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Small-scale Aquaculture for Rural Liveliboods

Edited by
Madhav K Shrestha
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Proceedings of the Symposium on 'Small-scale Aquaculture for Increasing Resilience of Rural Livelihoods in Nepal'
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Preface

Over the years, aquaculture has developed as one of the fastest growing food production sectors in Nepal. However, local fish supplies have been extremely inadequate to meet the ever increasing demand in the country. Nepal imports substantial quantities of fish and fish products from India, Bangladesh, Thailand, and elsewhere. Integration of pond aquaculture in existing crop-livestock-based farming system is believed to be effective in increasing local fish supply and diversifying livelihood options of a large number of small-holder farmers in southern plains (terai) and mid-hill valleys, thereby also increasing resilience of rural livelihoods. There is growing appreciation of the role of small-scale aquaculture in household food and nutrition security, income generation, and empowerment of women and marginalized communities.

This book includes a total of 25 papers presented at the 'Symposium on Small-scale Aquaculture for Increasing Resilience of Rural Livelihoods in Nepal', held in Kathmandu on 5-6 February 2009. The papers cover technological, social, economic and environmental aspects of small-scale aquaculture development emerged from research and development initiatives of governmental, non-governmental and international research organizations in recent decades. All the papers have been reviewed and updated for their inclusion in the book.

We would like to thank all the authors for their contributions and also for their timely responses to our queries during the review process. Editorial assistance of Ms Anita Pandey Pant is thankfully acknowledged. We also thank Mr Jeevan Marimothoo for his help in cover design. Funding for the publication of the book was provided by the WorldFish Center, Penang, Malaysia and Institute of Agriculture and Animal Science, Tribhuvan University, Nepal. Our thanks are also extended to the organizers of the Symposium, which include a total of nine national and international organizations, namely Institute of Agriculture and Animal Science (IAAS), Tribhuvan University, Nepal; Nepal Agriculture Research Council (NARC), Nepal; Directorate of Fisheries Development (DoFD), Department of Agriculture, Nepal; Nepal Fisheries Society (NeFiS); Plan Nepal; Canadian Cooperation office/CIDA Nepal; Nepal Academy of Science and Technology (NAST); The WorldFish Center, Penang, Malaysia; and Asian Institute of Technology (AIT), Thailand.

We hope this book will be useful to planners, researchers and development workers in carrying out aquaculture research and development activities aimed at diversification of livelihoods in small-scale farming system contexts.

Editors

Contents

Fisheries and aquaculture policy for education, research and extension in Nepal

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Abstract

Fisheries and aquaculture policy for education, research and extension is derivatives of the main national agriculture policy. Fisheries and aquaculture is a dynamic sub-sector of agriculture sector having high growth potential but with low organizational stature in Nepal. The modern aquaculture along with fisheries practices contributes nearly 1% of Gross Domestic Production (GDP) and 2.68% of Agriculture Gross Domestic Production (AGDP). This positive achievement of the sub-sector, contrary to others whose contribution in GDP has declined over the years, suggests its popularity among farmers. Similarly, Government of Nepal has recognized the importance of fisheries and aquaculture for nutritional supply and poverty reduction. The primary objective of the national fisheries and aquaculture policy is to contribute to economic growth and poverty reduction through inclusive, equity- based and Ecosystem Approach of Aquaculture (EAA). Specific laws and legislation on aquaculture development have to be formulated or enforced for building capacity and facilitating entrepreneurship, especially in the context of the World Trade Organization (WTO). Besides, Best Management Practices (BMPs) also need to be identified and adopted to achieve sustainable growth of the sub-sector.

Keywords: Policy; Legislation; Aquaculture; Fisheries; WTO; Research; Extension; Education

1. Introduction

Overall fisheries activities in Nepal are primarily governed by policy laid down by the government (MoAC, 2009). Fisheries have a long-rooted tradition and custom in Nepalese society. Aquaculture is a relatively new and dynamic sector of agriculture in Nepal (APP, 1995). The growth rate of fisheries and aquaculture sector is more than 9% in the last decade (FPP, 2000). Experiences have shown that there has been a significant impact of fisheries and aquaculture development on communities in terms of relatively high returns on investments compared to other agriculture sub-sectors (Mathema, 1992; FPP, 2000). Fish farming is currently one of the popular agriculture enterprises among Nepalese farmers. The aquaculture in the country started with the introduction of carps in the early 1950s (Woynarovich, 1975).

Government of Nepal has recognized the contribution of aquaculture to poverty alleviation, and food and nutritional security. Fisheries and aquaculture development has been prioritized, with special attention paid to productivity and production enhancement (MoAC, 2009; NARC, 2010). As per the current national plan, fisheries has been focused as a tool for mainstreaming deprived, marginalized and poor communities in the society (NARC, 2009; NARC, 2010). The specifc attention is on livelihood improvement and poverty alleviation for economic growth through active participation of deprived and poor communities.

2. Vision of fisheries and aquaculture policy

The vision of fisheries and aquaculture policy is transformation of small-scale fisheries into competitive and commercial aquaculture.

3. Objectives of fisheries and aquaculture policy

For achieving food security, poverty alleviation and sustainable economic development, transformation of small-scale aquaculture into competitive and commercialized sector has been envisaged. The main objectives of the fisheries and aquaculture policy are to:

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- Increase fish productivity and production;
- Strengthening the foundation of commercial aquaculture to make the product competitive in regional and global market; and
- Utilization, promotion and conservation of natural resources, fish biodiversity and environment.

4. Fisheries and aquaculture policy

To achieve the above objectives by mobilizing resourceful and resource-poor communities, the following specific policy measures have been adopted.

4.1. Aquaculture production and productivity enhancement

- Based on local feasibility, comparative advantage, and specific opportunities, suitable technologies will be developed, scaled up and extended to increase fish production and productivity. In addition, commercialization and diversification of aquaculture production will be promoted for income and employment opportunities.
- The sloppy land on hills will be used for increasing fish production through developing cold water aquaculture technologies.
- In the North-South road corridor, high-valued fish production will be prioritized.
- Based on the local need, specific fisheries programs will be implemented and subsidized.
- For the extension of food and nutritional technologies, farmers' group will also be mobilized, through government extension services and Institute of Agriculture and Animal Science (IAAS), Tribhuvan University, Chitwan. For fisheries extension, media will be used to provide information services to the stakeholders.
- Fisheries and aquaculture research that is compatible to specific location will be promoted through competitive grant system.
- National and international collaboration on fisheries research and extension will be promoted through exchange of technologies and experts.
- International and private investment will be encouraged to enhance fisheries and aquaculture sub-sector.
- Supply of the main production material such as fingerlings will be monitored and guaranteed.
- Bank loan will be made available for the promotion of aquaculture.
- An insurance system for commercial aquaculture development will be promoted.
- For capability enhancement, of the farmers, various training programs will be organized.
- For sustainable human resource development, establishment of agricultural university in the country will be made a priority. There will also be a provision of expert exchange among academic institutions, research and extension related institutions.
- Women's participation in all sectors will be encouraged up to 50%.
- Common water bodies, such as community ponds, lakes, rivers, reservoirs and swamps, will be leased for fisheries and aquaculture activities to the deprived, marginalized and poor.

4.2. Promotion of commercial aquaculture

- For the promotion of commercial fish production, pocket or large potential areas will be identified. In such areas, support services will be furnished in an integrated manner.
- In suitable locations, government farms will adopt Double Track Model, or lease out farms for cooperatives management.
- For high-value organic farming, use of hybrid and high-yielding species will be prioritized as far as possible.
- Local and indigenous knowledge of fish production will be promoted for identification and registration
- Special opportunities to educate the unemployed youth will be provided.

4.3. Natural resource management

- Eutrophication of water bodies will be regulated.
- Degraded water bodies will be restored, conserved and used.
- In-situ and ex-situ measure will be promoted for biodiversity conservation.

5. Implementation and monitoring management

To monitor and evaluate the special projects and regular achievements, participatory approach will be adopted.

6. Fisheries and aquaculture educational network

The importance of education in the fisheries sector got priority during the 1980s (Mathema, 1992). Fisheries trainings are provided to farmers, entrepreneurs, national and international personnel. Tribhuvan University, through its affiliated institutions, also provides basic fisheries and aquaculture education. In general, following institutions are engaged in different knowledge-based supportive activities related to fisheries research, development, and extension activities:

- Tribhuvan University for education and scientific research;
- Nepal Academy for Science and Technology (NAST) for scientific research; and
- Nepal Fisheries Society (NEFIS) for technical partnership.

7. Fisheries and aquaculture research network

Fisheries and aquaculture research was prioritized in the early 1990s, as a result of which Nepal Agricultural Research Council (NARC) - an autonomous public institution - was mandated to conduct fisheries and aquaculture research. The former focuses on capture fisheries and conservation aspects, while the latter is more culture-based, applied and productivity-related. NARC has the following fisheries research institutions:

- Tarahara and Parwanipur Fisheries Research Programs under the Regional Agricultural Research Centers for warm water aquaculture;
- Fisheries Research Center Pokhara for lake and reservoir fisheries;
- Fisheries Research Center Trishuli on riverine species; and
- Fisheries Research Division Godawari on cold water fisheries.

8. Fisheries directorate for extension

The Directorate of Fisheries Development (DoFD) under Department of Agriculture, Ministry of Agriculture and Cooperatives is responsible for fisheries and aquaculture extension-related policy and implementation. It also coordinates with national and international institutions with focus on fisheries extension (FPP, 2000). The Directorate performs its work through the following major institutions:

- National Inland and Aquaculture Development Program
- Central Fish Laboratory
- Fisheries Development and Training Center
- Fisheries Development Centers situated in different districts
- District Agriculture Development Offices
- Agriculture Development Bank for credit facilities and services

9. Legislation for aquaculture trade promotion

Specific legislation on aquaculture production, development and extension has not yet been formulated or enforced in the country. The aquaculture industry finds this of utmost concern to increase its contribution in fish production. Moreover, specific legislation will be needed for sustainable growth of aquaculture sector, in view of the challenges and opportunities relating to the World Trade Organization (WTO).

10. Legislation for aquatic animal protection act

The importance of fisheries resource conservation was realized long ago in the country. As a result, the Aquatic Life Conservation Act 1961 - "*Jalchar Sanrakshan Ain - 2017*" was promulgated but its execution is limited due to lack of rules and regulations. The Act was revised and amended in 1999 (2056 BS). The amendment has now covered restrictions on killing and capture methods of specific vulnerable and rare fish species. Provisions of punishment to culprits, obligations of citizen and role and responsibility of local and technical authorities have also been included. The Act has also provisioned for establishment of fish hatcheries in regulated water bodies like-hydropower reservoirs and irrigation dams. The Actstill needs additional rules and regulations for its smooth implementation.

Acknowledgments

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Small-scale aquaculture: Global and national perspectives

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Abstract

Fish has been a staple food for over a billion people. Its demand is increasing due to growing population and awareness about health benefits of aquatic animal food. Disappointingly, wild catch worldwide is on the decline and aquaculture is emerging as the only solution. It grew at 9%/yr in the last 10 years becoming the fastest growing food production sector. At present, aquaculture produces only about 45 million t per year but it needs to be doubled by 2030 to meet its growing demand. Asia produces over 85% of the global farmed fish - mostly by small-scale farmers. Nine of the top 10 fish producing countries in the world are in Asia, all of which started from small-scale aquaculture. Small-scale aquaculture has not only supplied animal protein to the rural poor but has also generated income. Apart from this, it has also served as a gateway to commercial farming and export earnings, e.g., pangasius farming in Vietnam and shrimp in Thailand. Total fish production in Nepal is estimated at about 45,000 t/yr supplying less than 2 kg/caput which is far below as compared to the neighboring countries. Protein intake from animal sources in the country is only about 10%. Furthermore, over half of the total fish consumed comes from India. The country plans to construct more dams to increase electricity generation which will seriously affect natural fish stock. Cage culture in reservoirs, trout farming in hilly areas and backyard fish farming in integration with agriculture in rural areas need to be promoted through government support, donor assistance and international collaborations.

Keywords: Small-scale aquaculture; Aquaculture success stories; Aquaculture extension

1. Global perspectives

1.1. Aquaculture/fisheries in general

Fish is a staple food for over a billion people in the world. It is well known for its lean and white meat with low fat and cholesterol levels. Diet-conscious people, especially in the West, are shifting from red to white meat (such as chicken) and then towards seafood, whereas consumption of aquatic organisms is a tradition in Asia and many other countries that are adjacent to sea. Because of the shifting consumption behavior coupled with ever increasing population, demand for fish is steadily increasing. At present, about 160 million ton of fish - captured and farmed - is produced annually, out of which only about 106 million ton is used for human consumption (FAO, 2006; De Silva and Davy, 2010). The remaining is used as feed for livestock and fish or lost during processing/handling. About half of the fish consumed by human is now farmed. Disappointingly, catch from the wild has either reached to the maximum point or even declining. Researchers have claimed that most of the species will disappear from the sea if the consumption pattern, catch level and other human activities keep increasing continuously (BBC, 2006), indicating that we have to culture ourselves if we want to have fish as a regular diet. Fish farming grew by 9%/yr in the last 10 years, becoming the fastest growing food production sector. Therefore, it has been considered as the only solution to compensate the decline in wild catch. At present, aquaculture produces only about 45 million t/yr but it needs to be doubled by 2030 (80 million t/yr (FAO, 2006) or has to reach at least 50% more production level by 2020 (De Silva and Davy, 2010). It is possible only if a significant technological break through - often termed as Blue Revolution - takes place. Asia is a hub of aquaculture development which produces over 85% of the global farmed fish, mostly by small-scale farmers. Nine of the top 10 fish producing countries in the world are in this continent, all of which started from small-scale aquaculture.

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The annual production of aquaculture products is valued at about US$ 70 billion. The trade (export and import) of fish is higher than that of meat, dairy products, cereals, sugar, or coffee. A large portion of the aquaculture products are still consumed at home or sold in domestic markets. The value of such products traded globally is approximately US$ 18 billions per year, out of which 90% comes from Asia and 75% from developing countries. China and India remained the top two, probably because of their size and population. They both started fish culture as a tradition a long time ago. China realized the value of aquaculture well and gave a high priority to its development. It is the only country which produces more than the wild catch and has always been on the top position, whereas in India, even though fish culture is a tradition, aquaculture has not been widely adopted probably because a large proportion of its population (at least a third) is vegetarian. Other top five fish producing countries are also from Asia, namely Indonesia, Bangladesh, the Philippines, Japan and Thailand. These countries produce fish for their domestic market as well as for export.

1.2. Small-scale aquaculture

Almost all (98%) of the world's small-scale fish farmers are in developing countries - mostly in rural areas. In many communities, fish farming has been practiced as a tradition. Fisheries and aquaculture employs over 40 million people worldwide. It contributes significantly to the daily diet such as in Cambodia, where fish accounts for up to 75% of the total animal protein intake. Fisheries and aquaculture contribute about 6% of the Gross Domestic Product (GDP) in Laos. Various reports have shown that there are over a million fish ponds in Bangladesh - mostly belonging to the poor, which are often called fish factories. Bangladesh earns about US$ 0.5 billion from fish exports from which small-scale farmers are also receiving direct benefits. Fish farming has proved its potential to increase their income up to four times, especially from prawn farming in rice fields. The country earns about US$ 400 million a year from shrimp and prawn export (Nesar, 2009). An increase of 28% in the income of farm families was possible in Malawi through a fish farming intervention. Cage farming in Cambodia and Vietnam has also provided shelter to the landless people who live on the water, popularly known as "floating villages".

Small-scale aquaculture also serves as an entry to commercial aquaculture. Being small and less risky, it can be adopted easily by resource-poor farmers. Upon learning the farming techniques, they can scale up it if they find it comparatively advantageous. Shrimp culture in Thailand, which is valued at about US$ 2 billion annually over the last two decades with a large proportion related to export, was started as a small-scale enterprise and may still remain like this only. More recently, pangasius culture in Vietnam has made a dramatic turn to commercial level, the total value of which is about US$ 1 billion per year since 2007 (Phuong et al., 2008). The majority of the farmers (72%) are still relatively small-scale (Phan et al., 2009). Shrimp culture in Thailand and pangasius culture in Vietnam play a considerable role in foreign currency earning in these countries and also in job creation for the local people both directly and indirectly. For example, a single processing plant in Vietnam employs over 1,000 persons, most of whom are women. The position of these women in the household has improved by virtue of their stable earnings.

2. Aquaculture: National perspectives

2.1. Present status

Directorate of Fisheries Development (DoFD), Ministry of Agriculture and Cooperatives has estimated that total fish production (catch and culture) in Nepal is about 46,000 t for 2008. FAO statistics also show an impressive double digit annual growth (Fig. 1). However, fish farming is concentrated in Terai region (southern plains) (90%) and mainly in earthen ponds (95%). Average productivity of ponds has been achieved at 3.6 t/ha with limited amount of inputs and no commercial feed. Existing system includes occasional feeding of rice bran and cakes without any regular fertilization. There is a scope for intensification by promoting on- farm feed using locally available ingredients, in addition to regular fertilization of ponds with urea and di-ammonium phosphate (DAP). Considerable improvement in the production can be achieved through an effective extension program.

Based on the FAO data (2006), silver carp has been the number one species produced in the country, followed by grass carp. Grass carp has not received adequate attention for semi-intensive farming as in China where it is considered the most important species for polyculture. Emphasis on using grass carp could further enhance productivity. Although rohu (*Labeo rohita*), catla (*Catla catla*) and mrigal (*Cirrhinus mrigala*) are widely cultured especially in polyculture systems, their production has been reported only after 2002. Similarly, African catfish farming has rapidly expanded in recent years mainly because it can be cultured in small ditches and even in dirty water with high density. However, its further expansion is questionable. As it is carnivorous in nature, it can be a big threat to local indigenous species and farmers face feeding problem as well. Some are using chicken and livestock viscera, while others are struggling to collect snails, tadpoles and other aquatic organisms from the wild. Similarly, attempts have been made to promote Nile tilapia (*Oreochromis niloticus*) as it breeds easily in any culture systems without requiring hormone injection. This means farmers in rural areas do not need to purchase fry and fingerlings from the hatcheries repeatedly. However, it has not been promoted adequately fearing that this species also affects natural habitats of indigenous species and compete with them for food. Biodiversity and environmental concerns have presently received overriding attention compared to the rampant malnutrition and food insecurity. Although this is a never-ending debate, in a country where the majority of people are suffering from malnutrition and low income, biodiversity conservation and environmental issues should get low priority (Stewart and Bhujel, 2007). However, promotion of indigenous fish species has been one of the main agenda of the government. Basic principle is that indigenous species are assumed to have had better adaptation to local environment. Breeding programs for two of such species - sahar (*Tor putitora*) and asala (*Shizothorax sp.*) - have been carried out. Although they are highly preferred fish, their slow growth hinders farmers to adopt them for commercial purpose. More research is needed as regards to the type of fish to be promoted but time is running out; farmers cannot wait for a new technology to be developed when techniques and species are already available domestically or can even be imported easily. The promotion of exotic species and the development of culture techniques of indigenous species should go side by side. Considerable efforts have been made in the development and transfer of technology for rainbow trout culture (Rai et al., 2005). However, it has not been expanded as it was expected for various reasons. One of them might be the high capital investment for the construction of facilities and need of specialized care as the fish is very sensitive to water quality fluctuation. Arranging high investments and managing risky businesses require capable and willing entrepreneurs which is lacking in the country. In order to expand trout culture widely, either existing techniques have to be subsidized heavily or new cheaper techniques/systems need to be developed through research.

