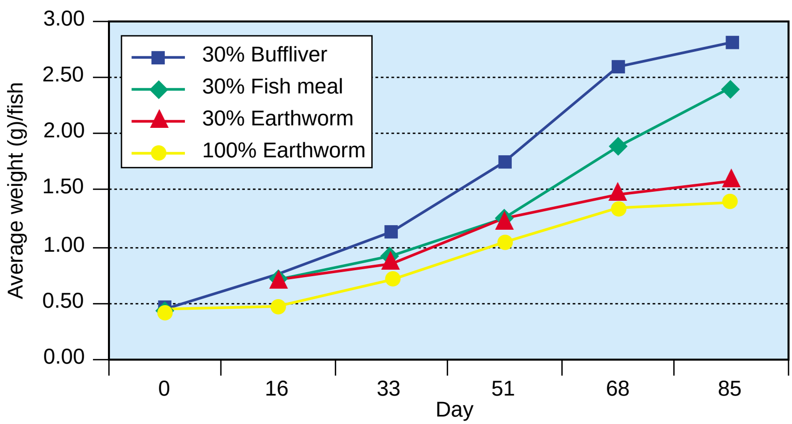

Figure 6. Effects of different starter feeds during fry nursing

Table 6. Locally formulated feed for the nursing of 0.8 g size trout

Feed ingredients	Composition (%)
Dried shrimp	28.50
Soybean	33.25
Wheat	16.15
Rice bran	9.50
Soybean oilcake	5.00
Oil cake	5.70
Minerals	0.95
Vitamins	0.95
Supplementary Vitamin C	0.10
Total	**100.00**

Table 7. Locally formulated feed for grow-out

Feed ingredients	Composition (%)
Shrimp meal	20
Soybean meal	35
Wheat flour	22
Rice bran	12
Mustard oilcake	9
Minerals	1
Vitamins	1
Total	**100**

f) Grow-out culture

Trout can be stocked at 50-100 fish.m^{-2} depending upon the quantity and the quality of water available. The marketable size of 200-300 g can be achieved within 14 months of the culture period. Basically, fish need to be graded timely to avoid cannibalism and to allow all the fish to grow uniformly. Specific growth rate (SGR) decreases with the increasing size of fish and the feed conversion ratio (FCR) has shown the ideal ratio to be 1.9:1, meaning about 2 kg of feed is needed to produce 1 kg of trout. Bromage and Shepherd

(1990), and Gibson (1998) have also reported that FCR has occasionally been found to be as poor as 2:1 or higher with low protein or poorly digestible diets. In order to improve FCR, thereby minimizing the production cost, fish are generally grouped into four sizes; i) 2-5 g, ii) 10-20 g, iii) 50-60 g, and >100 g. The size of the feed is prepared depending upon the size of the fish (Figure 8). The harvest size ranges from 200-300 g. The bigger the fish the more feed is consumed and more waste is produced in the system. Fish growth slows as fish get larger. The longer the culture period, the higher is the cost of production. So the trout should be harvested right after they attain the marketable size of about 200-300 g in order to maximize the profit. Feed efficiency in trout in Japan ranges from 60-80% (Tasiro et al. 1974) but has been found to be lower (43-46%) in Nepal (FRD 1999/2000a), which means there is room for improvement through research. The cost of rainbow trout production has been analyzed and attaining marketable size costs about NRs 170/kg (Joshi and Westlund 1996). However, this figure can be higher or lower depending upon the change in prices of inputs.

2) Economics of trout farming

Economic analysis (Table 8) shows the cost benefit analysis of trout farming based on the case of a private farm of Nepal. The present farm-gate price of per kg trout is 350 NRs (300 NRs at government farms). The price could go upto 500 NRs depending upon the demand/season and the size of the fish. Smaller trout can be sold at higher prices. As there are limited farms, people visit these private trout farms and farmers cook and sell their trout to them on the farm (Figure 7). If there is low demand, farmers can smoke their trout and keep it for longer periods or send it to nearby towns as well. Cooked trout can be sold at 25-30% higher prices.

Figure 7. Purna B. Lama, a successful trout farmer, with his wife. The farm is located just below the road. They also cook and sell to the travelers who stop-by to taste their trout.