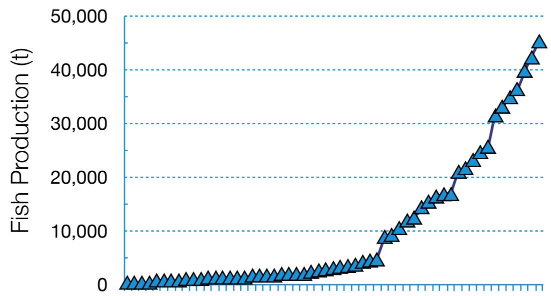

Fig. 1. Annual total fish production (t) (catch and culture) in Nepal.
Source: FAO, 2006

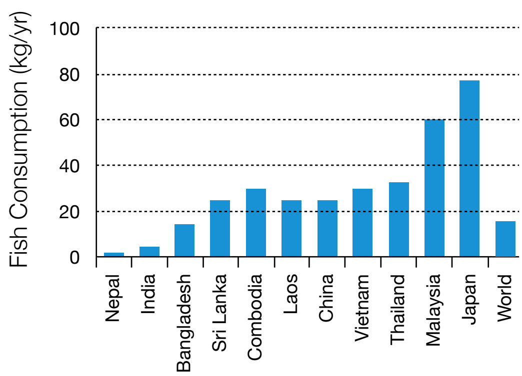

Fig. 2. Annual per capita fish consumption (kg) in various countries.
Source: FAO, 2006

From the viewpoint of human health, about 33% of the total protein should come from animal sources (AIT, 1994), whereas it is only 10% in the case of ordinary people in Nepal. Based on this fact, at least a three-fold increase in the animal protein supply is required. Similarly, it is estimated that over 80% of the fish consumed in major cities of Nepal come from India (Tiwari, 2008). To be self-sufficient, production thus needs to be doubled. There is general consensus that the consumption and import of fish have dramatically increased in the past few years - mainly from India, which was also observed by the author during his visits to various shops in Chitwan and Kathmandu. It was found that almost every shop was selling rohu, pangasius catfish and even some marine species which had come all the way from Bengal or Andhra Pradesh of India loaded in trucks with ice. Consumption of fish is increasing probably because of the increased awareness of the health benefits of fish such as low fat, well-balanced amino acids and w-3 fatty acids, and increased prices of other meat products. Growing import is inevitable as catches from the rivers and lakes have declined. However, no reliable data are available so far and more research is needed on this aspect. Nevertheless, annual per capita fish consumption (less than 2 kg) is far below as compared to other Asian countries (Fig. 2). Even in India, where at least a third of the population is vegetarian, annual per capita consumption is still over 5 kg. The same for Bangladesh, which is known as fish-eating country in South Asia, is over 15 kg and for most of the Southeast Asian countries well over 25 kg. Although Japan is considered to be a seafood-loving country with annual per capita consumption of 77 kg, the Maldives, where main occupation is fisheries and every item of the diet consists of fish or fishery product actually tops the list with 190 kg (FAO, 2006). These facts demonstrate that Nepal is far behind and needs a lot of efforts in promoting small-scale aquaculture by setting immediate and long-term objectives. Immediate need is to increase awareness among rural communities about the backyard fish farming, while in the long term, private sector should be encouraged. Agriculture Prospective Plan (APP) targets 2.3 kg per caput by 2018, which might have been already achieved. As there is no reliable data collection mechanism in place, fish catch, production and consumption figures provided by the government are mainly based on the estimates. The target was perhaps determined while political uncertainty was engulfing the country, leaving little hope for any development. Current development indicates that out of a growing interest among people and various organizations, production and supply have increased considerably. Therefore, a new target should be set in the context of political change and subsequent change in the aspirations of the people, considering the demand to be created by chain reactions of various other factors such as tourism and potential of export market. As the country plans to attract more tourists, there will be bright scope for the fish farmers to sell their products in hotels/restaurants at high prices and earn good incomes, in addition to supplying for the family consumption only.

2.2. Some success stories

Nepal already has typical success stories in aquaculture and fisheries. These tested models should be highlighted and scaled up for their expansion throughout the country and some of the potential systems from abroad should also be adopted with necessary modifications. Some of these are briefly described in this section.

2.2.1. Cage culture

The cases of roaming fisher communities converted to permanent settlers practicing cage culture, in addition to fishing in lakes (Phewa and Begnas) and reservoir (Kulelkani), is a unique example. Based on a recent research, on an average, a fisher family living around Phewa lake is earning about 13,000 NRs/month (nearly US$ 200), which is considerably high. Management effort on the part of the user groups of lakes and reservoirs has been very successful. This should be promoted to other areas of the country where there are unused lakes, reservoirs and swamps, for the benefit of local communities, especially the landless.

2.2.2. Tanks and raceways

Research and development in Rainbow trout farming has proved that it is also possible to promote even exotic species and the associated technology. For various reasons, it has though not spread as widely as it was expected. Trout farming could utilize abundant clean and cold waters of mountainous parts of the country if the techniques are made cheaper and easily adoptable by the poor people in rural areas. For example, finding ways of reducing tank construction costs and developing methods of producing on-farm feed locally are necessary. One of the ways to reduce cost might be using plastic liners in earthen ponds.

2.2.3. Commercial pond aquaculture

The first phase of aquaculture development project, which was started in 1980, has shown that relatively better-off farmers are interested in producing fish at a commercial level. Most of them have larger ponds of over 2,000 m^2 which were constructed from loans under a government scheme. They are found mainly in central and eastern parts of Terai. In some of the areas these farms are organized in groups / clusters (such as those in Shankar Chowk and Madi of Chitwan). There is growing appreciation that such cluster- based approach is likely to be an ideal commercial aquaculture model in the country.

2.2.4. Backyard pond aquaculture

Women in Aquaculture (WIA) project, launched in Chitwan and Nawalparasi since 2000 by Asian Institute of Technology (AIT), Pathumthani, Thailand and Institute of Agriculture and Animal Science (IAAS), has been considered one of the successful initiatives under which small-scale aquaculture has been promoted by initially forming women's groups and later organizing them in cooperatives. The conceptual model (Shrestha et al., 2009; Bhujel and Shrestha, 2007; Bhujel et al., 2008) includes formation of fish farming groups (15-20 farmers/group); construction of small family fish ponds (~200 m^2) close to home; fertilization of the pond water to enhance natural food (green water); use of kitchen wastes and on- farm byproducts as feed inputs; and vegetable farming on the dykes using fertile pond water. Results showed year-round nutrition supply (40% fish consumed) and a cash income from the sale of the remaining (60%) of the total fish produced. Among the vegetables, pumpkins, gourds or other summer vegetables hanging over the fish ponds at the corners or along the dikes are popular in Bangladesh and Vietnam and could be worthwhile trials elsewhere. The model has been found highly successful as evidenced by increase in the size of existing ponds or construction of additional ponds. This is now under expansion in Mid-western (Lamjung and Gorkha) and Western (Banke, Bardia and Kailali) parts of Nepal, with the support of Aquaculture without Frontiers (AwF) and United Sates Agency for International Development (USAID), respectively. As a result, over 2,000 family fish ponds have already been constructed (Pandey et al., 2009). Similar effort on the part of the government and other development organizations is needed.

2.2.5. Rice-fish/prawn culture

Fish culture in the rice fields has been reported in various parts of the country but with little success. It requires at least one year of culture cycle, whereas rice is harvested in 3-4 months. Various reports have shown that nursing of fingerlings is more suitable for this short period. Another option is to culture fast- growing fish such as tilapia. Social factors affecting rice farming are overlooked by many organizations. Poaching is unavoidable if fish are stocked in the fields that are far away from home. Therefore, rice fields that are close to home might be suitable for fish farming. Growing freshwater prawn (*Macrobrachium rosenbergii*) with rice has now been the most promising option. One of the Royal Thai Government (RTG) projects in Thailand has demonstrated that 200 m^2 pond can yield 10 kg of rice giving only 120 Baht (approx. NRs 240), while growing prawn together can earn more than 10 times revenues (up to 1,300 Baht or NRs 2,600). A similar system has alsobeen practiced in Bangladesh, generating up to 4 times returns on investment. Most of the farmer culture prawns in small rice plots. This still has good potential of reducing poverty among thousands of people as they can be sold at high price. For instance, their price in Kathmandu goes up to NRs 850/kg. Realizing this, AIT and IAAS are working together, distributing about 20,000 post-larvae introduced from Thailand to the farmers. Research has shown that the farmers have been successful in growing prawns and now asking for seed which is the main constraint. Prawn breeding program is underway at IAAS. Hopefully, seed can be produced and supplied to the farmers in the near future.

2.2.6. Fish-livestock

Many people might think that fish farming is alternative to animal husbandry but the both can be actually very well integrated, using urine and litters of animals as pond inputs. Ducks is the most suitable species as they like water. Buffaloes, which need water for wallowing, can be another option. Poultry farming over fish ponds, which is quite popular in Thailand at a large commercial scale, can be another possibility. Efforts were also made to promote this in Nepal. However, it was not adopted widely. The possible reasons are yet to be analyzed. Traditionally, pigs are reared over or at the side of fish ponds in Vietnam. Possibility of rearing goats by the side of fish ponds should be explored in Nepal since goat meat is preferred most and each family requires at least one for annual Dashain festival.

2.3. Comparative advantages

During the symposium on small-scale aquaculture held in Kathmandu on 5-6 February 2009, the then Right Honorable Prime Minister said that small-scale aquaculture would be promoted as a campaign and that it would form part of action for building “New Nepal”. The fundamental question to be posed by the people then would be: Why is small-scale aquaculture a better alternative as compared to others? Extension workers and promoters should be able to answer this question showing comparative advantages of small-scale aquaculture in relation to their local contexts. Some of them are described with examples in this section.

Rice is the main crop in Nepal and farmers allocate the majority of their lands to its cultivation. A rice-growing farmer would obviously compare between growing rice and farming fish before taking a decision to construct a pond. Various data have shown that average production of rice is about 4 t/ha per crop. The same amount of fish can easily be obtained from the same area of land with even limited input. But the price of fish is 10 times that of rice whichmeans that farmers can get 10 times higher revenue. With regards to time and labor use, rearing fish requires a lot less - about a fourth. Housewives and children can easily take care of fish without any additional burden once they are stocked. Unlike other animals, fish do not require frequent watering and feeding. For these reasons, fish farming has become so popular that rearing large animals is rapidly declining in Thailand and other parts of Southeast Asia. Milking cows/buffaloes needs very intensive care around the clock. Although milk is considered a good diet for children and adults, compared to fish, it supplies little amount of protein; 100 g milk contains 4 g protein (if no water is added), whereas 100 g fish (75% DM) has about 40 g protein. Among the people of Nepal, the most preferred meat is of goat. With the decrease in pasture/forest, goat farming is also on the decline. As a result, goats are becoming rare and their meat is getting expensive, i.e., over NRs 400/kg, whereas the price of fish is only around NRs 100- 150. Even to celebrate Dashain, people in towns have to wait for the herds of goats to arrive from the high hills or Tibet. In view of the frequency of consumption as well, it is not a suitable option. In order to slaughter a goat and have meat in rural areas, the whole village or a number of families have to come together and share the meat, which can be possible only once a month or even once in 3-4 months. Hence, frequency of meat consumption is very low even for those who can afford it. Recently, commercial chicken farming in Nepal has taken off in some Terai districts (e.g., Chitwan) and peri-urban areas. Raising a few chickens at home is also a tradition in some communities, especially for festivals and to treat guests. The country is said to have become self-sufficient in chicken meat and eggs. In rural areas, farming is still carried out in a conventional way though. Since chickens consume anything they get, including wastes, they are reared in an open area, which is absolutely unhygienic. Besides, the locally-raised chickens are so expensive that they may cost over NRs 300/kg and have very little amount of meat. Compared to vegetables, meat items are becoming either rare or expensive, which has restricted the common people’s access. As an alternative source of protein, fish farming has a good scope to fill this gap, if promoted adequately and appropriately.

3. Policy implications

3.1. Water resource utilization

There are plenty of water resources in Nepal, although it does not have coastal areas. Over 6,000 rivers and streams, which are flowing down to India, could provide water for aquaculture development in the country. However, only their potential for electricity generation has been recognized well. This has over shadowed their contribution as sources of fish for various communities living along the banks. While electricity is important for the daily life of the people and for industrial development, the country should not overlook the need for natural food supply. Indeed, one can argue that food security should come first. At the same time, the present electricity crisis has hit the whole country so hard that any power project cannot be stopped either. There is a need for consideration of fishery resources while developing electricity generation plans. As the country plans to generate massive hydro power (10,000 MWT), many dams will be constructed, but how they are going to affect fish populations and the rural communities that depend on them should be investigated and appropriate mitigation measures need to be applied. If integrated properly, the fisheries/aquaculture sector could benefit from the hydro power sector. A hatchery like that of Kali Gandaki reservoir could be built as a small part of hydro power projects, with the view to breeding indigenous species and releasing them into the upstream and the reservoir itself so that wild stock would not be depleted. More dam construction means more reservoirs, which could be utilized for cage culture. Cage culture in reservoirs does not affect power generation, and hence should be considered a potential venture. In addition to utilizing rivers and reservoirs, policies should be made to utilize unused swamps and natural lakes for cage as well as pen aquaculture.

3.2. Institutional set-up

Institutional set-up and human resource play important roles in the development of any sector. IAAS of Tribhuvan University, Fisheries Research Division of Nepal Agriculture Research Council (NARC) and DoFD of Department of Agriculture are responsible for education, research and extension, respectively. However, their activities are mostly overlapping and they work in a competitive way rather than sticking to clear mandates and building good cooperation. More importantly, there is a lack of apex body to coordinate and oversee the aquaculture/fisheries sector in the country. A national advisory board/council such as Aquaculture/Fisheries Development Board (A/FDB) should be established comprising experts from various organizations in the country as well as those working abroad who can play a considerable role. At the same time, present DoFD should be upgraded to Department of Fisheries/Aquaculture (DoF/A) with full authority of planning and decision-making for the sector.

3.3. Human resource

Research is greatly needed to develop new technologies in the country, and hence the backbone of development. If introduced from outside, they have to be adapted to the local conditions before they can be recommended to the masses. There are a very few fisheries/aquaculture researchers in Nepal, for instance, Fisheries Research Division of NARC has only eight scientists. In DoFD as well, personnel with higher education are very limited. If aquaculture is to be launched as a campaign throughout the country, at least one Subject Matter Specialist (SMS) is needed for each district. Many of the current officials are retiring soon, and shortage of human resource is going to be further critical. Concerned authorities need to take this issue seriously and make a plan (short- as well as long-term) for human resources development urgently. In order to produce more technical experts, greater collaboration with national and international academic institutions is needed. Promotion and leadership training program for existing personnel might also help mitigate human resource problem to some extent. Policies to encourage all officer-level researchers and extensionists to write project proposals and compete both nationally and internationally should be implemented. More importantly, projects should be allowed to be handled independently by the winners as Principal Investigators (PIs), with the provision of agreed reasonable overhead (say 10-15%) to the central fund. Aside from this, they should be allowed to have supplementary salaries on top of their base salaries. While evaluating the performance, generation of project funds from internal and external donors, professional publications, community services and direct impacts should be used as criteria. In addition, there should be mechanisms to reward and recognize best performers and punish those who do wrong intentionally.

3.4. Education and training

Formal education and training should be adequately emphasized for the dissemination of technologies and the rapid and sustainable growth of the sector, of which the country is in dire need. There is a worry of over-production of post-graduates as apparently there are no jobs available in this sector. However, high-caliber graduates may not necessarily seek jobs, and hence not be a burden for the country. They can be innovative and job creators themselves depending upon the type of education they get. IAAS has been working with various national and international institutions in improving curricula and delivery methods of aquaculture education with the view to making it very effective and adaptive so that its graduates can play a crucial role in the development of the sector. An internship program launched with the assistance of EU/AIT focused onthe field-based knowledge and skills. Aquaculture education should be incorporated more in the curricula of secondary schools, colleges and universities. Improving traditional curricula and teaching methods in these institutions is important. More efforts are needed in generation and sharing/dissemination of knowledge and skills through collaboration among individuals and organizations from within the country and abroad.

3.5. Extension and outreach

Aquaculture technologies (systems, species and other inputs) that are suitable for different agro-ecological zones need to be identified and promoted. However, extension services have been hindered by the shortage of experts. Most of the SMSs promoting aquaculture have only a bachelor's degree in general Agriculture. Many of them might not be capable of receiving new information and technologies regularly, and transferring them to the communities in need. They need regular interactions, guidance and monitoring. There also seems to be overlap of activities between researchers and extensionists, resulting in confusion or feeling of competition which hampers technology transfer. This should be eliminated through clear demarcation between the research and extension work. Otherwise, ultimate impact will be that farmers or the end users will be deprived of new knowledge and technologies. As far as research is concerned, it should be carried out exclusively by NARC and IAAS. Once fruitful results are produced, they should be handed over to the extension and development offices, which perform the piloting and then transfer to the masses. However, it has been perceived that researchers develop technologies and possess the required skill, but extensionists have problem of understanding them and transferring to the farmers. Firstly, they do not feel the ownership of technologies produced. Second, neither do researchers want to give the ownership to extensionists. In this situation, there is a need to make a provision to involve some of the extension officials in research and researchers in extension. Extension officials often think hi-tech knowledge is needed to pass on technologies to farmers, which is not true. To offer examples from Thailand, nursing of fry for about 1-2 months in hapas before stocking into pond for grow-out significantly increased the survival of fingerlings, and fertilizing pond water with animal manure and chemical fertilizers (e.g., Urea) to make it green helped 2-3 folds increase in production. These were proposed and tested after identification of the problems of low survival and slow growth while surveying farmers' fields. Similar approach could be applied by the extensionists in Nepal as well.

4. Conclusions and recommendations

Protein deficiency is critical in Nepal, and the first and foremost step towards addressing this problem is the realization of its seriousness by community leaders and managers, who can create awareness among people. Aquaculture should be promoted as a campaign by establishing national A/FDB. Although small-scale aquaculture is more suitable to increase resilience of rural livelihoods, it can also serve as entry to commercial aquaculture once private sector gets attracted towards it. Very unique and successful aquaculture development models that are suitable for both the purposes exist in the country (described above). Their potential of addressing the problems in the ground should be adequately analyzed. While campaigning, approaches, salient features and values of small-scale aquaculture need to be highlighted. Models from other countries should also be explored. Some might be suitable for certain ecological zones, and hence should be scrutinized and tested before their adoption. Care should be taken to avoid competition and conflicts of aquaculture with other sectors of farming systems such as goat, chicken and pig farming. Instead, it should be integrated with them for which various ways need to be identified. Several methods should be used for extension of technologies such as producing effective posters, brochures and documentaries of successful farmers. Besides, farmer-to-farmer extension, formation of womenís groups and cooperatives, and other potential field-based methods should also be emphasized. Extension officials should be trained in groups for doing so. Promotion and other performance - based incentives should be established for extension and research staff. Skilled human resource is badly needed, and hence should be developed. Appropriate planning needs to be carried out well in advance to meet the present as well as the future needs.

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Aquaculture and resilience: Women in aquaculture in Nepal

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Abstract

Farming-based rural livelihoods are becoming increasingly vulnerable to the effects of global climate change and sudden and profound changes in social and economic systems. Diversification of livelihood options is believed to be vital to maintaining ecosystem resilience and building social systems resilience. Integrated agriculture-aquaculture (IAA) farming systems, considered among the promising options for small-scale farming households in China and Vietnam, are likely be relevant in the context of mixed crop- livestock farming systems elsewhere as well. An adaptive research project carried out involving women members of ethnic *Tharu*, *Darai*, *Bote* and *Gurung* communities in Chitwan and Nawalparasi districts in Nepal between 2000 and 2007 evaluated the role of farm pond in diversifying livelihoods and reducing vulnerability. A newly introduced aquaculture sub-system complemented well with the existing mixed crop-livestock systems by virtue of increased synergistic relationships among the three sub-systems. Food and nutrition security of the participating households increased due primarily to a notable rise in quantity and frequency of fish consumption. In addition, household incomes were augmented through the sale of surplus fish. Development of Community Fish Production and Marketing Cooperatives exclusively owned and managed by the women themselves helped in women's empowerment through their improved access to and control over resources and increased roles in decision-making at both household and community levels. The study strongly suggests that IAA farming households are likely to be more resilient in coping with ecological, social and economic perturbations than their counterparts practicing traditional mixed crop-livestock farming.

Keywords: Fish; Integrated agriculture-aquaculture (IAA); Livelihoods; Resilience; Nepal

1. Introduction

Rural livelihoods in Asia are becoming increasingly vulnerable to the effects of global climate change and changes in social and economic systems. This is attributed to growing incidences of one or more types of "shocks", namely physical, biological, economic, social and policy-related (Resilience Alliance, 2007; 2010). In Nepal, common effects of global climate change - melting of glaciers at a rapid rate, uneven distribution of monsoonal rainfall, and increasing incidences of floods and droughts - have become phenomenal in recent decades. Consequently, adaptive capacity of semi-subsistence crop-livestock-based rural livelihoods in the country is believed to be declining. The landless, socially marginalized, ethnic minorities and those living in disaster-prone areas are among the most vulnerable sections of communities (Beveridge and Phillips, 2010) due to limited livelihood opportunities available to them.

Diversification of livelihood options is vital to maintaining ecosystem resilience and building social systems resilience. Integrated agriculture-aquaculture (IAA) farming systems, which is considered among the promising options for small-scale farming households in China and Vietnam for ages, is likely be relevant in the context of mixed crop-livestock farming systems elsewhere as well (Pant et al., 2005). The role of IAA systems in household food and nutrition security, income generation and empowerment of women and marginalized communities has been increasingly appreciated in recent decades in a number of countries of Asia and Africa. Adaptive capacity of traditional small-scale mixed crop-livestock farming communities in a relatively poor resource-base context in Nepal can also be improved through the introduction of an aquaculture sub- system. It is believed to be effective in increasing local fish supply and diversifying livelihood options of small-holder farmers in Terai (southern plains) and mid-hill valleys, thereby also increasing resilience of rural livelihoods.

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An adaptive research, namely "Women in Aquaculture in Nepal" involving women members of ethnic *Tharu, Darai* and *Bote* - traditional fishing communities - was carried out in Chitwan and Nawalparasi districts in Nepal between 2000 and 2007, with the objective of diversifying livelihood options of these ethnic minorities. The project was jointly implemented by Institute of Agriculture and Animal Science (IAAS), Nepal, Asian Institute of Technology (AIT), Thailand, and Rural Integrated Development Society-Nepal (RIDS-Nepal), a local NGO. The project, considering social, economic, ecological and institutional aspects, has successfully developed a model for small-scale aquaculture development in Nepal, which is described in a separate paper (Shrestha et al., 2009) in this volume. In this paper, based on a survey carried out with the project households in Chitwan in January 2009, we present the key processes of aquaculture development and women's empowerment side by side, and discuss how aquaculture sub- system complemented with existing rural livelihoods of ethnic minority communities and contributed towards building them resilient.

2. Declining fisheries: Aquaculture as a safety net

Semi-subsistence farming was essentially the only source of livelihood of the majority of the project households. The farming systems were characterized by cultivation of crops, paddy, wheat and maize in particular, in multiple cropping systems; and raising of a few heads of livestock, namely cattle, buffaloes and goats. Most of the households also raised a few scavenging chickens/ducks.

Household food sufficiency from on-farm sources, one of the major indicators of social well-being in rural Nepal, ranged between 3 and 12 months, with an average of 11.5 months (Standard deviation: 1.9), reflecting a situation where some of the households are required to augment their family incomes through alternative sources for their sustenance. Off-farm works such as unskilled/semi-skilled labor contributed significantly to the household income of a notable number of families.

Whilst most of the project households belonged to traditional fishing communities, fish captured from local water bodies had contributed significantly to their food and nutrition security in the past. Besides, some of the households had also augmented their incomes through selling their catches that were surplus over household consumption. Most of the households used to go for fishing when the agricultural activities were slack. Drying and storing of surplus fish over fresh consumption was common among these communities. Treating guests with a meal without fish or meat is rather uncommon in these communities. Family deities are offered with the preparations made from fresh or preserved fish on special occasions (personal communication - Mr. Jiyan Chaudhary).

However, there has been a sharp decline in natural fish stock over time due essentially to increased fishing pressure. Declining availability of natural fish among the traditional fishing communities has negative implication not only for food and nutrition security but also for their cultural and social values. Whilst reducing exposure and sensitivity, and increasing adaptive capacity (Beveridge, 2009) to cope with socio-economic and environmental perturbations are key to increasing resilience, rationale for theintroduction of aquaculture was to reduce the dependence of these communities on ever-declining capture fisheries and at the same time to ensure sustainable supply of fish for family consumption as well as to augment household income from the sale of surplus. Besides, aquaculture development in the area was also believed to have positive impact on local aquatic resources by reducing fishing pressure.

3. Small-scale aquaculture development: Key processes

The project interventions were centered around two key areas - one was development of sustainable aquaculture aimed at improving food and nutrition security and augmenting household income, and the other empowerment of women through organizing them in cooperative owned and managed by themselves. The project followed a systematic process in both the interventions which we summarize in this section of the paper.

3.1. Sustainable aquaculture development

Unlike crop and livestock production, indigenous technical knowledge on aquaculture is virtually inexistent due essentially to its being a relatively new farming activity in many areas. Therefore, integration of aquaculture, particularly in small-scale farming systems, requires a systematic process (Pant et al., 2004 and 2005) as any perturbation in the initial years may even lead to the abandonment of aquaculture practice. Considering this, the project judiciously emphasized on introduction of backyard pond aquaculture during the first phase (2000-2002); its integration with livestock and horticultural enterprises in the second phase (2003- 2005); and intensification of fish production system through development of freshwater prawn-fish integrated systems in the third phase (2005 -2007).

Although most of the project households belonged to traditional fishing communities making their living partially from capture fisheries, none of them had experience in culturing fish. Converting a paddy plot into a pond was a crucial turning point for the participating households to transform their livelihood from crop- livestock-based to ones based on IAA during the first phase. Excavation of ponds was carried out by using family labor force but a partial subsidy covering 50% of labor costs was provided to ease the transition. Size of pond, which raged between 59 and 300 m^2, with an average of 234 m^2 in the initial years, largely depended on land availability, size of family labor force, and willingness of the households to convert their lands into ponds (Bhujel et al., 2008). However, farmers continued expanding their ponds, resulting in an average size of 314 m^2 (range: 33-3,019 m^2) by the end of the third phase (2005 - 2007). Besides, spillover effects of the project have been quite impressive as over a dozen of relatively better-off farmers in the area have also started fish culture at Small and Medium Enterprise (SME) level in recent years, which would inevitably contribute towards ever-growing fish demand in the area. The project households were provided with a series of practical trainings on pond construction, stocking, feeding and water quality management, harvesting and post-harvest handling, and maintaining farm records during the project period.

Integration of aquaculture with crop and livestock enterprises was the focus of the second phase (2003-2005). A farm pond in crop-livestock-based farming systems in rainfed areas plays a central role in increasing food security and diversifying livelihood options. In resource-poor areas, it is not only meant for fish culture, but it also serves as a reservoir for irrigation to crops in the pond dykes and adjacent farm plots. Benefits of aquaculture in the area were adequately realized through increased fish consumption and supplemental income from the sale of surplus. In the third phase (2005-2007), integration of freshwater prawn with fish resulted in further increased efficiency of aquaculture as the farmers realized additional returns from prawn without compromising fish yields. Aquaculture sub-system complemented well with their existing farming systems.

3.2. Empowerment of women through organizing them in cooperative

Women's empowerment through developing and strengthening farmers' organization was key focus of the project throughout. Therefore, concurrent to aquaculture intervention, savings groups involving women members of the households were formed in the initial years, which later developed into a full-fledged cooperative by the sixth year. During the first phase, all the members organized themselves in savings groups in which each of them saved a small amount on a monthly basis. They were registered as aquaculture farmers' groups with Agriculture and Cooperative Office at the district level during the second phase. They continued increasing their monthly savings, corresponding to increase in returns from aquaculture. In 2006, the women's groups were developed into a full-fledged women fish farming cooperative exclusively owned and operated by the women themselves.

Initially, a total of 63 women farmers were embraced by the cooperative. The project provided a sum of NRs 200,000 (1 US$ = NRs 72) as seed money, while the members deposited NRs 183,000 of their savings as share (a total of 183 shares). The cooperative has been providing loan to its members at the interest rate of 12% for a maximum of six months per loan cycle. Members can apply for loan equivalent to a maximum of 20 times of their share in the cooperative. As of May 2010, over NRs 400,000 was disbursed - mostly for aquaculture and no defaulters have been reported so far.

4. Increasing resilience of rural livelihoods: Can aquaculture help?

The project households reported a range of benefits related to livelihood resilience that they realized from fish farming (Table 1). The major one was improved household food and nutrition security. In the past, cash expenses on meat or fish items were high as they had to buy these from market. However, expenditure on these items has reduced substantially in recent years due essentially to the availability of fish in their own ponds. In addition, fish culture has been a good source of household income. Returns from fish were reported higher compared to other enterprises. Yet, labor requirement was substantially lower and the practice was considered rather easy. Institutional development and women's empowerment were indirect benefits realized (Fig. 1). The role of aquaculture in improving household food and nutrition security, augmenting household income and empowering women is described below, along with its contribution towards increasing resilience of rural livelihoods.

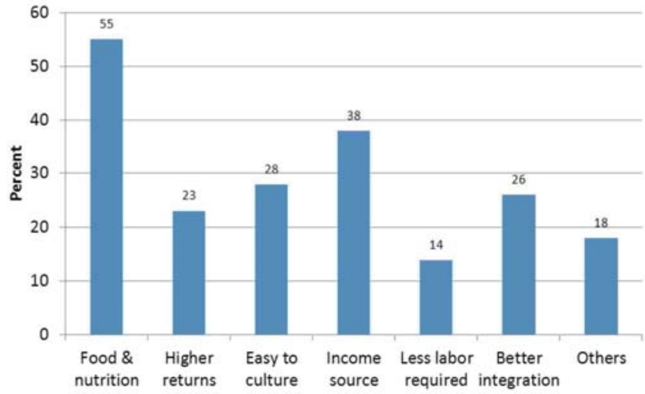

Fig. 1. Households' responses on benefits of fish culture in Kathar, Chitwan (n=98).
Rounding number exceeds 98 due to multiple responses. Source: Household survey, 2009

4.1. Increased food and nutrient security

A notable improvement in household food and nutrition security was evident among the project households. Per caput fish consumption was estimated at 11 kg (range: 0.5-42.5 kg), which was over 7 times higher than the national average of 1.5 kg (FAO, 2010). In the initial years (2001-2002), average per capita fish consumption among the same communities was estimated at 3 kg (Bhujel et al., 2008), which increased steadily reaching 11 kg in 2009 (Table 1). Such an increase in fish consumption was associated with the corresponding increase in fish production over time due to increase inproductivity as well as expansion of pond areas by the majority of the households.

Even in small quantities, fish can have a significant positive nutritional impact by providing essential amino acids that are often present in vegetable-based diets but in low quantities. Clearly, as opposed to very low national average in Nepal, per caput fish consumption among the project households was estimated to be close to the same in Bangladesh - one of the top 10 food fish producing countries. Frequency of fish consumption by the project households was estimated at over 6 times per month. In a situation where the majority of the project households were practicing semi-subsistence farming, their frequent consumption of fish - an expensive food item - has been possible only due to its on-farm production, confirming the pivotal role of aquaculture in improving household food and nutrition security.

Table 1
Fish production, consumption and sales in Kathar, Chitwan (n = 98)

	Mean	Standard deviation	Median	Minimum	Maximum
Pond area (m^2)	314.0	395.0	198.0	33.0	3019.0
Fish production(kg/year)	114.0	105.0	80.0	10.0	550.0
Fish consumption:					
Household (kg)	58.0	49.0	50.0	7.0	200.0
Per caput (kg)	11.0	9.7	6.8	0.5	42.5
Frequency (times/month)	6.5	5.4	4.0	2.0	16.0
Income (US$)	103.0	185.0	51.0	7.0	430.0

Source: Household surney, 2009

4.2. Increased income

Aquaculture played a vital role in augmenting household income right from the first year of project intervention. In the initial years, the project households used around 40% of the fish for household consumption and sold the remaining 60% (Bhujel et al., 2008). In recent years, however, they were using around 50% of the total production for household consumption. An average income from selling surplus fish over household consumption in the initial years was estimated at US$ 47, which increased steadily over the years, reaching US$ 103 in 2008. In addition to its significant contribution to household food and nutrition security, aquaculture has thus become a viable source to augment household income (Table 1).

Income from fish sale was used for a wide range of purposes (Fig. 2). Purchasing food and household merchandises and re-investing in aquaculture (pond expansion, seed and feed) were the major ones. Children's education (including school fees, books and stationeries, and school uniforms) was another important area where income from fish was being used. Besides, paying for health care expenses and repaying family loan were also reported by a number of households.

Essentially, all the project households were planning to continue fish farming. Whilst most of them had already expanded their pond area once, nearly a quarter of them were considering expanding it again in the years to come.

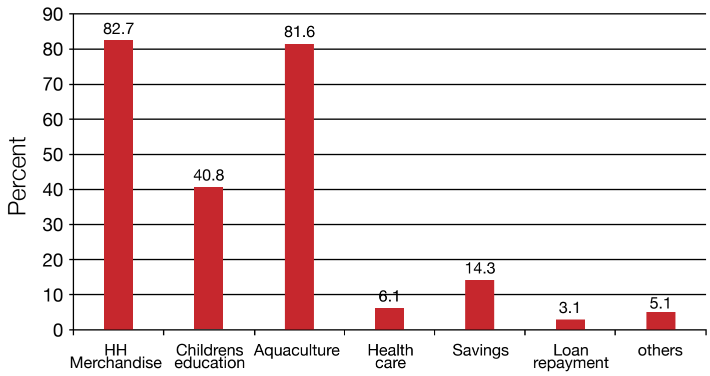

Fig. 2. Households' responses on use of income from fish sale in Kathar, Chitwan (n=98).
Rounding number exceeds 98 due to multiple responses. Source: Household survey, 2009

4.3. Institutional development

Women fish farmers' improved access to resources and their increased role in household decision-making were noted as important outcomes of the project. Besides, organizing them through their own cooperative also contributed to their empowerment significantly. In over 40% of the households, farming decisions were made jointly by men and women, while it was exclusively men's domain in another 40%. Female members were the primary decision-makers in nearly a fifth of the households. These findings reflect that women were directly or indirectly involved in household decision-making in over 60% of the project households.

The majority of the women fish farming cooperative members have expanded the area of their ponds. Spillover effects of the project have also been impressive as over a dozen of relatively better-off households have voluntarily started SME-level fish farming in recent years, confirming a catalytic role of the cooperative in developing aquaculture enterprises in the area.

The cooperative was providing not only loans but also technical support to its members. It was coordinating in purchasing inputs, including seed and facilitating to schedule harvesting and marketing time. Moreover, increased participation of the cooperative members in a wide range of social activities was observed, reflecting the massive success of the endeavor - "empowering through organization". The role of the cooperative in addressing the problem of food security has been exemplary and secured a very good media coverage at local and national levels. The success of Women in Aquaculture project in Nepal in diversifying rural livelihoods and empowering women has been widely commended by governmental and non-governmental organizations both at national and international levels.

5. Conclusions

Upon the introduction of aquaculture sub-system, crop-livestock-based mixed farming systems of traditional ethnic communities, namely Tharu, Darai and Bote were turned into a more diversified IAA systems. Our work with these communities for over a period of a decade clearly demonstrated that IAA farming households are likely to be more resilient to cope with ecological, social and economic perturbations than their counterparts practicing traditional mixed crop-livestock farming. Increased capacity of IAA farming households to cope with social and economic stresses is attributed to such factors as improved food and nutrition security, increased household income and empowerment of women members who - after getting organized in a cooperative owned and managed by themselves - could enjoy improved access to and control over resources and increased decision-making role in the households and the community. Whilst the scope of this study was mainly to assess the role of aquaculture in social systems resilience, future research should focus on examining its role in agro-ecosystem resilience.

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Small-scale aquaculture in Nepal: Principles and practices

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Abstract

The basic principles of Nepalese small-scale aquaculture research and extension are in compliance with all applicable international, national and local laws and regulations. They are based on ecological approach to aquaculture activity within the wider ecosystem, prioritizing the promotion of sustainable development, equity, inclusion and resilience of interlinked socio-ecological system, for nutrition, poverty alleviation and income for sustenance. Aquaculture practices in Nepal have been developing since the last 60 years. They predominantly represent small-scale systems, which are mostly family-owned and managed in ponds, cages and rice fields, with major carps in warm waters while rainbow trout (*Oncorhynchus mykiss*) in cold waters of mountain areas. Besides, the cultivation of tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) from southern tropics to the mid-hills is also on the increase. Basic technologies and major inputs seem adequate to extend suitable technologies from warm tropics to high mountains in the country. The current trend of small-scale aquaculture growth and its potentiality in terms of water resources, human capital and ecological suitability suggest that the practices should soon be commercialized and improved with effective research, education and investment, delineated with code of conduct and the Best Management Practices (BMPs) in order to achieve social transformation of the poor through the "Blue Revolution".

Keywords: Aquaculture, Tilapia, Catfish, Principle, Commercialization, Blue Revolution

1. Introduction

Generally, small-scale aquaculture is characterized by low-input- low-output fish farming (Martinez-Espinosa, 1997; Edwards, 1999). There are several definitions of small-scale aquaculture, depending on prevailing biogeography, socio-economics and level of technological innovations. For example, small-scale aquaculture in Uganda means part of subsistence farming with low or no inputs, with little or no routine management, and with ponds usually <500 m^2 and constructed by family labor (Wilson, 2005).

Large-scale aquaculture might target profitability, business and employment with longer value chains, while the small-scale one mostly represents a complex blend of food security, income generation, livelihood strengthening and poverty alleviation (Martinez-Espinosa, 1997). Several definitions of small-scale aquaculture have been proposed at par the level of aquaculture technology and socio-economics of the specific areas, focusing on the capacity of the farmers and families involved to operate the technology.

According to NACA (2008), small-scale aquaculture is a family-based enterprise, where fish are produced with the involvement of family members of the farm owner, regardless of farm size, species reared and volume produced. This definition is one of the best, which includes diversity and dynamism of aquaculture from a non-profit to highly profitable family-run practice, covering almost all aspects of small-scale aquaculture. However, the profitability might depend on the level of innovation, degree of complexity and socio- economic conditions of the farmers. The most deficient part of this definition is that it covers only those farmers with land or water ownership and leave out thousands of others practicing aquaculture in common waters such as lakes, reservoirs, rivers and even ocean.

Thus, a more comprehensive definition could be: "small-scale aquaculture is a family-based enterprise, where fish are produced with the involvement of family members of the farm owner in common, leased, private or self-owned property, regardless of the farm size, species reared and volume produced". Aquaculture practices are diverse and also ancient. In order to manage these diverse practices better in terms of cost and efficiency and from economic and social perspectives, there have been attempts to frame them into the categories of small, medium, commercial and large in recent times. This definition encompasses the dimensions of social inclusion and equal opportunity.

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Although aquaculture practices in Nepal mostly represent small- scale ones, a road map on guiding principles and practices will be important to maximize production for the welfare and benefits of all the stakeholders involved. The present paper attempts to carry out the rare task of synthesizing such principles and practices to achieve social transformation through the "Blue Revolution" - a term coined for sudden bumper commercial production of fish in harmony with surrounding environment.