The impressive net profit or annual rate of return (40%), return on investment (56%) and gross margin (66%) should be the attraction for more private farmers to adopt trout farming. As feed cost is nearly half (47%) of the total cost of production and this cost could be reduced to 30%, there is still room to increase the profit margin if a cheaper feed, using locally available resources, could be formulated through research.

Table 8. Cost benefit analysis of a private trout farm of Nepal (1 US$ = Approximately 75 NRs) (A case of Purna B. Lama's Trout farm, No. of tank = 8, Area = 215 m²)

1)	**Initial cost/capital cost**				
SN	**Items**	**Cost (NRs)**	**Economic Life (years)**	**Depreciation (NRs/yr)**	**Remarks**
1	Land cost (1,500 m²)	150,000	–	–	
2	Raceway construction	150,000	20	7,500	
3	Water supply system (e.g. pipes)	37,000	20	1,850	
4	Stores/workshop construction	50,000	20	2,500	
5	Drag net (5 m long)	1,200	3	400	
6	Netlons/graders/cages/hapas	18,000	5	3,600	
7	Small pumps/equipment/balance	5,000	5	1,000	
8	Others (buckets, soft wood etc.)	3,000	2	1,500	
	Sub total	**414,200**		**18,350**	
9	Bank loan	350,000			
2)	**Annual operation costs**				
	Particulars	**Quantity**	**Unit**	**Unit price (NRs)**	**Total cost (NRs)**
	A. Variable costs				
1	Feed for table fish	4,500	Kg	60	270,000
2	Feed for advance fry (upto 10-g)	200	Kg	75	15,000
3	Fry (2-g size)	15,000	No	2	30,000
4	Wages		NRs		20,000
5	Glass ware/tools/chemical/nets		NRs		5,000
6	Farm fuel		NRs		1,000
7	Electricity		NRs		6,000
8	Others (oil, medicines etc.)		NRs		5,000
	Sub total		**NRs**		**352,000**
	B. Fixed/non-operating cost				
9	Salary for manpower	365	Man/day	150	54,750
10	Bank interest (14%) for first year		NRs	14	49,000
11	Pay back of loan (1st installment)		NRs		70,000
12	Depreciations		NRs		18,350
13	Maintenance (5% of capital costs)		NRs		13,210
14	Telephone/communication		NRs		4,000
15	Gasoline for bike transportation		NRs		12,000
	Sub total		**NRs**		**221,310**
Total annual cost			**NRs**		**573,310**
Total income (prod x price, after deducting 20% mortality)		**2,300**	**Kg**	**350**	**805,000**
Total net profit/year			**NRs**		**246,690**
Cost per kg of trout			**NRs**		**249**
Net profit per kg of trout (NRs)					**101**
Return on Investment (RoI)					**56**
Gross margin (%, Return on operating costs)					**66**
Annual rate of return (ARR) %					**40**

VI. Promoting/Strengthening the Rainbow Trout Industry – A National Asset

1) Development of production technologies

Visualizing the potential of rainbow trout culture in the mountainous and hilly regions of Nepal, which cover about two-thirds of the country, a trout research programme was initiated to develop and test practical and economical production techniques in the national context. A series of research activities were carried out at two Fisheries Research Centres in Trishuli and Godawari, starting in 1989. With nearly a decade of continuous research efforts, production techniques have been successfully developed. These studies have proved that production of upto 150-200 $mt.ha^{-1}$ can be achieved, depending mainly upon the quantity and quality of water, its flow and other management practices.

Being carnivorous species, rainbow trout need a diet rich in protein, which is the main concern when formulating feed. However, techniques of feed formulation have been developed for all the stages of its life cycle using local feed ingredients available in the country, which is a great achievement. Local shrimp/prawn have been found to be of good quality and have become the main protein source in trout feed in Nepal (FRD 1998/1999). For this feed, prawn is mixed with local feed ingredients, namely, soybean, wheat, oil cake, rice bran, a vitamin mixture and some minerals. With the success of research on feed formulation and the subsequent testing in farmer's fields, NARC has demonstrated the commercial viability of these developed technologies.