Rapid acceleration of aquaculture for fish production is called the "Blue Revolution". Its goal is to achieve a very efficient mass production of animal protein for ever-increasing population (McGinn, 1998; Costa-Pierce, 2008). Mass adoption of small-scale aquaculture technologies at community level is expected to bring copious fish production. In order to realize this, however, a well-planned and well-defined system will be necessary. Regardless of the scale of aquaculture, the primary concern is productivity, which is associated with its economics anything from very simple to complex type, as stipulated in the most acceptable definition of small-scale aquaculture (NACA, 2008).

2. Guiding principles of small-scale aquaculture and their compliance in Nepal

The guiding principles based on ecosystem approach, which is often been termed as Ecosystem Approach to Aquaculture (EAA), is a major trend for general aquaculture around the world (FAO, 2007; Soto, 2007; Costa-Pierce, 2008). An EAA is defined as "a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems". Soto (2007) has developed principles of an EAA which are highly relevant to the guiding principles of small-scale aquaculture applicable to Nepal.

The guiding principles of aquaculture proposed by Soto (2007) along with their improvement (FAO, 1995; Martinez-Espinosa, 2001) are provided below.

Principle I:

Aquaculture should be developed in the context of ecosystem functions and services (including biodiversity) with no degradation beyond their resilience capacity.

Corresponding to the above principle

- Small-scale aquaculture should be developed in the context of ecosystem function and services.

Principle II:

Aquaculture should improve human well-being and equity for key stakeholders. It should ensure equal opportunities for properly sharing benefits by all while not resulting in detriment to society, especially the poor. Both food security and safety are key components of societal well-being.

Corresponding to the above principle

- Small-scale aquaculture should mainly be promoted for poverty alleviation, following the doctrine of social inclusion, equity and welfare to ensure equal opportunity and provide food security and safety to society, especially the poor.

Principle III:

Aquaculture should be developed in the context of other sectors, policies and goals.

Corresponding to the above principle

- Small-scale aquaculture development should be in compliance with other sectors, policies and goals.

Based on the above guiding principles proposed by Soto (2007), the basic principles of Nepalese small-scale aquaculture research and extension comply with all applicable international, national and local laws and regulations. They also abide by EAA within the wider ecosystem, prioritizing the promotion sustainable development, equity, inclusion and resilience of interlinked socio-ecological system for nutrition, poverty alleviation and income for sustenance (Gurung and Bista, 2003; Gurung et al., 2005; Gurung, 2008).

3. Practices of small-scale aquaculture

Modern aquaculture practices in Nepal were started around the 1950s (Rajbanshi, 1979). Since then, aquaculture has contributed about 1% of the Gross Domestic Product (GDP) in the country. The current total fish production is nearly 48,000 t in 2007/08 (DoFD, 2007), out of which, the contribution from aquaculture alone is approximately 25,000 t. The actual production is low despite considerable potential of different forms of aquaculture practices developed earlier. Innovative methods of aquaculture development are desirable, considering the eco-agricultural zonation of the country. Nepal represents most of the climatic conditions of the world - from tropics to alpine within a narrow range - providing opportunities to develop different forms of small-scale aquaculture. Most of the fish farms established throughout the country from Terai to the high mountains should belong to the category of small-scale aquaculture. Since carp culture flourishes well in tropical climate, it has expanded in Terai. Small-scale aquaculture in Nepal can be divided as follows:

3.1. Warm and cool water aquaculture

- Pond aquaculture
  - Carp-based
  - Tilapia-based
  - Catfish-based
  - Ornamental fish-based
- Rice-fish farming
  - Carp-based
  - Tilapia-based
- Cage-fish farming

3.2. Cold water aquaculture

- Rainbow trout-based

Nepalese aquaculture is predominantly small-scale, which is mostly family-owned and managed in ponds, cages and rice fields, with major carps in warm waters, while rainbow trout (*Oncorhynchus mykiss*) in cold waters. Rainbow trout farming in cold waters (Rai et al., 2005; Rana, 2007a, b; Gurung, 2008) and community-based fish farming with tilapia in warm waters (Bhujel et al., 2008) are among the most recent achievements in the area of aquaculture development in Nepal. Small-scale aquaculture in warm water regions is mostly low-input-low-output type. In most practices, no outside feed is used and fish is produced with the ambient productivity (Gurung et al., 2010).

Contrastingly, cold water aquaculture in mountains is highly desirable, based on composite feed for rainbow trout production. This is in line with the principles of small-scale aquaculture as this is practiced in small land areas in mountain slopes using spring and river waters. Although the investment in raceway construction might be argued to be high considering the size of the area and magnitude of production, this can still be included in small-scale aquaculture as per the definition proposed by NACA (2008).

Besides, the cultivation of tilapia, African catfish and striped catfish (*Pangasius hypophthalmus*) from the southern tropics to the mid-hills is also increasing (Roy and Gurung, 2008). Tilapia was introduced in Nepal around 1985 (Yadav, 2006). However, the farming practices were not publicized to private sectors, but recently with the technological packages, Tilapia has been extended to private farms (Yadav, 2006; Bhujel et al., 2008).

Recently, African catfish has also been popular for farming because of its several advantages over others such as low dissolved oxygen tolerance. Since it could be cultivated in "nano-ponds" to support the livelihood of "ultra poor" communities, farming of this fish has been extensively promoted in various hilly districts on farmers-to-farmers basis (Roy and Gurung, 2008). The government has not given priority to this fish though.

Basic technologies and major inputs seem adequate to extend suitable small-scale aquaculture technologies from warm tropics to high mountains in Nepal. The current trend of growth and potential in terms of water resources, human capital and ecological suitability suggest that the existing practices need to be commercialized and improved soon, with effective research, education and investment delineated with code of conduct and Best Management Practices (BMPs) for social transformation of the poor as depicted in Fig. 1 and Fig. 2.

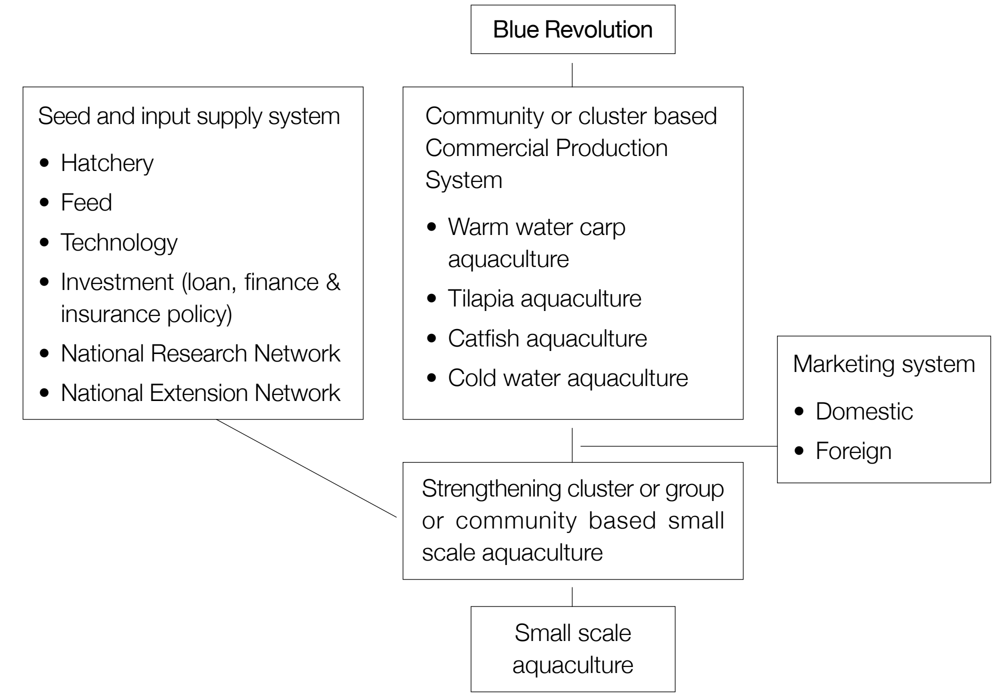

Fig .1. Proposed road map for "blue revolution: through of small scale development in Nepal

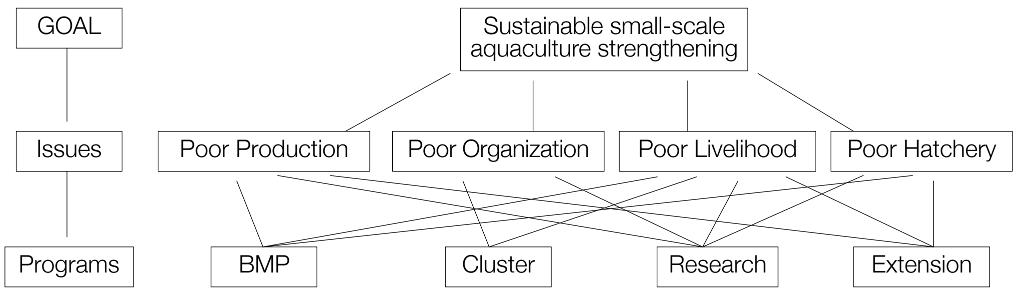

Fig. 2. Schematic representation for sustainable small-scale aquaculture strengthening.
Source: adapted from Umesh et al., 2008

4. BMPs of small-scale aquaculture

Practices that are thought to be the most effective practical methods of reducing environmental impact levels to those compatible with resource management goals are called BMPs (Hairston et al., 1995). The term practice refers to structural, vegetative or management activities needed to solve one aspect of a resource management problem. In some situations, a single practice may solve the problem, but usually a collection of practices or a "system of BMPs" is needed for effective environmental management. There has been widespread application of BMPs in traditional agriculture to prevent soil erosion, causing turbidity and sedimentation in streams and other water bodies.

BMPs are most commonly associated with agriculture and other activities that cause non-point sources of pollution. However, they may also be included in permits for non-agricultural point source effluents (Gallagher and Miller, 1996). Due to the diversity of cultured species, types of facilities and management techniques, it is impossible to list BMPs that would be standard for all aquaculture operations. Ideally, they should be site-specific for each individual operation. It must be stressed that these management practices for aquaculture are strictly voluntary. They are not requirements or even recommendations, but are simply suggestions that may be adopted by existing and potential aquaculture producers to increase efficiency and reduce effluent discharge from production facilities.

5. Code of conduct, legislation and licensing for aquaculture practices

Aquaculture is one of the fastest food-growing food production sectors in the world. Thus, aquaculture products are increasingly becoming subject to safety measures as required by international trade regulations (Josupeit et al., 2001). Increasing production level of aquaculture in Nepal could soon be regulated in terms of safety, hygiene and BMPs. To be in the business, it would be essential to produce the products that comply with the international standards. In Nepal, such a regulatory mechanism has not yet been put in place. Nevertheless, these aspects would soon be part of the management, especially for trading under the World Trade Organization (FAO, 2005).

In some advanced countries, obtaining license is essential to perform aquaculture practices (NMFC, 2005). Implementation of such apolicy requires farmers to be educated. However, at present literacy rate among farmers in Nepal is rather low. The country might need to wait a few more years to introduce this legislation. The licensing requirement might curtail economic growth of the country and deprive many poor communities of involving themselves in aquaculture, and hence further aggravate the poverty. In the present context, such legislation might streamline aquaculture only theoretically but not practically.

6. Way forward: Is "blue revolution" by clustering small-scale aquaculture units possible?

Fish farming as a source of animal protein could be a blessing, especially in low-grain production area, as the conversion rate of rice or wheat would be far more economical with regard to fish production than goat, pork or buff (Costa-Pierce, 2008). On an average, 4 kg of grain are required to produce 1 kg of pork, and 7 kg to produce 1 kg of beef, while it is only 2 kg in case of 1 kg of fish production. Besides, approximately 65% of the raw weight of finfish is eaten, compared with 50% of chicken and pigs, and 40% of sheep; fish are supported by water, but terrestrial animals and birds require comparatively strong bones so they spend their substantial energy into the growth of the bones, which cannot be consumed as food (McGinn, 1998). Fish are low in fat, protein and cholesterol. Omega-3 fatty acids in them help reduce blood clotting and thus minimize the risk of heart attacks. Consumption of fish protein has several health, nutritional, environmental and social advantages over other terrestrial animal meat (Martinez, 1998; Costa-Pierce, 2008).

With such benefits in mind, in the early 1980s, international aid agencies and resource planners called for a "Blue Revolution", mirroring the high hopes of the agricultural Green Revolution that had begun nearly half a century ago (Martinez, 1998; McGinn, 1998). Aid agencies funded research aimed at genetically modifying fish to resist disease, grow faster, taste better and thrive in highly controlled environments. In 1993, it was announced that scientists had successfully cultivated a strain of tilapia with 60% faster growth than its wild cousin, which is called "aquatic chicken" (McGinn, 1998). This result was referred to as the "next great leap on food production" techniques in 1995. In spite of the selection efforts by Filipino farmers in 1989, their tilapia turned out to be less efficient than new founder stocks collected from the wild in Egypt. As a solution to this problem, ICLARM launched a program in the mid-1980s to develop genetic resources for tilapia that has led to the creation of the "super-tilapia" using Egypt's wild populations (Martinez, 1998).Today, aquaculture constitutes one of the fastest growing sectors in world food production (FAO, 2007), as stated above. The demand for fish is ever increasing mostly in urban centers probably due to change in the food habit pattern of their citizen. In the year 1988, the per capita fish production in Nepal was about 350 g but now it has exceeded to 1.8 kg. The growth rate of aquaculture in the past decade was about 9.5% per annum. However, the present level of fish production in the country is inadequate and large quantities of fish are imported. The import of food fish alone in Kathmandu is estimated to be nearly 7-10 mt/day, depending on season.

Fish cultivation using modern techniques started in the country recently around the 1950s with the introduction of carp. Soon after the modernization, fisheries sector progressed rapidly and its contribution to GDP began to reflect (Mathema, 1992). In the decade of 2000s, its share in Agricultural Gross Domestic Production is estimated to have reached nearly 2.47% from 1% in the 1990s. One of the primary reasons behind the success of carp cultivation in Nepal was probably breakthrough in artificial breeding technology and its spread in eastern and central Terai districts. As a result, Nepalese fish products have also partly occupied the market in nearby Indian borders.

The success of carp breeding and its management for fingerlings production is not only limited to Terai but exteneds to the mid- hills as well. As a result, cage fish culture and recapture fisheries in lakes and reservoirs in the region have been growing (Gurung et al., 2005), with their main focus on deprived fisher communities, who have been able to sustain their livelihood through these actvities (Gurung and Bista, 2003).

Rainbow trout (*Oncorhynchus mykiss*) is one of the world's renounced fish for commercial cultivation in cold water regions (Rai et al., 2005). Considering its popularity and importance for the prosperous aquaculture development in the hills, Nepal Agricultural Research Council had initiated research on this species. Earlier studies have shown that Rainbow trout can successfully be grown in hill terraces of Nepal using streams flowing throughout the Himalayan region (Gurung and Basnet, 2003). Recently, Government of Nepal has included it under "One Village One Product" (OVOP) program of Federation of Nepal Chamber of Commerce and Industries (FNCCI) as one of the important commodities. The OVOP scheme is based on the principle of Private-Public-Partnership (Pandey, 2008). Following the same principle, small-scale aquaculture in the country - regardless of geographical zone - should be sensitized, clustered and mobilized with further investment plan and technical back stopping through developing network as proposed in Fig. 1 and Fig. 2. With this, it could be anticipated that Nepal, having unusual geographical setup with predominant mountains but blessed with abundant water resources, will also be successful in the "Blue Revolution" (Fig. 2). Then, the vision proposed to improve the standard of living of the people through sustainable aquaculture growth by transforming the subsistence farming system to a competitive and commercialized one could be achieved.

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Development of small-scale aquaculture in highland and remote areas: An opportunity for aquaculture development in Nepal

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Abstract

Aquaculture has been the fastest growing food producing sector in the world in the past three decades. It supplied 41.74% of fish products globally in 2006. Asia is the most important aquaculture region in the world, which currently contributes 92% of the world aquaculture production. Different from some other regions, aquaculture in Asia is a rather diversified industry in terms of production system and scale, and culture species. Culture of some important commodities, such as shrimp and marine finfish, has developed into an industrial business in many countries. Yet, aquaculture still remains as a rather small-scale operation, and simple culture practices in highland and remote areas are emerging even in countries where aquaculture has developed well. Despite its limited role in international trade of fish products, small-scale aquaculture contributes significantly to rural livelihoods and social development. Aquaculture is facing a rapidly changing environment and the industry itself has also been driven for higher output and better efficiency. There are several challenges to small-scale aquaculture business nowadays. This paper briefly assesses the present status of small-scale aquaculture business in Nepal. Major constraints and challenges to its sustainable development are identified based on the analysis of the recent development trend. Timely collaborative efforts at a regional level, including national actions are recommended for its promotion in highland and remote areas, particularly in countries such as Nepal, Laos, Vietnam and Thailand. As the most needed supports, improving the supply of major production inputs, specifically seed and feed; strengthening technical services to the farmers; and improvement of production - and marketing-related infrastructure are recommended.

Keywords: Asian aquaculture; Small-scale operation; Integration; Sustainable

1. Introduction

Aquaculture has been the fastest growing food producing industry worldwide in the past three decades. Over this period, the world aquaculture production has been growing at an average annual rate of 8.63%. It reached 66.75 million mt in 2006 (Secretan et al., 2007), which accounted for 41.74% of the world total fisheries production. Considering the quality of the products, the actual contribution of aquaculture to global supply of fish products is much more significant.

While contributing to supply of animal protein food to the world population, aquaculture also plays a significant role in employment creation and income generation, and hence accelerates rural development. For instance, it provides some 7-8 million jobs to rural population in China only.

Aquaculture is a fast growing Industry, as explained above. At the same time, it is also a much diversified food production sector. It includes very diverse species of aquatic animals and different culture systems. Moreover, aquaculture is operated on different scales of production, particularly in developing countries. Although large-scale aquaculture plays a very important role in developed countries in culture of some commodities such as salmon and shrimp, small-scale aquaculture plays even more important role in developing countries due to the features of its operation and socio-economic conditions in those countries.

2. General concepts of small-scale aquaculture

Small-scale aquaculture is often defined in different ways. The following concepts are basically cited from Bueno (2009).

2.1. Definition of small-scale aquaculture

Although it is difficult to find a universal standard for small- scale aquaculture, it is generally defined as those operations that are typically family-owned, rather vulnerable, not formalized into business operations and that have a small economic turn-over. There are two sub-groups of small-scale aquaculture farmers:

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- farmers with little or no significant investment in assets (infrastructure), whose investments are in operational type costs, a little labor and feed; and probably who farm fish as one of their several livelihood strategies (i.e., aquaculture does not constitute the most significant source of livelihood or income); and
- farmers whose aquaculture operations are a principal form of livelihood in which the family/operator has invested significant livelihood assets in terms of time, labor, infrastructure and capital (Adopted by the Aquaculture Insurance for Small-Scale Farmers in Asia-Pacific, Bali 2006).

2.2. Features of small-scale aquaculture

A simplified characterization of small-scale aquaculture was adopted by the NACA-ASEAN Foundation Project on Promoting the Competitiveness and Sustainability of Small Holder Aquaculture Farmers in ASEAN, as follows:

- Small land and water area, often within a hectare or few hectares with very extensive culture;
- Family scale operation, or small community or partnership operation without commercial investment;
- Mostly based on family labor or sometimes on seasonal hired labors;
- Often based on family land; and
- Often with one or few production units (pond, cage and paddy plot, etc.).

In addition to the above adopted characteristics, the authors believe that the following two should also be added as important features of small-scale aquaculture: (i) farmers do not have any specific channel for the marketing of their products; and (ii) farmers are rather vulnerable to external strikes.

3. Advantages of small-scale aquaculture

Due to its features, small-scale aquaculture has a number of advantages over its large-scale counterpart in contributing to local food and nutritional security and livelihood of rural populations. The major ones include the following.

3.1. Utilization of locally available resources

Small-scale aquaculture is more efficient in using locally available resources, such as small water bodies, homestead land, family labor and cheep household feed stuff, than large-scale operation. This kind of operation usually does not create much adverse impacts on the environment and is more sustainable, though its economic sustainability may not always be sound.

3.2. Adoption of simple technology and easy management scheme

Small-scale aquaculture usually employs simple technology, and hence is easy to manage. Therefore, it is relatively easy to get started with and operated by small rural households/community with poor knowledge and skill.

3.3. Integration with other livelihood activities

Small-scale aquaculture can easily be integrated with other livelihood activities, such as crop farming, poultry farming and horticulture, which not only reduces the production costs and make more efficient utilization of the resources, but also increases the resilience of rural livelihoods through diversification.

3.4. Low initial investment and operational cost

Small-scale aquaculture is characterized by simple culture infrastructure and production inputs. Therefore, initial investment and operational cost involved in it are very low compared with large-scale operation. This enables the small household to start production with very small investment and also minimizes the potential economic risk of the business.

3.5. More direct contribution to local economic development and social well-being

Compared with large-scale aquaculture business, small-scale aquaculture can make more direct contribution to the local economic development and social well-being. Its major contributions include the following: (i) provides livelihood and income to small rural households because it is more inclusive to the poor in terms of business and employment opportunities; (ii) makes direct contribution to the improvement of local food and nutritional security as it is more targeted to meet the local demand for fish and other aquatic products; and (iii) promotes social equity by ensuring wider participation of different disadvantaged groups, such as the landless, poor households and women, and greater sharing of the benefits among them.

4. Dominant small-scale aquaculture practices in asia

Small-scale aquaculture has been practiced for millennia in Asia. As stated earlier, there has been considerable progress in its development in the region during the last three decades. Various suitable farming systems and practices have been developed for different natural and socio-economic conditions. The following are a few perfect systems that fit well into the concept and goal of small-scale aquaculture.

Fig. 1. Freshwater crab culture with paddy cultivation in Nantong, China.

4.1. Integrated paddy-fish culture

Paddy plantation is one of the most important traditional rural livelihood activities in the region. There are vast areas of paddy fields that are suitable for integrated paddy-fish culture. Fish and other aquatic animals can synchronously or alternately be integrated with rice plantation. Such integration can significantly reduce the production costs in both rice cultivation and fish culture through symbiosis which minimizes the feed requirement for fish, and fertilizers, herbicides and pesticides for paddy. Varieties of aquatic animals can be integrated with paddy cultivation, which include different herbivorous and omnivorous fish and freshwater prawn and crab (Fig. 1). Some 300-1,000 kg/ha of fish or other aquatic animals can be produced in addition to improved rice production. Major requirements for successful paddy-fish production include limited investment (basically labor) for modification of paddy fields, supply of good quality fish seed, limited supplementary feed, good water and pest management scheme.

4.2. Pond fish culture integrated with other agricultural livelihood activities

Pond-based integrated fish farming has a history of some 2,000 years in China. Many such traditional practices still perfectly fit into the present concept and need of small-scale aquaculture development. Models that are perfect for small-scale aquaculture include poultry-fish, crop-fish, sericulture-fish, horticulture-fish and green fodder-fish, etc (Fig. 2). Despite differences among the various models, the basic principles are to minimize production cost; make most efficient utilization of resources and inputs; and achieve sound economic and ecological benefits through the recycling of various byproducts and wastes within a system.

Fig. 2. Integrated duck-fish farming in Jiangsu, China. *Source:* Miao, 2010

4.3 Cage culture in rivers, lakes and reservoirs

Cage culture in rivers, lakes and reservoirs is another suitable system for small-scale aquaculture in remote and hilly areas (Fig. 3). Such a system basically does not require land resource and just uses the additional service of open water bodies. Its operation scale is very flexible according to the capital affordability of the households. Construction of cage usually costs less than land-based culture infrastructure. Filtering and herbivorous fish species are among the best choices. Production can be solely dependent on plankton of the water body or enhanced by application of locally available supplementary feed, such as aquatic weeds, terrestrial grass, and byproducts from grain processing and oil extraction. For successful cage fish production, what is most important are supply of large-sized fish seed, and cage that is designed and manufactured well.

Fig. 3. Tilapia cage culture in reservoir in Guangxi, China.

5. Opportunities for small-scale aquaculture in Nepal

5.1. Present status

Started in the early 1950s, aquaculture is a relatively new activity in Nepal. Over the past 20-25 years, there has been a significant increase in the production of fish and the annual per capita fish consumption has risen from 0.330 kg in 1982 up to 1.753 kg in 2006. Aquaculture products have also been exported to neighboring countries. The export is increasing although the volume is rather small at the moment. Fisheries and aquaculture are an important supplement to the daily food in rural areas though they are not a main agricultural activity in Nepal. The Nepal Agriculture Perspective Plan (APP) has categorized fisheries and aquaculture in Nepal as a small but important and promising sub-sector of agriculture, contributing about 2.47% of Agricultural Gross Domestic Product (AGDP). Fish is considered as good luck (Sagun) in Nepal.

Good understanding of the basics of the three main geographical regions of the country would be very helpful in envisaging different opportunities for small-scale aquaculture in Nepal. They are: (i) the high altitude and colder mountainous region along the northern border; (ii) the moderate climate and medium altitude hilly region in the central part and the southern region; and (iii) the Terai plains with low altitude and warm climatic conditions (Fig. 4).

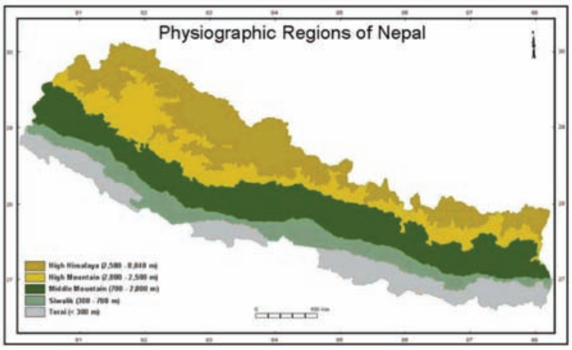

Fig. 4. Five main physiographic regions of Nepal (often summed into only three , namely Mountainous Region (High Himalaya and High Mountain); Hilly Region (Middle Mountain) and Terai Plain (Shiwalik and Terai).

The main volume of aquaculture comes from the Terai plain, where polyculture of carps in earthen pond is commonly practiced. In addition to temperate fish culture in this region, coldwater fish culture has also been started recently at small-scale in the Hilly Region and its potential for further expansion has been envisaged. Another recent development is cage culture in lakes and reservoirs as well as raceway production of Rainbow trout in the same region. Table 1 shows details of aquaculture production in Nepal.

Table 1
Estimated water surface area and fish production in Nepal (2005/2006)

Aquaculture system	Production (mt)	Area (ha)	Productivity (mt/ha)	Potential area (ha)
Ponds	20,213	6,220	3.250	14,000
Government farms	32			-
Enclosure	130	100	1.300	-
Rice-fish culture	111	277	0.400	-
Cage culture	216	36,000 m^3	6 kg/m^3	-
Ghol (Swamp) Culture	1,778	1,400	1.270	-
Total aquaculture	22, 480 (25,409*)			
* = 2006/2007 estimates				

Aquaculture in Nepal not only supplies more than 50% of fish, but also is an important source of employment for the rural people. It is estimated that some 750,000 people are directly or indirectly involved in aquaculture activities in the country and the number is increasing (DoFD, 2006).

5.2. Future potential

There are about 11,100 ha of scattered swamps and Ghols in the marginal forest areas in the Terai region of Nepal. This land is considered waste land and not useful for agriculture activities. Irrigated rice field covers about 398,000 ha. But rice-fish culture is practiced in only 0.07% of the total paddy field area and is currently producing only 111 mt of fish. Warm water carp culture is the main practice, which is concentrated in Terai. There are a considerable number of reservoirs in the country that have not been used for aquaculture production.

Thus, there is huge scope for enhancing aquaculture practices in the country if the unused irrigated rice fields are used properly. A well-managed rice-fish culture practice can increase rice production by more than 10% and produce more than 500 kg/ha fish additionally. It can significantly reduce or even avoid the use of pesticides in rice production, which not only lessens cost but also produces high quality rice. Practice of extensive cage fish culture can effectively increase the service provided by reservoirs, which are traditionally used for irrigation, flood control and power generation only.

6. Constraints to development of small-scale aquaculture in Nepal

There exist a number of factors that have considerably hampered the development of aquaculture in Nepal. The followings are among the major ones: (i) effective policy framework and appropriate strategies, which include legal arrangement for access of aquaculture to some important water resources, e.g., reservoirs; (ii) inadequate human capability to provide managerial and technical support in remote and hilly areas; (iii) generally weak infrastructure such as transportation and power supply; and (iv) inability to provide the farmers with high quality fish seed.

Despite extensive efforts on the part of various organizations to promote aquaculture, some of their efforts failed to effectively address the country's priority need of improving food and nutritional security and rural livelihood. All issues such as this need to be dealt with to push aquaculture forward in the country.

7. Promoting small-scale aquaculture in highland and remote areas

Small-scale aquaculture can play very important role in improving rural livelihood and overall social well-being in highland and remote areas in countries located in hilly areas such as Nepal, Laos, Vietnam and Thailand. There is also great potential in South-western China - the country with the largest aquaculture industry in the world. These countries are basically featured by diversified environmental conditions, rich natural resources and manpower, and need for more fish to improve the food and nutritional security and improve livelihood in the rural areas. However, appropriate strategies need to be implemented to fully utilize such potential to make substantial contribution to national food and nutritional security and improvement of rural livelihood. They are presented below:

7.1. Improving public support

Small rural households in remote and hilly areas are usually among the disadvantaged groups in terms of economic and social conditions. They will not be able to develop efficient aquaculture operation without much needed public support. Despite relatively small initial investment requirement, it is often difficult for many of them to manage even the minimum investment in culture facility and material inputs essential for reasonable production. Therefore, appropriate mechanism is needed to enable small farmers to gain access to initial investment. Government should take more responsibility than private credit providers in this regard.

Small rural households usually do not have any fish culture related experience and knowledge. Further, their poor educational background often prevents them from learning and mastering the basic techniques and skills by themselves. Therefore, appropriate technical extension service is essential to help them to start effective aquaculture operation. Public technical extension system of countries in the region is often weak in terms of human capacity and resources availability. There is great need to strengthen the aquaculture technical extension service capability through joint efforts of national and international institutions. Special attempts should be made to promote integration of small-scale aquaculture production with other agricultural livelihood activities such as crop farming, poultry farming and horticulture. While introducing culture systems and species of aquatic animals, diversification of social and natural conditions should be taken into consideration.

Nowadays, small-scale aquaculture often goes beyond subsistent level, with more and more farmers producing fish for income generation rather than for mere household consumption. In remote and hilly areas, farmers usually face difficulty in marketing their products at a reasonable price. They are often over-exploited by middlemen and get the least benefit from their production. External assistance is essential to help them sell their products, which may include establishment of marketing facilities, provision of market information and promotion of fish consumption.

7.2. Improving supply of material inputs

Reasonable production efficiency (both per unit production and economic return) is very important for small-scale aquaculture to make significant contribution to food and nutritional security, and improvement of rural livelihood, given the limited natural resources (land and water) available to them. Good supply of certain material inputs for effective production is of great importance and supply of quality fish seed is the most crucial material basis. Many countries in the region are having difficulty in providing small farmers with sufficient high quality fish seed. This is a huge constraint to the aquaculture development at the initial stage. This also holds true in the case of Nepal. Therefore, efforts should be made to establish national capability to ensure supply of high quality fish seed in the long term.

Use of supplementary feed is an essential way to improve the production efficiency. Reasonable intensification is an unavoidable trend of aquaculture development, given the limited natural resources. There is a need to develop cost-effective feed with locally available ingredients to help small farmers raise their production. This is even more urgent in places where there is a desire and potential for the development of small-scale cold water fish culture such as trout.

7.3. Regional collaboration

Many countries in the region have great potential of developing small-scale aquaculture in highland and remote areas. They have similarity in their national development needs, and social and natural conditions. At the same time, they also face similar constraints. Collaboration among them can significantly facilitate the development of small-scale aquaculture and make great contribution to the improvement of livelihood and social development in such areas. Therefore, it is highly suggestible to establish a regional forum to discuss common problems faced and share successful experiences gained by them. Regional collaborative activities are also greatly needed in the area of human resource development, which can include international training and exchange visits.

Considering the wide interest of countries in the region in introduction/reintroduction of exotic or improved species, there is a great need to set up international protocols and mechanisms to supervise and facilitate careful exchange of germplasm of aquatic species for the small-scale aquaculture development in highland and remote areas.

8. Conclusion

In conclusion, small-scale aquaculture has unique features in effectively addressing the need of improving national food and nutritional security and improving the livelihood of rural population in highland and remote areas of countries in Asia. In order to realize its full potential, joint efforts should be made by national governments, international organizations and non-government organizations towards mitigating major barriers. Such efforts should include enactment of policies and strategies with clear goals and targets; improvement in basic infrastructure and public service; and introduction of appropriate farming systems and technologies. Regional cooperation can significantly benefit small-scale aquaculture development. In order to maximize its contribution with limited resources, it is highly suggested that development efforts on the part of various organizations should be in line with the priority goals of the national development plans.

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Community-based approaches to aquaculture in seasonal water bodies: Lessons learned

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Abstract

Initiated in 2005, “Community-based Fish Culture in Seasonal Floodplains”[1] project is a pilot testing approach to introduce Community-based Aquaculture (CBA) in a variety of ecological and socio-cultural settings, with sites in Bangladesh, Cambodia, Vietnam, China and Mali. The project has been designed to address multiple objectives, including improved and sustainable livelihoods based on enhanced fish production from seasonal water bodies and a greater understanding of the landscape dynamics and trends of the floodplain resources in a multiple water use system. This trans- disciplinary action research project is centered on building a collective fish culture approach at the community level in seasonally inundated croplands.

The small-scale community-based initiatives have achieved varying levels of success in each of the project countries due to the many challenges inherent in introducing CBA in a situation characterized by overlapping and dynamic property rights. Overcoming these challenges to achieve the potential for income generation and food security that CBA can offer requires a clear understanding of the complex socio-ecological context, which can support or undermine equitable and sustainable fish production. In order to support initiatives that aim to introduce CBA into a seasonally flooding environment in various countries, this paper presents experiences and lessons learned under a variety of scenarios. We place special emphasis on the experiences from Bangladesh, which both topographically and hydrologically most closely resembles the Nepalese floodplains, particularly in the Terai (southern plains). The findings of the project are related to the prospective opportunities for developing aquaculture in seasonal water bodies in the Terai and the mid-hill valley regions in Nepal.

Keywords: Sustainable livelihoods; Seasonal water bodies; Floodplain resources

1. Introduction

Floodplains provide the most fertile agricultural lands in the world with alluvial deposits enriching soils, providing an ideal medium for crop production (Reij et al., 1991; Erenstein et al., 2006). Floodplains along the world’s major rivers such as Nile, Ganges, Brahmaputra, Yangzi, and Mississippi cover a large part of the world’s surface, and support occupations and trade for millions of people (King, 2008). In tropical landscapes, these rich environments provide a diverse range of livelihoods, often characterized by dry season cropping and flood season fishing. In some regions, flood waters are controlled to permit an additional cropping season (Baran et al., 2001; Winklerprins, 2002). Where the flood waters are deep, private land gives way to open access water resources during the flood season, opening up capture fisheries to the surrounding population as explained by Dey and Prein (2006) in case of Bangladesh and Ahmed and Tana (1996) for Cambodia.

In much of the developed world, the floodplain dynamics have been brought under control by elaborate engineering structures, exerting our control over nature (Parker, 1995). Throughout the developing world, floodplains are still subject to the natural seasonal patterns of flood, following a regular pattern of inundation and recession (Tamuno et al., 2004). Diverse food production systems of seasonal tropical floodplains in Asian countries like Bangladesh, China, India, Indonesia, Malaysia, Thailand and Vietnam reflect a high degree of complexity in human and the ecosystem interactions (Little and Muir, 1987). For example, Bangladesh has 2.8 million hectare of floodplains, of which 1.5 million hectare are suitable for fish production (Rahman and Ranamukhaarachchi, 2003; Shankar, 2002). The Vietnamese Mekong Delta is responsible for nearly 60% of Vietnam’s aquaculture (Wilder and Phuong, 2002) and its contribution to rice crop production is more than 50%, which is further growing (Brocheux, 1995; Lam, 2001).

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[1] This paper presents findings from PN35 “Community-based Fish Culture in Seasonal Floodplains” - a project of the CGIAR Challenge Program on Water and Food.

It is anticipated that fisheries production will no longer be able to meet the needs of increasing global population (FAO, 2002). Aquaculture is seen as a potential alternative to capture fisheries as a source of both food and income (FAO, 2002). In floodplain regions, extensive water resources have the potential to support aquaculture production, augmenting supplies from capture fisheries and supporting the livelihoods of the many vulnerable people who live in these dynamic environments. For instance, it is estimated that annual fish production in Bangladesh will increase 4 to 5 times if 50% of the 1.5 million hectare of floodplains suitable for aquaculture can be brought under community management (Dey and Prein, 2006).

In 2005, WorldFish Center initiated a project with an overall aim of enhancing fish production in seasonal floodplains to sustain and improve rural livelihoods. The project has sought to develop technologies and institutional arrangements to support collective fish culture in the flood season appropriate to a variety of environmental and socio-cultural settings represented by Bangladesh, Cambodia, Vietnam, China, and Mali (Sheriff et al., 2008). As the initial start-up cost for an aquaculture system can be prohibitive for individual poor households, a community-based approach was selected to allow poorer households to participate in and benefit from aquaculture production.

2. Approach and methodology

To date, Community-based Aquaculture (CBA) has been tested at 24 locations in 5 countries. Project sites were selected based on hydrological conditions (height, extent, and duration of flooding), existing infrastructure (dikes and irrigation canals), willingness of local communities to participate in the project, and support from local authorities. Although the exact nature of participation varies among the countries, membership of a group that is convened to undertake fish culture activities and to share the benefits of fish production is open to all the members of the community. A management committee is elected from within the group to provide leadership and to oversee the coordination of fish culture activities. The creation of fish culture groups is supported by field staff from within the national partner institutions, who visit the groups regularly to provide guidance to farmers, and occasionally, assist them in conflict resolution.

Fish stocking has been carried out at each of the project sites under the guidance of national partners having expertise in local aquaculture systems. Locally preferred species have been stocked in polyculture systems, with stocking densities and proportions varying from year to year as the culture systems have evolved. Enclosure designs have similarly been locally adapted and modified.

3. Discussion

3.1. Analysis of activities in each country

Implementation of the project has lead to a range of outcomes - both anticipated and unanticipated. Collective approaches to aquaculture have met with variable success in each of the project countries, with the project delivering different levels of benefits both within and among countries. Negotiating access to water bodies and fisheries resources, development of community-based institutions and benefit sharing arrangements within a system where rights are dynamic, overlapping, and heterogeneous have created particular challenges to the development of the project. At each location, agricultural production dominates during the dry season, with cropping of rice and other commodities for sale and domestic consumption. Boundaries between private and commonly-owned land are clear, and households focus on production from their individual homesteads or providing labor to other households. In the flood season, land boundaries in deep-flooding areas become indistinct, and many areas revert to common ownership. Water resources become subject to multiple uses by multiple users.