2) Transfer of technology

The government of Nepal has made various policies and applied strategies to facilitate the transfer of developed production technology to

Figure 8. Locally prepared pellets for different size groups of rainbow trout

the private sector. The extension media, e.g. radio, TV and publications, have been the most effective means of providing knowledge and creating awareness. However, demonstration as well as verification of the developed technology in the farmer's fields (Figures 9 and 10) has proved to be more useful, as it has attracted and encouraged several commercial farmers. This is probably due to the fact that first hand experience builds confidence in the farmers. For demonstration purposes, a number of farmers who had adopted the technology comfortably were selected. They were then used as agents in the transfer of this technology as a part of Outreach Research Programme (ORP). They were involved directly with the new farmers, demonstrating the importance and describing the practicality of this method of trout farming. On the other hand, commercial farmers who were willing to get involved in a higher level of production in order to fulfill domestic and export market demand were encouraged and assisted under the technical supervision of NARC. This technology has successfully been transferred to the private sector on a small scale (Table 9, Figure 11). As trout culture has a great potential, it can be expanded widely in the future. Further expansion will depend on the overall situation of the country and its promotional activities.

Figure 9. Outreach programme for the verification of technology at a farmer's field in Birethati Parwat district, Nepal

Figure 10. Outreach programme for the verification of technology at a farmer's field in Satghumti, Dhading district, Nepal

Table 9. Some of the successful trout farms/farmers of Nepal and their production capacities

Main trout farm entrepreneurs	Number of raceway tanks (No.)	Area (m^2)	Production capacity (mt)
Government sector			
FRD, Godawari	19	247	5.0
FRC, Trishuli	44	2,122	10.0
Private sector (examples from Ranipauwa, Dhading)			
Mr. Gopal Lama	8	185	3.5
Mr. Chitra B. Lama	7	131	2.2
Mr. Padam Lama	6	101	2.0
Mr. Kancha Lama	3	25	0.8
Mr. Purna B. Lama	8	215	2.3

Figure 11. A private trout farm in Ranipauwa, Dhading district, Nepal

3) Market demand

There is usually a strong market for trout since it is in high demand both inside and outside the country. It can be sold directly to hotels in the capital, Kathmandu (e.g. Yak and Yeti, Mall Hotel, Shangri-La, Sunset View etc.), as well as to local restaurants in the towns. Tourists are the main consumers of trout in these hotels and restaurants. There is also a high demand for its export to other countries (e.g. Singapore); however, for export to be viable, the quality of fish produced should be high and reliable, and the production and supply should be regular and sizeable. Therefore, in order to be competitive in the international market, trout should be produced commercially to take advantage of the economy of scale so that cost of production and handling could be reduced. Although it is a relatively expensive fish, it has been accepted as a special delicacy and people are willing to pay a premium price for it. Recently, the domestic consumption of trout has increased due to its good taste and relative ease of preparation. There is great prospect for trout culture industry in Nepal; therefore, more private entrepreneurs and organizations should be attracted to this business.

VII. Secrets of Success

The success of rainbow trout culture in Nepal is due mainly to the research and development efforts put forth by NARC scientists and other collaborators such as JICA over the last decade.

Direct involvement of JICA/JOCV in research and human resource or capacity building has played a key role behind the success of developing the technology. Direct assistance/support for materials and development of physical facilities has been an important aspect of the cooperation.

Continuous and dedicated efforts of scientists and technicians under Nepal Agricultural Research Council (NARC), which conducts on-station and on-farm trials to suit various agro-ecological zones of the country, have played vital roles in making the success story. In addition, good cooperation among research institutions, development agencies, and the private sector for the testing and promotion of the technology in wider areas form the excellent grounds for its inception and expansion in which the scientists, policy makers, technicians, JOCV and farmers are working together in participatory mode.

Government of Nepal has played a supportive role for the trout research and extension activities rendering as a national interest that helps make the programme sustainable in the long-run. Therefore, introduction of rainbow trout as technical assistance from Japan, a joint effort signifies a successful cooperation between the Government of Nepal and JICA, Japan.