Many of the challenges which have emerged during the course of the project can be attributed to the inherent complexities of the community-based approaches that are greatly influenced by the socio- economic context in which the intervention takes place. In addition, we have noted that there are a number of site attributes which may support or undermine CBA approaches. Clearly identifying these attributes and other factors that contribute to continuance or discontinuance of CBA provides the principle focus of on-going work on the project. The paper describes preliminary findings from this research, which may serve to guide the implementation of similar initiatives in Nepal.

Community-based approaches are often seen as a panacea for many natural resource management problems. “Community” is often idealized and the ability and willingness of the members to work collectively is often assumed at the outset of such an intervention (Vernooy and McDougall, 2003). However, individuals bring in their own set of values, needs and aspirations to collective action which may change as the value of the resource, and access to it, change. This issue is exacerbated when collective management is based upon private land ownership.

In Bangladesh, successes have been substantial at some project sites, whereas disputes, conflicts, and ultimately discontinuance have arisen at the others. Building on previous community-based fisheries management experience in the country, community-based fish culture has been introduced in the floodplains, which is subject to a complex array of administrative arrangements. The project is currently being implemented in government khas lands, or land reserved for distribution to the landless, and in areas with public and private ownership where no leasing arrangements exist. In each system, enclosures have been created within floodplain depressions. Fish culture is managed by a committee made up of the representatives from all the communities surrounding the floodplain, with the participation of landowners and the landless. As described by Sarker et al. (2003), however, the complexities of access to and ownership of land, water, and fishing rights have created serious challenges to the project. Despite these challenges, the community fishers' society at Beel Mail, Rajashahi District, with the support of local authorities, has secured an extension to the current leasing arrangement, allowing the fishers to continue fish culture until 2013. It is now financed by savings from successful culture practices in the previous years.

Fish culture activities in Southern Vietnam have been introduced on a collective basis in flooded rice fields of the Mekong Delta. In contrast to Bangladesh, the flooded land is entirely under private ownership, with the members of the fish culture group drawn from the households whose land is situated within the flooded area. Where annual flood height is low enough to permit the creation of enclosures around individual household plots, there has been a general preference toward fish culture, or a third rice crop, on an individual basis and insufficient incentive for farmers to work together collaboratively. Consequently, there has been high level of discontinuance of the community-based practices in these areas, although approaches to collective practices are now evolving amongst the households, which favor culturing fish in a small number of enclosed rice fields. In the provinces of the Mekong Delta that border Cambodia, flood waters are deep, permitting only two rice crops each year. In these areas, the cost of creating individual enclosures - using fences of sufficient height to contain stocked fish - is prohibitive, making collective fish culture a more viable option. The benefit-sharing arrangements, management and leadership of fish culture in community groups and marketing presents significant challenges to the success of the approach.

In Cambodia, establishing community groups to manage fish culture within flooded areas successfully has proved problematic. Fish culture activities have been introduced in open access reservoirs and flooded rice fields. Initially, households were keen to participate in the project. Farmers have since demonstrated a preference for fish culture on an individual basis, introducing the technology on their own homesteads and private plots. As in Vietnam, in some areas, there has been a move toward collective practice amongst small groups of 10-12 households who farm fish in 3-4 enclosed rice fields. Members of these groups are currently improving the rice field environment by creating ditches along the rice field perimeter to act as refuges when waters are shallow. Fish culture activities have continued only in Takeo province, a fish- deficit area. The approach has met with less success in Prey Veng province. Although the reasons for the failure are not yet clear, it is possible that incentives to participate may have been lower by virtue of the support from various international organizations and non-governmental organizations (NGOs). During the next phase of project development, community-based management of dry-season fish refuges will be introduced.

Farmers in China have adopted a different approach to collective fish culture than their counterparts in the other project countries. The project is being implemented in two provinces - Yunnan and Jiangsu. In the latter, fish culture has been introduced into irrigation canals. In the former, fish have been stocked in flooded rice nurseries which are also used for the production of lotus. In both the cases, the management has been entrusted to an individual who acts as a caretaker and is involved in feeding and guarding the stocked fish. In return, he/she receives a larger proportion of the benefits from the production, with the remainder shared amongst project participants and local community funds.

Fish culture is a new activity in Mali, creating a new set of challenges, in addition to those faced in the Asian countries. Fish will be stocked into mares or floodplain depressions, which are generally managed by one community. Caution is needed to ensure that the introduction of fish culture does not undermine traditional access to the water which is subject to multiple uses by a variety of resource users, or that the change in the value of both the water resource and fish production transforms the management and allocation of rights to water and fishing. A detailed analysis of access rights and institutions forms the basis of the research in this area.

3.2. Factors contributing to continuance and discontinuance of activities

From this brief analysis of activities in each country, a number of patterns begin to emerge as described below, which are being explored in more detail through on-going research. Factors contributing to the continuance and discontinuance are being assessed in each community within eight broad categories:

3.2.1. Incentives and motivation

Community-based fish culture has continued where the incentives are the greatest, primarily where alternative livelihood options are limited and the community is remote from urban centers. In Vietnam, many communities where fish culture was introduced had a number of economic alternatives, including the production of alternative crops such as mangoes, sweet potatoes and rice. Fish culture increased in value during the course of the project, making it a more attractive option. The production of rice also became a political issue, with countries seeking to ensure sufficient rice production at domestic level to feed the country in the face of rising food prices.

Other issues cited included lack or high cost of labor to protect stocked fish, particularly where the culture area was large; limited capacity of the management committee; and lack of access to flooded areas for fishing during the flood season.

3.2.2. Participants' expectations

Most of the households who participated in CBA were motivated by the potential economic benefits available from the fish culture in flooded areas. However, their expectations were high and the results were inevitably disappointing in the initial trial stages of the project. The approach adopted was one of adaptive management, which sought to learn from successful culture cycles, to develop the most locally appropriate and farmer-determined system during the course of the project. However, where communities had numerous alternatives, the incentive to wait for the delayed benefits was undermined; the participants often preferred to invest time and labor elsewhere.

An adaptive approach to the development of fish culture systems has proved to be most effective in assuring continuance of the culture activities, and the evolution of locally appropriate systems. Rigid adherence to a single model is counterproductive. Successful models have tended towards smaller group size and smaller culture plots where households have adapted the culture techniques learned through the project and applied them on a smaller scale. Management committees in many communities have commented on the difficulty of managing a large culture area, and a large number of households.

3.2.3. Technical and bio-physical factors

Floodplain agricultural land is a valuable commodity, which is subject to competing claims for production. It was found that where waters are relatively low (less than 2 m), sufficient water management infrastructure may continue to bring the flooded area under production by controlling the height of the waters (UNDP, 1989; World Bank, 1989). The importance of rice for both domestic consumption and export means that a third rice crop is often preferred over capture fisheries or aquaculture. This was observed in the low flooding regions of Vietnam, where fish culture activities gave way to an additional rice crop when fish production was not sufficiently lucrative to make it worthwhile. Where households have continued fish culture in smaller groups, low water levels or short flooding periods have been offset by modifications to the rice field environment. Construction of ditches on the perimeter of the rice fields has been used to successfully extend the culture period, and increase production. Additionally, the landscape pattern and relief are important parameters to determine the hydrological flow and interactions that can potentially support or undermine the fish culture activity during the wet season.

3.2.4. Institutional factors

In most areas, CBA is a new activity, requiring new skills on the part of fisher-farmers and new ways of working together. Support to farmers' groups from local authorities, extension units and national research organizations are essential, and the issue of support from local authorities is often raised in discussions relating to discontinuance and continuance. Local authorities can play an influential role in encouraging and supporting community groups, providing technical and management support. In some cases, representatives from local authorities have been called upon to act as independent observers and mediators, at the request of the community group. Where support from local authorities has been positive and attentive, both local authorities and community groups have commented on the benefits of this increased communication, which has led to improved understanding and support in other areas of community development. However, in case of privately-owned lands, the inclusion of local authorities was seen as challenging.

3.2.5. Conflicts and social cohesion

The degree of conflict and extent of social cohesion are very much dependent on the efficacy of the leadership and the management of the intervention process. The important contribution of a strong leader to the success of community-based management has been shown throughout the study, and borne out by literature (Wayne et al., 1999). Leaders who were respected in the community; had previously held a leadership role either in the community or local government; had experience in fish culture or other economic enterprises; and who were charismatic enough to bring a group of people together to undertake a new venture were most likely to hold the group together, even if the outcomes of the fish culture did not meet the expectations of the participants. Trust in the management committee was also an important factor in keeping a cohesive group together. The provision of training and support to the management group is critical. Experiences suggest that the existence of other community- based institutions fosters collective actions and increases the likelihood of success in collective activities (Ostrom, 1990; Leach et al., 1999; Woolcock and Narayan, 2000).

3.2.6. Socio-ecological context

The varying level of success of the community-based fish culture activities in the project countries has also led to a deep consideration of the context and its contribution to the success or failure of collective action under differing socio-ecological conditions, recognizing that the results of stocking are often unexpected (e.g., Lorenzen and Garaway, 1998; Garaway, 2006; Garaway et al., 2006). Socio-political history, in particular, is likely to have had a strong influence on project success. For example, the suggestion that private property - although no longer recognized as privately-owned during the flood season - should be reverted to collective management for the purpose of fish culture has important implications in countries such as Cambodia and Vietnam, where recent history makes collectivization socially sensitive.

Recognizing the broad influence of the context on project success, a framework was developed to guide the research during the final phase of the project. The framework provides a basis for the comprehensive analysis of the many factors that make up the complex socio-ecological context in which the project sites are embedded. The framework addresses issues of historical, political, socio- economic and cultural contexts, placing them firmly within an understanding of the socio-ecological linkages occurring at the landscape level.

3.2.7. Inclusion and equity

Introducing community-based management into a system based on private land ownership beneath a seasonally flooded water body creates a particular set of challenges for ensuring inclusiveness and equity in CBA. As community groups are formed, socio-historical context may influence the level of inclusiveness permitted by the group members. In some regions, communities sought to restrict participation in the project to those households which own land within the perimeter of the project site. This raise a number of concerns regarding the exclusion of households that do not own land; have a greater dependence on the fishing resource in the flood season; and that may belong to the more vulnerable sector of the community. Fisher households may be able to find alternative fishing grounds close to the community, but the implications for scaling up and the reduction of open access fishing grounds should be given serious consideration. In Bangladesh, fish culture in seasonally flooded areas is a very inclusive activity, providing opportunities and benefits for all the members of the community. Negotiating access for all groups and ensuring equitable sharing of the benefits are the key challenges to be addressed when implementing this technology.

We briefly explain in depth the case of Bangladesh from a landscape perspective. The country is subdivided into thirty agro-ecological[2] units, and our sites are representative of three major floodplain zones, viz Ganges, Brahmaputra and Tista (Fig. 1(A) and 1(C)). This is crucial to the understanding of the variation and the appropriateness of the intervention at the basin-scale and assists in scaling up to a wider area. The agro-ecology provides broad information on defining the geographical and ecological boundaries of the flood plain. Information on the flooding depth, elevation (Fig. 1(B)) and the inundation level (Fig. 1(D)) are more [locale] site-specific parameters that determine the gradient of suitability for a need-based livelihood intervention within the agro-ecological boundaries. For sites at Rajashahi, Mymensingh and Ranpur, the elevation is between 5-30 m which qualifies them as lowlands. The inundation level at Rajashahi and Mymensingh is intermediate, while it is comparatively low for Ranpur. This would mean that the standing water level in the wet season reaches above 1.5-2 m in most cases, and hence they are suitable for stocking fish and maintaining inflow-outflow hydrodynamics, using low-cost technical options. When water level is above or below the specified range, it needs more investment and human effort in order to regulate hydrological flow. In summary, biophysical assessment significantly determines the appropriateness of the intervention for the site and its potential for replication in a broader context of floodplain management.

As we realize the significance of appropriate technological options, proper institutional arrangements and people's participation for the success of CBA in seasonal floodplains, understanding of the argo-ecological and biophysical characteristics of the landscape is equally pertinent for the success of CBA in seasonal floodplains.

Serving as important guidelines, these eight broad categories of the factors presented above primarily reflect the considerations to be made while implementing similar activities in Nepal.

3.3. Relational context for nepal

The topography and ecological profile (Fig. 2) of Nepal suggests that there exits potential for the introduction of CBA in the mid- hills, Shivaliks (also called Churiya) and the Terai of the country. Viewed from the experience of fish culture based on collective action in other regions, the incentive and motivation for fisheries and aquaculture seem promising. Nepal is a landlocked country. Therefore, the opportunities for livelihood and trade diversity is narrow (Madeley, 2002). Additionally, production of fish is totally dependent on the use of inland waters. Fish culture is a recent activity in the country and the scope for its expansion to increase production has taken due consideration in the National Policies Related to Food Production (FAO, 1976; Swar and Pradhan, 1992). Along with the increasing popularity of cage culture in lakes and open water bodies, communities are willing to extend the activity to fields and homesteads as reported by Kumar (2003).

The success of community fish culture in seasonal flood plains of Terai and low-lying mid valleys will also depend on good economic returns from the activity. However, the likelihood of good benefit can be anticipated due to the increasing fish prices, good internal market opportunity (Shakya, 2008) and limited options for crop diversification caused by geological and climatological conditions (FAO, 2001). Second, the source of animal protein in the region is limited and fish as food is acceptable to the population (Karna and Shrestha, 2006). A report by United Nations World Food Programme on the market food price statistics states that as an impact of bird flu cases in the region, consumers are instead purchasing fish in greater quantity, and its price has increased by 10% (UNWFP, 2009).

The mid-hills, Shivaliks and the Terai are the crop-rich zones. However, unregulated water management in the upstream has severely altered the seasonal water flow in these regions. In addition, the growing incidence of flash floods adds to the plight of crop producers in the densely populated flood plains (SAARC, 1992). Concurrent or consecutive rice-fish production is a potential adaptation measure, as supported by Yadav and Bhujel (1998). The major challenge would be to build capacity of people to adopt the change, considering that their traditional knowledge of fish culture is limited when compared to Bangladesh (UNDP, 2004).

[2] Agroecological units in most of the Asian region, especially in South Asia, refer to land areas recognized on the basis of hydrology, physiography, soil types, tidal activity, cropping patterns and seasons. These areas are mostly used by the National Resource Management Committee/Institutions for development interventions and resource management planning activities. The intermediate layers /information that are generally integrated to define an agro-ecological unit are individually relevant for thematic decision-making process.

In terms of institutional setting to support collective actions for resource management, Nepal presents a number of success stories. The Joint Forest Management (JFM) initiative was built on the understanding that economic activity should be the entry point with the social communities and participation of the resource users and the economic benefits that one derives increases interest in collective resource management (World Bank Institute, 1998). The impacts of JFM included: formal and informal institutional arrangements were strengthened; increased levels of participation by women were reported and the social capital was beefed up to benefit the poorer households (Jordan and Shrestha, 1998; Khatri-Chhetri, 2006). The CBA approach can potentially benefit from existing and newly agreed arrangements between the communities and the decision-makers.

The forest decentralization program in Nepal is based on the co- management of forest resources engaging the traditional forest- dwelling communities. It was a stimulating initiative that strengthened people's participation in development programs and capacity building for community leadership (Bartlett and Malla, 1992). Although cases of sporadic disagreements with various groups were periodically reported, in general, a good rapport was established between community people and governmental officials, non-governmental organizations (NGOs), and international non- governmental organizations (INGOs) (Jordan and Shrestha, 1998). Such an interaction was helpful in ensuring inclusion of all beneficiaries and equitable distribution of benefits. The arrangements that are already in place may support CBA in Nepal. Nonetheless, a broad understanding of the socio-ecological context of the country is relevant.

4. Conclusion

Experiences from CBA in different geographical regions and socio-economic settings have laid a preliminary framework for employing collective approach to fish culture in seasonally flooded zones. For instance, Bangladesh has demonstrated that informal institutional arrangements where benefits to all the local stakeholders (particularly the landless, but also land owners) are taken into account greatly enhance the likelihood of an uptake. With regard to the participants' expectation, the pre-negotiated roles and sharing of benefits, and also compensation of those who are negatively affected, are a reasonable motivation.

The degree of benefits varied in Bangladesh, Cambodia and Vietnam. In Bangladesh, the project sites have been operational for three years, and thus there have evolved community perspective; capability to cope with the fluctuation of economic returns; and improved interactions among the different stakeholders within the community and outside. Project intervention sites in the country are located in seasonally inundated floodplain depressions, and are partially or entirely enclosed by embankments. Technical interventions are done with low-cost and locally-available materials. Bangladesh also has an extensive seed supply network. Rural residents have a long-standing tradition of fishing and gathering of aquatic organisms (including plants) for their daily subsistence. Farmers have adapted their cropping strategies based on empirical and indigenous knowledge.

The trends in the development and farm attributes of integrated agriculture-aquaculture using a participatory community appraisal in several regions of Mekong Delta (Van Zalinge et al., 2000) and Indo- Gangnetic (Ambastha et al., 2007) floodplains have been researched in the past. The prevailing issue is to understand the broader context of community involvement and the factors that influence the success and failure of such an action in relation to small-scale aquaculture activities.

We anticipate that similar conditions are likely to be found in floodplain areas in Nepal's foothills but this has to be assessed further. The proposed methodology of (agro) ecological zonation, which takes into account seasonality, landscape characterization and dynamics, is underway. The method aims at identifying areas that are agro-ecologically similar among Nepal, Bangladesh and India (Bihar, Orissa and parts of Assam). Scenarios based on a thorough understanding of agro-ecological conditions, with incorporation of lessons learned from the CBA project described above, might usefully inform the development of similar interventions in Nepal.

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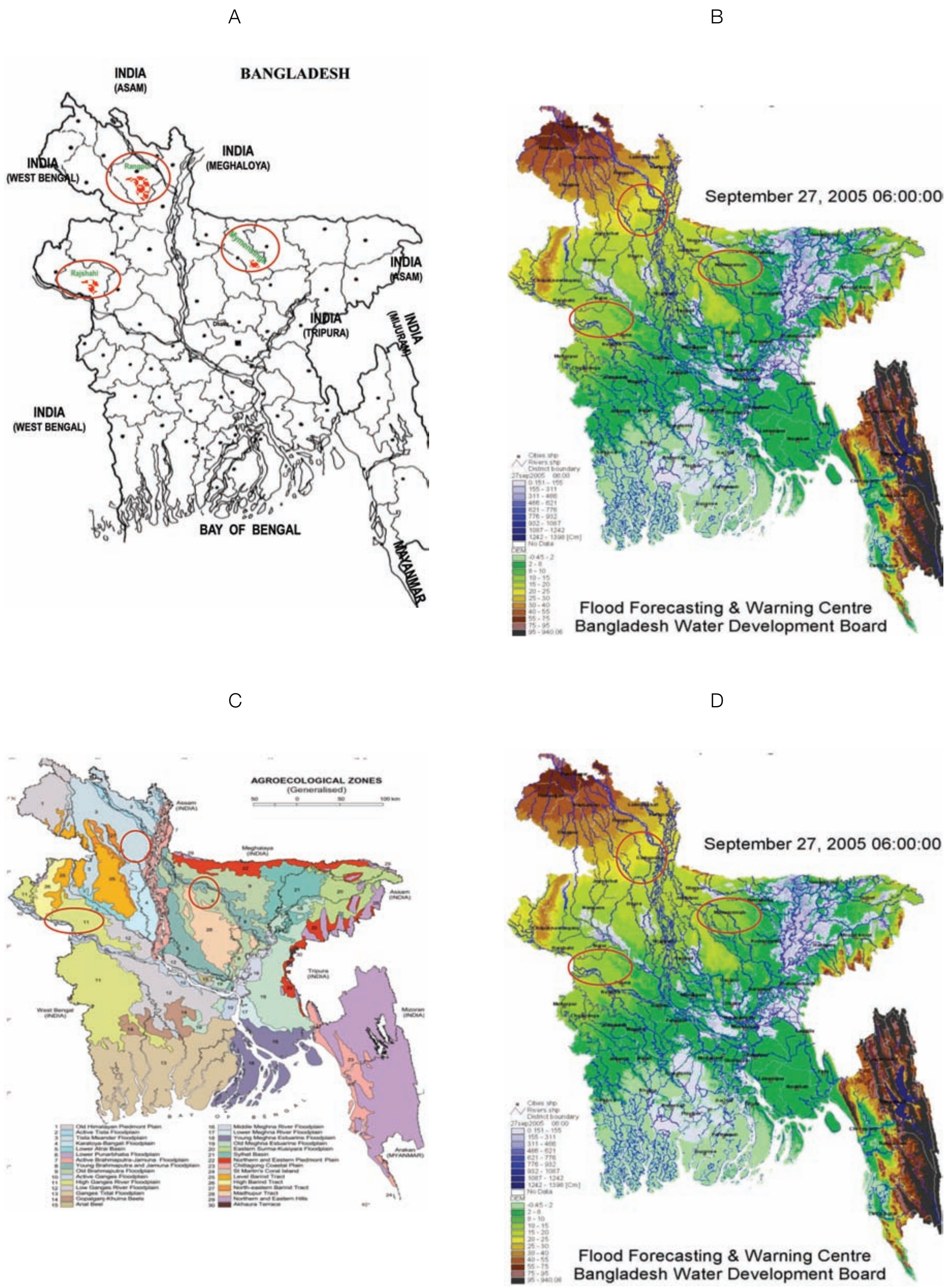
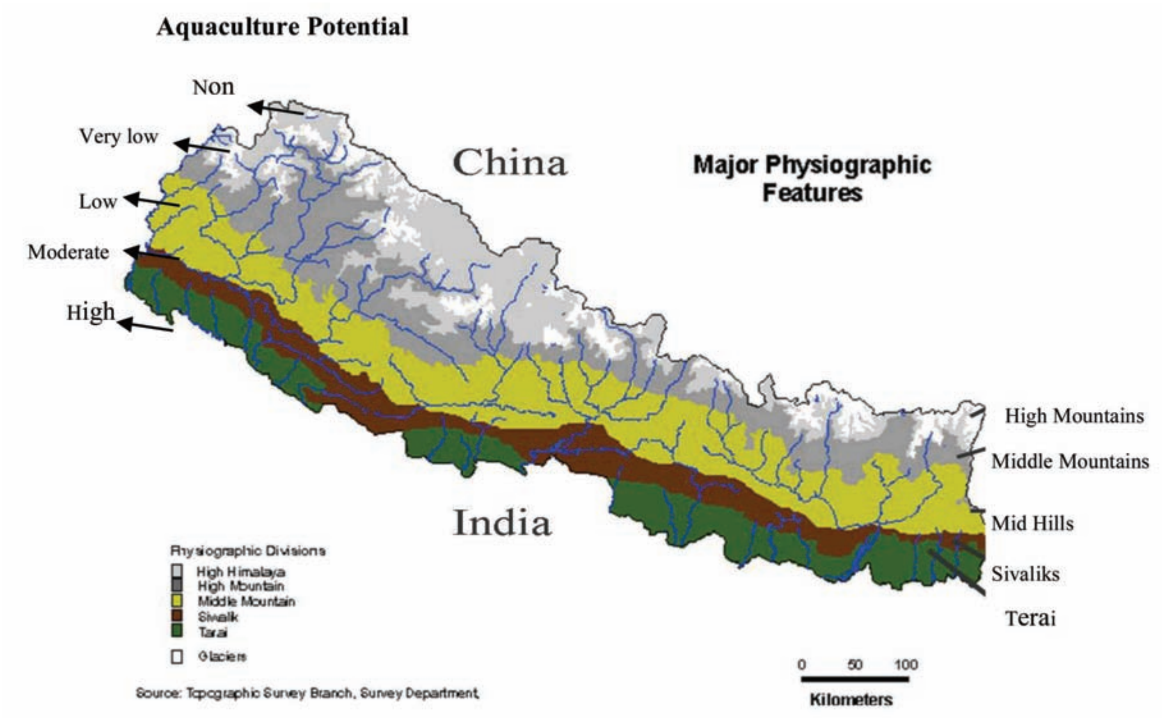


Fig. 1. Community-based aquaculture sites overview in Bangladesh: (A) Site location, (B) Elevation and flooding depth, (C) Agro-ecological zones, (D) Inundation. The sites are representative of Ganges, Tista and Brahmaputra River floodplains. Source: Bangladesh Agriculture Research Center (BARC)



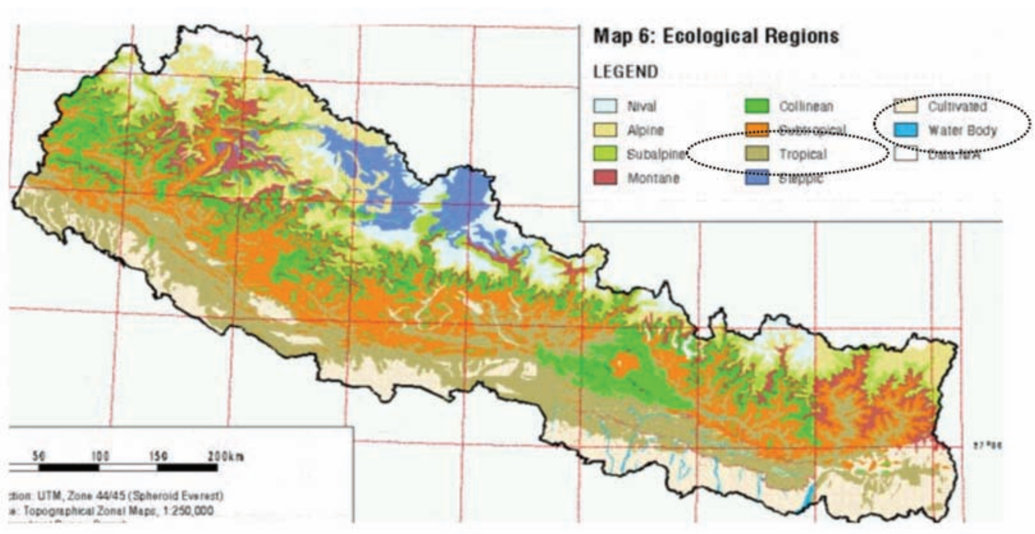


Fig. 2. Physiographic features and ecological divisions in Nepal showing the mid-hills, Shivaliks and Terai with potential for aquaculture. Source: International Center for Integrated Mountain Development (ICIMOD)

Small-scale fish farming in mid- and far-western regions of Nepal

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Abstract

Nepal is a country with tremendous water resources. However, aquaculture has been in practice for only about five to six decades. During this period, it has been demonstrated that warm and cold water aquaculture can be promoted for substantial reduction in poverty. In the present paper, an elucidation of the progress achieved in Mid-western Region has been presented. Several United States Agency for International Development (USAID)-funded projects have supported aquaculture development in Nepal by building ponds and providing technical assistance. The Ujyalo project, one of them, established two fingerling nurseries in Banke and Bardiya districts of Mid-western Region. The annual production of large-sized fingerlings from these nurseries is approximately 300,000. After the successful completion of the Ujyalo project, the USAID funded Education for Income Generation (EIG) project which has begun supporting 400 fish ponds with funding for construction from World Food Program (WFP). Farmers can also cultivate vegetables on dike areas using carp-based polyculture with low-cost production technology. Each pond produces 100-150 kg of fish and 300-500 kg of off-season vegetables annually. Each one generates an annual income of approximately NRs 15,000-20,000 per household. Due to lack of technically knowhow, people harvest limited quantities of catfish in Nepal. In 2007/08, Nepal Smallholder Irrigation Market Initiative (Nepal-SIMI) provided technical support to 25 households under a pilot project in Bardiya. Fish ponds of 25 m^2 water surface area produced as much as 7-35 kg of catfish within a four-month growing period, indicating that the farmers require additional technical support to achieve the normal production levels. This study shows that the promotion of small scale-fish farming can play a very important role in the livelihood enhancement of poor communities.

Keywords: Carp polyculture; *Clarias gariepinus*; Fish ponds; Income generation; Fingerling

1. Introduction

Fish accounts for about one fifth of world's total human consumption of animal protein. This has risen five folds over the last forty years from 20 million mt in the 1950s to 98 million mt in 1993 and is projected to exceed 150 million mt by the year 2010 (Olagunja et al., 2007). Fish farming generates direct and indirect employment. Moreover, the majority of the population in developing countries like Nepal is small-scale farmers. Experience in Asia and Africa in particular indicates that small-scale farming systems based on the integration of crops, livestock and fish can make a significant contribution to required increase in food supply and income.

The basic advantage of integrated farming systems is that through the application of the waste products from one system as supplementary feed to boost the production in another system (as in the application of vegetable waste as compost or feed in a fish pond), the total output of the farm increases beyond that which would be possible if the different production systems were operated independently (Beem, 1993). A major socio-economic benefit of integrated fish farming is that inputs to the various sub-systems, which comprise the farming system, tend to come from within the farm. Moreover, fish efficiently convert low-grade feed into high quality animal protein and can be kept alive on sustenance diets. Through integrated farming systems, high-value and nutritious source of food can be obtained with a minimum effort and external inputs.

The western part of Nepal was highly affected by a 12-year political insurgency, which increased rural instability and poverty. In this context, the Ujyalo project was launched in 2005 to develop agriculture entrepreneurship targeting small farmers. It included small scale-fish farming as one of the important sub sectors among Dalit (scheduled castes), Janjati ((ethnic minority), conflict victims and other marginalized households. The Ujyalo project for fisheries was implemented for two and half years by Winrock International (WI) and International Development Enterprises (IDE) with the financial support of the United States Agency for International Development (USAID) in 3 districts (Banke, Bardiya and Kailali) of Mid- and Far-western Regions that were severely affected by the conflict.

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Small-scale low-cost fish production technology is based on the principle of cultivating Grass carp (*Ctenopharyngodon idella*), Silver carp (*Hypophthalmichthys molitrix*), Bighead carp (*Aristichthys nobilis*) and Common carp (*Cyprinus carpio*) by feeding them grasses. This technology in the context of western Nepal is linked with pond aquaculture by small-scale irrigation systems. Farm households possessing a treadle pump have been successful in diversifying their farming system through introduction of vegetables and high-value crops. Construction of a small pond adjacent to a treadle pump provides the basic infrastructure for fish culture as well as a small reservoir for irrigation. This enables farm households' transition from traditional farming system to integrated agriculture aquaculture (IAA) farming systems. Key premises of IAA farming systems are enterprises symbiosis maximizing the efficiency of resource use, multidimensional use of space, intensive use of household labor, minimizing cost of production and income risk and enhancing the quality of the environment.

Carp polyculture has been practiced in Nepal for the previous five to six decades. Both the government and private sector are actively involved in fish seed production. In addition, technology for fingerlings nursing has been adopted successfully in the country. However, fish farming has not yet been realized as a major source of income generation in conflict-affected communities. One of the hindrances has been the inadequate technical knowledge of low- cost production technology.

Besides carp polyculture, catfish culture is becoming popular in Nepal. It is more productive than the traditional carp culture (Zheng et al., 1988). The landless and poor, especially from Tharu and other marginalized communities have been involved in catfish (*Clarias gariepinus*) farming in western Nepal. Most of the fish ponds are constructed in the backyard of homes. Due to inadequate technical knowledge, the farmers hardly harvest any fish or harvest limited quantites of catfish as mentioned above. Reports reveal that traders in Banke and Bardia are also importing catfish fingerlings from India worth approximately NRs 5 million annually. Nepal-SIMI provided technical supports to 25 households in Bardia in 2007/08 under a pilot project.

Small farmers as recognized by the Uyjalo project are those who are holding land smaller than 0.33 ha (10 kattha). Due to requirement of high capital investment, these farmers can not afford pond digging. Construction of a total of 1,010 ponds was supported by the project. The Ujyalo project had the following objectives of:

- increasing additional annual income by US$110 per household through fish farming in western Nepal;
- establishing harmony and peace among the conflict-affected communities;
- transfering low-cost fish production technology to the small land holders; and
- providing better nutrition to poor families.

2. Materials and methods

The Ujyalo project was implemented in Mid- (Banke and Bardiya) and Far-western (Kailali) Regions of Nepal for two and half years (2005-2008). A feasibility study was carried out in Banke from 18 to 24 December 2004. Sites for small-scale fish pond construction were selected in consultation with locals and experts. The project worked in areas that were most affected by the conflict. Farmers' groups were formed in accordance with the project norms, mobilizing the farmers having small land holdings (less than 10 kattha) and those highly affected by the conflict. The project was implemented through local NGOs.

A total of 1,010 small ponds were constructed in clusters for carp ployculture in water logging areas and unfertile low lands in Banke, Bardiya and Kailali districts. Each pond consisted of 200 m^2 water surface area with the following dimensions: length: 20 m, breadth: 10 m and depth: 1.3 m with a dike of 3 m width and 1 m height. A treadle pump was installed near each pond to irrigate vegetables on the dike; to maintain pond water depth; and to balance dissolved oxygen in pond water. Farmers were encouraged to produce vegetables on the pond dikes using improved technology.

Fast growing fish species, such as Grass carp, Silver carp, Bighead carp and Common carp, were cultured in the first year (2005) of the project with stocking ratio and density as given below (Table 1). The stocking ratio was determined as per the work experience of Dr. A. K. Rai (Chief, Fisheries Research Division, NARC) and R. P. Pandey (Coordinator, Ujyalo project (Fish)). Fingerlings were stocked in July and harvested in December due to late construction of ponds in May. In the second year (2006), a regular growing period of 8 to 10 months was adopted by stocking fingerlings in February- March and harvesting them in November-December. The fingerlings ranged from 3 to 5 g in weight. During the first and second years of stocking, fish were fed on a mixture of rice bran and mustard oil cake (2:1). During the third year, they were initially fed on rice bran and mustard oil cake (2:1) for 3 months, and an intensive grass feeding without using any manure and fertilizers was adopted for the remaining period.

Because the body weight gain of Grass carp was higher than that of the other carp species, the project increased its ratio in the third year by replacing some of the underperforming Common carp with Rohu (*Labeo rohita*) and Naini (*Cirhhirnus mirgala*). For details, see Table 1.

Table 1
Stocking ratio and density of carp polyculture in different years of Ujyalo project (2005-2007)

Years	Stocking ratio (CC:GC:SC:BHC:R:N)	Stocking density (No. of fingerlings per ha)
2005	30:20:40:10:0:0	10,000
2006	30:20:40:10:0:0	10,000
2007	15:25:40:10:5:5	10,000

CC-Common carp; GC-Grass carp; SC-Silver carp; BHC-Big head carp; R- Rohu; N-Naini

Two nurseries were established during the project period in Chisapani (*Banke*) and Bagnaha (*Bardiya*) with an annual production capacity of 300,000 large-sized fingerlings. Following this, a pilot catfish project (Nepal-SIMI) was implemented from April to July 2008. Twenty five fish ponds were constructed at Mirchaiya (*Bardiya*) with water surface area of 25 m^2 (5 m x 5 m) and depth of 1m. Some fish farmers also practiced two crops (April-July and August- November) in a year. The stocking density of catfish in the pond was maintained at 5 fingerlings per m^2 of water surface.

Trainings in fish culture were also conducted involving resource persons from the government prior to project implementation, and were continued at intervals during the entire project period to address field problems.

In the first year of project, 150 fish ponds were constructed in Banke and Kailai districts. The total production from ponds, including fish and vegetables, were recorded to calculate the income per household from different crops. In the second year, 16 ponds were randomly sampled to compare the growth of carp species. The body weight of different carp species was recorded and tabulated for comparative growth analysis. In the case of catfish, data were recorded from all the 25 ponds to calculate the gross income per pond. Catfish harvesting was carried out from the fourth month of stocking by angling. A complete harvesting was done only by pond drying in the fifth month.

3. Results and discussion

The Ujyalo project successfully supported fishery enterprises in three Terai districts: Banke, Bardiya and Kailali. A total of 41 fishers' groups were formed from households having less than 10 Katthas of land. On an average, there were 17-20 members in each group. INFRIN covered the labor cost of NRs 17,031 for smallholder farmers using their family labor for the construction of a small fish pond of 200 m^2 size. The allocated money was used for treadle pump installation and fingerlings purchasing. In addition to this cash support, they were also given some material support (including a soil carrier, shovels, two spades, five polythene pipes and a rope).

Recognizing the need for locally produced fingerlings, WI/IDE supported the establishment of two fingerling nurseries run by two lead farmers. Integrated culture of vegetables and bananas along the pond dikes provided the farmers with additional income. The multiple income sources for the farmers were an unanticipated positive outcome of the Ujyalo project.

3.1. Carp polyculture

3.1.1. Fish production

During the first year of the project, 150 fish ponds were constructed. The total yield from these ponds was 7,916 kg and income earned from fish sale was NRs 692,860 (Table 2). Mean growth of carps obtained is shown in Fig.1.

Table 2
Fish production in irst year (2005-2006) of Ujyalo project

Pond area (ha)	3
Total No. of households involved	150
Fish yield (kg/ha)	2,638.67
Total fish sales (kg)	7,070
Price of fish (NRs/kg)	98
Gross income from fish sale (NRs)	692,860
Income from fish sale (NRs/HH)	4,619.07
Income from fish sale (US$/HH)	73.32
Home consumption of fish (kg)	846
Value of home consumption of fish (NRs/HH)	82,908
Value of home consumption of fish (US$/HH)	8.77
Home consumption of fish as % of total production	11

After deducting the value of home consumption of fish i.e., 11% of total fish production income from fish per house hold was US$ 73.32.

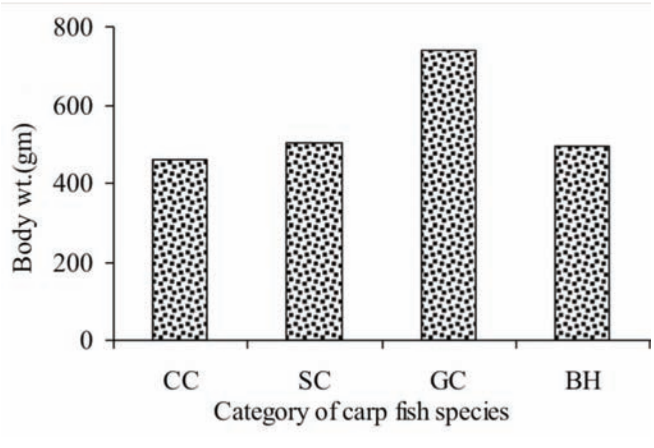

Fig. 1. Body weight gained by different categories of carp fish species at Naubasta, Banke (March-November 2006).

Gorder (1992) reported that a low-cost integrated small-scale fish farming system is the most appropriate aquaculture approach to a sustainable smallholder production. Home aquaculture can be as practical as gardening for providing healthy food to a family and one can harvest over 100 lbs of fish in five months.

3.1.2. Vegetable production

The total vegetable production from the 150 fish pond dikes was 56,869 kg, comprising bitter gourds, egg plants, sponge gourds, bottle cucumbers, cowpeas, snake gourds, tomatoes, pumpkins and leafy vegetables. They were produced in rainy and winter seasons when their prices were high.