VIII. Prospects of Regional Cooperation

Other countries of the region which have cold-water resources, for example, India, Sri Lanka, Bhutan, Pakistan, Thailand, People's Republic of China, Vietnam and South Korea, could also benefit from trout farming. The trout industry has a good scope in the Asia-Pacific region, and regional cooperation can play a very important role in enhancing this industry. This could be done through the exchange of technology and germplasm using selected strains and varieties, joint meetings, seminars/workshops and visits, exchange of scientists/ technicians, human resource development, collaborative efforts towards research and development involving both public and private sectors for rainbow trout production and processing technology. Rainbow trout is in high demand for consumption due to its high nutritive value. As a result, India, Sri Lanka, Thailand, Vietnam and other countries have shown interest in its culture and other related activities including the transfer of the production technology. The knowledge and experience gained by the Nepalese experts could be utilized for the expansion of trout culture in these countries. Furthermore, international organizations such as the World Fish Centre, the Network of Aquaculture Centres in Asia-Pacific (NACA) and other private or public organizations and their respective governments, including Japan, could further strengthen R&D activities in the region through their greater involvement by way of financial and other logistic supports including the transfer of technology.

IX. Future Strategies for Research and Development

An integrated or inter-disciplinary approach should be applied for the research and further development of the trout industry. An effective programme for mass production should be developed and launched through the appropriate research and development of low-cost feed formulated from locally available ingredients as well as criteria for selecting appropriate sites for trout farming.

Realizing the economic value and the future prospects of trout farming in Nepal, NARC has recently developed a complete package of culture techniques. As trout culture is a new venture that has high profit margins with a relatively higher initial investment, private entrepreneurs have been encouraged and efforts have been made to expand the industry by providing technical support from NARC. The trout farming industry can be a major source of income, especially for the people in the hills and the mid-hills of the country. In order for this to succeed on a large scale, sufficient attention has to be given to its promotion by the government and other related organizations.

Overall, research and development efforts have to be focused on the following aspects:

1) Breeding and seed production

The most important and crucial part of trout farming is the breeding and nursing of fry. The best breeders should be identified and selected for mass production in order to supply sufficient numbers of high quality fingerlings to the growers. Either the government or the private or both the sectors should maintain quality broodstock to ensure grow-out farmers receive quality seed so that they will be able to maximize production and profit.

2) Feed industry

As the feed cost comprises about 50% of the total cost of production (e.g. a case study provided earlier in Table 8), the success of trout farming depends on the quality and quantity of feed supply available. The cost of producing food can be relatively high due to the high protein diet that trout require. Therefore, the government may need to establish or subsidize the manufacturers of trout feed so that quality feed can be supplied at a low price to trout farmers. The mixture of different levels of defatted soybean meal, corn gluten meal and meat meal could replace up to 90% of the fishmeal to be used if the combination of these ingredients produces the profile of amino acids comparable to the fishmeal diet (Juadee and Watanabe 1993). However, research needs to be continued to search for locally available cheaper alternative ingredients for fishmeal so that manufacturers can produce low-cost feed.

3) Introduction of promising trout diversity

The present successes have been achieved utilizing a narrow range of trout germplasm introduced from Japan in 1988. For further development and expansion of trout industry in Nepal, widening the genetic base is essential which can be done by introducing more promising/proven strains of trout from other trout producing countries and through exchange of available technology. However, this activity needs to be well-planned for along with continuing research and testing. Although, trout is farmed in closed system, they will eventually escape and may breed in the wild, for example, rainbow trout has established its population in the wild through self-recruitment in some upland reservoirs and streams of India (Gopalakrishnan et al. 1999). Therefore, more research has to be carried out to investigate the risks that trout may pose to indigenous species and their habitats which may eventually lead to their extinction.

X. Other Developmental Constraints/Concerns

The preceding account amply points out that trout farming as well as in achieving success in this endeavor is not as simple as one may think, as various obstacles need to be overcome. Based on national experiences as demonstrated through the work carried out, promotion and establishment of the trout industry requires a well-integrated joint effort of national and international organizations, including the participation of the private sector. Good planning, careful management and dedication are essential. The following aspects need more emphasis:

1) Reliable source of cold water vis-à-vis site selection

Trout are very sensitive to the quality and supply of the water. Disruptions and fluctuation of water may negatively affect the trout and can cause heavy losses. Sites should be selected carefully where a sufficient supply of continuously flowing, good quality cold water exists. The water should have no turbidity or should be very clean. Road access to and distances between the hatchery and the grow-out farms should be considered when selecting the sites. A reliable electricity supply is one of the most essential necessities for trout farming.

2) Investment

As trout need clean water, they need to have primarily concrete tanks. The significant investment required for tank construction could be a main constraint. Unlike other fish species, trout production depends on quality feed and skilled manpower in order to manage operations properly and successfully. For these reasons, trout culture is normally costlier than the culture of carp and many other fish species. Therefore, in order to encourage private farmers, the government should make provisions for farmers to get low-interest loans for capital investment and should subsidize feed and/or feed ingredients, related equipment, fry transportation etc. to promote trout aquaculture.

3) Skilled personnel

For the expansion of trout farming commercially, a national programme needs many technical experts who have knowledge, skill and experiences in trout culture. The government should, therefore, provide training opportunities, either in country or abroad, to the scientists and technicians for the technical backstopping. The government should also monitor the private farms regularly, continuing the necessary research to develop appropriate techniques suitable for local conditions.

4) Market

In the initial stage of trout farming only the domestic market will be consuming the fish produced. It has been found that many hotels and restaurants are always in need of trout. However, there is not enough trout being produced to satisfy the demand, though production is increasing. There is a need to publicize the benefits of trout in order to create a market with local consumers. Appropriate media and other consumer awareness campaigns that increasing information through materials produced in the local languages would be the best means for achieving this. After the expansion of the market, good transport facilities and appropriate methods for packaging the trout will be needed. More importantly, if the volume is high and the quality can be maintained, there will be opportunities for processing and export to neighbouring countries and even overseas.

5) Diseases

Occurrence of disease has been one of the major challenges for trout culture in Nepal. The main problems are bacterial and fungal diseases e.g. *Columnaris* and others that cause tail and fin rot, gill diseases and abdominal dropsy. Another problem is related to the feed and feed quality e.g. *Hepatoma* i.e. enlarged and hardened pale lever which has been suspected to be due to afflatoxins. As the cure of fish disease in aquaculture has proven to be difficult as well as expensive, it is advised that preventive measure should be considered. The following conditions contribute to the occurrence of trout diseases: i) high water temperature (>20°C), ii) high stocking density and excessive feeding, iii) poor feed storage, iv) nutritionally deficient diets (more likely if on-farm and cheap feeds are prepared), v) excessive nitrogen gas i.e. >0.4 ppm in water, vi) turbid and polluted supply of water, and vii) poor circulation of water.

A farmer can avoid these conditions by following proper farm management practices. Regularly cleaning the system, avoiding the inflow of the turbid and polluted water into the trout fish tanks and removing the uneaten feed and excreta frequently have been found to be the best ways to prevent outbreak of disease.

XI. Epilogue

Trout farming has ultimately become a success story in Nepal after more than a decade of continuous and untiring efforts. The introduction of rainbow trout has opened a window of opportunity to enhance the commercial production of cold-water fish species in Nepal and has encouraged the people of the mountainous and hilly regions. A fully established trout culture industry could be one of the best means to reduce wide-spread poverty in high-land areas of Nepal. Trout farming can play a greater role not only by generating income for farmers but also by providing job opportunities to others involved in associated businesses/activities such as processing marketing. Further, in addition to increasing national fish production, exporting trout would help to earn foreign exchange. As a sport fish, trout production could also help to enhance a country's eco-tourism industry by providing fishing spots.

Adoption by commercial producers is the key indicator of the success of an effective transfer of technology. The government expects many farmers to get involved in trout farming. As a result, it has also laid emphasis on the potential environmental impacts on the cold-water bodies. However, because there is huge unutilized cold-water resource availability in the hilly areas, this should not be a major problem.

Undoubtedly, in view of the above findings and considering that the warm water bodies are limited in the Terai region of Nepal for the expansion of aquaculture, trout farming offers a better alternative and greater contribution, particularly to the livelihood of the people living in the mountaineous region of Nepal. In order to expand the industry, the government should initiate suitable measures by subsidizing trout production as well as providing technical support to the growers/ farmers. Further research and development of methods and technology are also necessary. Through this success story focusing on Nepal's experience with rainbow trout culture, considerable benefits could be derived for other parts of the Asia-Pacific region where similar resources and environments favourable for trout culture exist. In this context, APAARI, as a regional forum, has been instrumental in promoting such initiatives and highlighting the successes achieved by the NARC in the region through information dissemination and technology transfer.

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