Table 3
Vegetable production in first year (2005-2006) of Ujyalo project

Total No. of households involved	150
Total vegetable production (kg)	56,869
Total vegetable sales (kg)	42,914
Price of vegetables (NRs/kg)	13
Income from vegetable sale (NRs)	557,882
Income from vegetable sale (NRs/HH)	3,719.21
Income from vegetable sale (US$/HH)	59.04
Home consumption of vegetables (kg)	13,955
Value of home consumption of vegetables (NRs/HH)	181,415
Value of home consumption of vegetables (US$/HH)	19.20
Home consumption of vegetables as % total production	25

Vegetable production from individual pond dike was 379 kg/year. The income from vegetables sale was NRs 3,719 at farm gate. Traders picked up vegetables and fish at farm gate. There were very few instances of farmers selling their products in local market.

3.2. Catfish culture

The result of catfish cultivation in Mirchaiya, Bardiya was encouraging. Ponds of 25 m^2 water surface area produced catfish in the range of 7-35 kg within a growing period of four months, indicating that the farmers require additional technical support to achieve the normal production level (Fig. 2). Some fish farmers were practicing two crops (April-July and August-November) in a year to double the production.

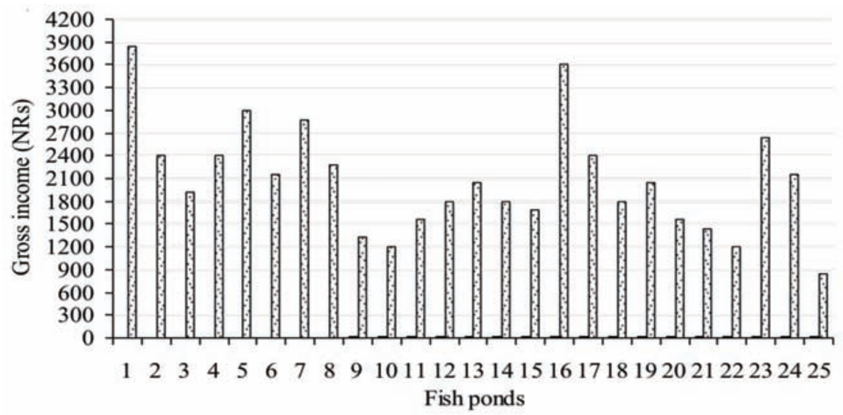

Fig. 2. Gross income from cat fish culture initiated and promoted by Nepal-SIMI at Mirchaiya, Bardiya (April-July 2008).

3.3. Social and economic aspects of the community

The small-scale fish farming project with carp polyculture improved nutritional status of the households through animal and plant protein sources grown in their ponds and pond dikes. The additional income supported their health and education and upgraded their financial status. In the first year of the project, the value of fish and vegetables produced and consumed per household was found to be US$ 132.36. Shang (1981) supported the result concluding that fish culture has an advantage over the husbandry of other vertebrates because fish use less metabolic energy for movement and thermal maintenance. In India, Sinha and Srivatava (1991) also added that returns from aquaculture can be up to 15 times higher than traditional agriculture.

A series of trainings were conducted on fish production technology, hatchling/fry nursery development and management, pond management, harvesting/post-harvesting, integrated fish farming, vegetable nursery management, and vegetable production management. They helped the farmers to commence their own micro-enterprises. This shows that the farmers know about the production techniques and sustainability of the enterprises.

4. Conclusions and recommendations

Nepalese aquaculture in recent years has been dominated by commercial production. The government has emphasized the need for the involvement of small-scale farmers in rural areas of the country in integrated fish farming, which can contribute to the expansion of food supply for poor farmers in Mid- and Far-western Regions of the country.

The Ujyalo project supported the fishery enterprise in three Terai districts for two and half years and produced very good results. For carp polyculture, 41 fishers' groups with 17-20 members were formed. INFRIN contributed NRs 17,031 to cover the labor cost for the construction of a small fish pond of 200 m^2 for each household. Fast-growing carp species such as Common carp, Grass carp, Silver carp, Bighead carp, Rohu and Naini were cultured. A treadle pump was installed near each pond to irrigate vegetables on the dikes; to maintain pond water depth; and to balance dissolved oxygen in pond water. In the first year of carp culture, fingerlings were stocked in July and harvested in December, whereas in the second year, a regular growing period of 8 to 10 months was adopted by stocking fingerlings in February-March and harvesting in November-December. The large-sized fingerlings were 3-5 g. During the first and second years of stocking, fish were fed on a mixture of rice bran and mustard oil cake (2:1) throughout the growing period, whereas during the third year, this diet was replaced after 3 months with an intensive grass feeding without manure and fertilizers.

The total fish and vegetable yields from integrated carp polyculture were found to be 53 kg and 379 kg, respectively, with each household earning a total annual gross income of NRs 8,976 (US$132). In the succeeding year and half, quantitative data were not recorded but the farmers claimed they harvested 100-150 kg of fish and 300-500 kg of vegetables from each pond, increasing their incomes by NRs 15,000 to 20,000 annually.

Catfish culture is widely spread in Tharu and other marginalized communities. Realizing the inadequacy of technical knowledge about it, Nepal-SIMI implemented a pilot project in 2007/08 in Mirchaiya, Bardia. As a result, the farmers were able to harvest 7-35 kg of fish from the ponds of 25 m^2 within a four-month growing period and an increase in gross income by NRs 3,840 was achieved.

Existing locally-based research programs and projects on farming systems can provide valuable information for integrated fish farming development in Nepal and help portray the true complexity of the farming societies and identify the reasons for farmers' decisions about production. Those involved in integrated fish farming research and development should consult these existing sources of information on local farming systems and collaborate closely with efforts in this area in the future.

The research and extension should focus on finding locally adapted, low-external input and low-level management solutions for small-scale farmers. Small-scale fish farming is significantly more sustainable than intensive production. Such practices can substantially reduce production costs as inputs are minimized.

Government of Nepal allocated NRs 400,000 through the Fisheries Development Center, Mahdevpuri, Banke, for the construction of 40 small fish ponds in Banke in the fiscal year 2008/09. In addition, construction of another 400 small fish ponds (300 m^2 water surface area) was being carried out in Banke and Bardia with WFP support in the same fiscal year under the USAID-funded Nepal EIG project.

Both the hilly and Terai areas of Mid- and Far-western Regions can support small-scale fish farming for the poor. Dang and Surkhet districts have been found suitable to launch small-scale fisheries programs using the same practice that has been successfully implemented in Banke, Bardiya and Kailali. Small-scale fish farming - whether it is leasehold or private - can play a very important role in enhancing the livelihood of poor communities.

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Community-based small-scale fish farming in Nepal: Challenges and opportunities

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Abstract

The main purpose of the paper is to share experiences of Community Fish Production and Marketing Project (CFPMP) funded by Canadian International Development Agency (CIDA), and analyze community-based fish production as a livelihood source, its commercial marketing, challenges and opportunities. The paper illustrates CIDA's community-based project approach, implementation mechanism, institutional arrangement, community mobilization and participation of women from indigenous Tharu community in small- scale fish farming and its achievements within the framework of community-driven development in Nepal. Exploring the realities of communities in rural Nepal, the paper investigates how various institutions, such as academic and research organizations, government line agencies, civil society organizations and private sector, can coordinate and collaborate for small-scale fish farming and marketing in Nepal. Finally, it recommends that small-scale fish production through active participation of women can be a good income-generating opportunity for rural communities and an important livelihood option for people having small land holdings and living under poverty in Nepal.

Keywords: Community-based development; Small-scale fish farming; Livelihoods; Women's participation; Poverty; Small land holdings

1. Introduction

Nepal is a predominantly agricultural country where more than 80% of the 26.5 million people are dependent on agriculture. Agriculture accounts for about 40% of the country's total gross domestic production (GDP). About 42% of the people are below poverty line with annual per capita income of ~US$ 236. Average family size of Nepal is six. Malnutrition among children and women has long been well recognized as one of the serious problems. Short supply of animal protein has been critical and its considerable decline over the past few years is alarming. In the fiscal year 1989/90, 7.2% of the per capita calories were available from animal products, but this declined to 5.3% in 1994/95 (MDD, 1996, cited in RIDS, 2007). Similarly, 16.3% of the per capita protein was available from animal products in 1989/90 which decreased to 12.4% in 1994/95 (MDD, 1996). For minimal nutritional standards, at least a third (33%) of the total protein intake should come from animal sources. Due to rapid population growth (@ 2.3% per annum), the situation will be more severe in the future resulting in more health problems in the small farm families. Data from the past 10 years (ASD, 1996) showed that the possibility to increase area for cultivation of cereal crops and their productivity is in slow progress. Various attempts were made to increase production of cattle, buffaloes, pigs and poultries in the past decades. However, these efforts were not so fruitful due to cultural and traditional reasons (e.g., slaughtering cows is not allowed; and some castes do not eat chicken and pigs.), high capital investments and running costs, unfavorable climate and lack of technical human resources.

The above facts show that it is essential to explore alternatives to feed the fast growing population of Nepal. Fish culture has high potential due to its technical efficiency (Sharma and Leung, 1998), high profitability (2-4 times) than other high-value agricultural sub-sectors (Baral, 1992) and high demand for local and export markets (Rajbanshi, 1995), and the country's abundant water resources (CBS, 1991; Yadav and Bhujel, 1998). More importantly, fish and fish products are acceptable to every segment of the population except for those who are purely vegetarian. In addition, farming of freshwater prawns - also known as the giant fresh water prawn (*Macrobrachium rosenbergii*) - has great potential in Nepal. Prawns have already been introduced in the country. Nepal Agricultural Research Council (NARC), an autonomous organization for agricultural research, has also started some on-farm trials. A preliminary study on fresh water prawns in farmers' ponds has shown encouraging growth (There are some problems though) (Shrestha and Rai, 2002). Fish and prawns have good demand in big hotels in Kathmandu valley as well as in other towns, mainly in tourist areas where restaurants offer fish and prawn dishes. Prawns fetch one of the best prices, and hence farmers will not have any marketing problem.

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Based on the above facts and context, Canada Fund for Local Initiatives (CFLI)/Canadian Cooperation Office (CCO) supported a community-based NGO called Rural Integrated Development Society (RIDS), Kathar, Chitwan and Institute of Agriculture and Animal Science (IAAS), Tribhuvan University, Chitwan to implement Community Fish Production and Marketing Project (CFPMP). The main purpose of this paper is to share experiences of CFPMP as a community-based initiative, and analyze fish production as a source of livelihood, its commercial marketing, challenges and opportunities.

2. Methodology, project purpose and expected results

2.1. Methodology

- The project was implemented in Kathar of Chitwan district and Kawashoti of Nawalpur district. RIDS-Nepal, with technical cooperation and managerial support from IAAS, managed the project. The project was owned and managed in partnership with local community members, particularly Tharu women. Small-scale farming households of traditional fishing communities were the beneficiaries of the project. This paper is based on the following methods:
- Project reports review;
- Field observation and interactions with the NGO, community members (women/men) and fish farmers; and
- Interactions with professional(s) from the supporting organization, the IAAS.

2.2. Project purpose

The purpose of the project is to increase income and improve nutritional status of disadvantaged community women and men through fish and prawn farming.

2.3. Expected results

2.3.1. Outcome level

- Developed fish and prawn production through institutionalization of cooperative network;
- Increased household income and improved nutritional status of the community members, particularly women and children; and
- Strengthened capacity of the executing agency (EA) to effectively plan and implement project activities.

2.3.2. Output level

- Establishment of community-based Fish-Prawn Production and Marketing Groups (FPMGs) in institutionalizing fish-prawn cooperative network;
- Increased fish-prawn production and marketing leading to rise in household income and improvement in nutritional status of the community members, particularly women and children; and
- Increased knowledge and skills of EA in project implementation and management.

3. Project components/activities

The activities were identified to contribute to achieving the output level results which, in turn, will contribute to achieving the outcome level results by the end of the project. The project mainly included the following two major components:

3.1. Fish and prawn production and marketing

This component included selection and recruitment of project participant households, pond construction, and fish and prawn production and marketing. All the project participants were provided with trainings on pond construction and management, and fish and prawn marketing. These trainings were conducted by project staff and resource persons from District Agriculture Offices and various other organizations.

3.2. Formation and strengthening of FPMGs and cooperatives

This second component was mainly aimed at empowerment of women through organizing them in production and marketing groups. In the first year, project participants formed small production and marketing groups. Members of these groups also started monthly savings. The members of savings groups were given trainings on management of savings funds. These groups were registered as women's FPMGs with Agriculture and Cooperative Offices at the district level. In the second year, FPMG members in both the project sites were provided with a series of trainings on formation and management of fish farmers' cooperatives. These trainings were of two types:

- A general training providing orientation on formation and operation of cooperatives was conducted for all the project participants. This primarily included what cooperative was and how existing women's FPMGs would function more effectively once these are developed into cooperatives.
- A series of trainings related to formation and management of cooperatives were provided specifically to the executive members of FPMGs. The focus of these trainings was on co-operative development and management, techniques of loan investment and accounting.

4. Findings and results achieved

4.1. Strengthening of producers' groups

The project has been successful in strengthening the producers' groups (FPMGs) ever since their formation. The groups formed are inclusive of all the caste and ethnic people living in the community (Table 1). They organize regular monthly meetings of the executive members and establish close relationships among them. Fish culture activities and group savings are regular agenda of these meetings. Major discussions and decisions are recorded in minutes. The RIDS staff also participate in such meetings and provide technical support as and when required.

FPMG members and executive members from both the sites were provided with a series of trainings on group responsibility, group dynamics, leadership development, gender, peace and development, financial management and local resource mobilization. The project supported training materials, trainers' fees, operational materials and stationery. Most of the technical trainings were conducted by experienced resource persons. Professional trainers were hired from outside to provide trainings on development and management of cooperatives, fund management, and savings and credit. Such trainings have been very useful in strengthening the groups and in increasing their members' capacity to manage the community-based activities.

To impart practical knowledge and information on fish-prawn culture in Nepal, the project supported a study/observation tour for all the project participants. The tour was organized to show fish farming carried out by the government line agencies and private sector in Makawanpur and Pokhara. The participants also visited different women's cooperatives in Makwanpur and exchanged ideas with the executives of the cooperatives and staff of Plan International's Makwanpur Women's Empowerment Program. The farmers could learn from and share with their peers and found the study to be very useful in pursuing them to adopt innovations.

Table 1
General descriptions of FPMGs

Description	Location	
	Kathar, Chitwan	Kawaswoti, Nawalparasi
No. of project participants	33	28
Formation of fish production and marketing sub-groups	Gothauli sub-group Kushana sub-group Gurung tol sub-group Sukumbasi tol sub-group Kathar 2 and 3 sub-group	Badrua tol sub-group Tarua tol sub-group Bandeuli tol sub-group
FPMG Executives	Chair: Gauri Chaudhary Secretary: Dilmaya Gurung Treasurer: Meena Chaudhary Members: Sabitri Chaudhary Harikala Dahit Bhikhani Chaudhary Usha Chaudhary	Chair: Lokmaya Gurau Secretary: Champa Gurau Treasurer: Tulsi Mahato Members: Dal Kumari Bote Bhagabati Mahato Maya Bote Lok Maya Gurau
Date of FPMG formation	12/02/2062 (2006)	14/02/2062 (2006)
Commencement of monthly savings by members	Ashad 2062 (2006)	Ashad 2062(2006)

Source: RIDS, 2007

4.2. Fish-prawn pond construction and culture

Strengthening of FPMGs has led to increased community cohesion and cooperation. Construction of farm ponds was carried out between December 2004 and March 2005. The majority of the participant households mobilized their household labor force to excavate farm ponds. The CFPMP provided them with technical support on planning, layout and construction of farm ponds. Besides, it also offered partial support to cover the costs of labor, fish seed and some construction materials. A total of 61 farm ponds were constructed with the active involvement of the participant households (Table 2). The number of ponds constructed in Kathar (33) was higher than that in Kawasoti (28). Pond size varied with resource base (land and labor) and willingness of the participant households to convert their agricultural lands into fish ponds. The mean pond size in Kathar (225 m^2) was higher than that in Kawasoti (116 m^2).

Table 2
Pond characteristics

Major activities/ accomplish ments	Location		Total
	Kathar, Chitwan	Kawasoti, Nawalparasi	
Ponds: General descriptions			
No. of ponds constructed	33	28	61
Pond size (m^2):			
Mean	225	116	170
Minimum	63	40	40
Maximum	696	255	696
Standard deviation	157	58	

Source: RIDS, 2007

All the participant households stocked fingerlings upon fertilizing their ponds for a few weeks after excavation. Fish species stocked included tilapia and carps (Chinese and Indian). Mixed-sex tilapia and carps were the major species stocked. Some farmers practiced polyculture of carps, while others stocked mixed- sex tilapia. All the participant households were advised on the number, type, and species combination (for polyculture), and hence essentially maintained stocking density and species combination within the recommended range. Post-larvae of fresh water prawns were stocked in around half of the farmers' ponds in both the sites. Prawns were integrated in carp polyculture ponds and tilapia monoculture ponds. Most of the households grew a wide range of vegetables and herbs in the dikes/ plot adjacent to their farm ponds.

The participant households utilized various on-farm resources as pond inputs. A large majority of them applied wastes from kitchen and home-gardens, and various crop byproducts as the major inputs. They included cooked rice, rice bran, wheat bran, wheat flour, mustard oil cakes, aquatic weeds available in the area, grasses, and vegetable residues. Besides, the ponds were also supplemented with limited amount of inorganic fertilizers in order to make water plankton-rich green.

4.1.1. Fish-prawn production, consumption and sales

Average fish production per pond in Kawaswoti was estimated to be 27 kg (range: 12-90 kg), while the same in Kathar was estimated to be 77 kg (range: 20-340 kg) (Table 3, Table 4, Fig. 1 and Fig. 2). The variation in total fish production between the two sites was associated with the variation in pond area and the amount of pond inputs applied. Average size of ponds in Kathar was estimated to be larger, and the farmers in this site applied larger amount of pond inputs. Consequently, the farmers in Kathar were successful in achieving notably higher fish yield compared to their counterparts in Kawaswoti. Estimation of prawn yield was difficult as the farmers, particularly in Kawaswoti site, indicated that they consumed prawns without any estimation of their weight. However, considering the total number of prawn harvested, average production was estimated to be nearly 1 kg.

Fig. 1. Women farmers netting fish and prawns.

Fig. 2. Fish and prawns harvested in Kathar, Chitwan.

Table 3
Fish production, consumption and sales in Kawasoti (Year 2)

Participant	Pond area (m^2)	Consumed (kg)	Sold (kg)	Total prod (kg)	Income (NRs)
Anita Bote	200	4.5	19	23.5	2,350
Chad Kumari Bote	106	4	16	20	2,000
Mina Bote	97	4.5	12	16.5	1,650
Bhagawoti Mahato	98	2.5	15	17.5	1,750
Maya Bote (ka)	102	6.5	13	19.5	1,950
Asha Bote	90	9.5	8	17.5	1,750
Rita Bote	80	5	10	15	1,500
Man Maya Budhathoki	40	3	50	53	5,300
Pabitra Mahato	40	5	7	12	1,200
Sita Devi Mahato	55	6	10	16	1,600
Lok Maya Gurau (ka)	224	7	34	41	4,100
Chhan Kumari Mahato	70	5	10	15	1,500
Hemanti bote	72	4.5	11	15.5	1,550
Man Kumari Bote	80	13.5	8.5	22	2,200
Aiet Kumari Bote	80	7	10	17	1,700
Surya Kumari Bote	92	8	4	12	1,200
Champa Gurau	120	10	22	32	3,200
Tulsi Devi Mahato	105	5.5	44	49.5	4,950
Tapli Maya Magar	58	4.5	10	14.5	1,450
Lok Maya Gurau (kha)	203	10	38	48	4,800
Sita Mahato	180	23	67	90	9,000
Prem Kumari Mahato	151	12	12	24	2,400
Khar Kumari Gurau	255	3.5	15.5	19	1,900
Man Kumari Gurau	150	10	15	25	2,500
Mina Thanet	190	12	27	39	3,900
Dhal Kumari Bote	140	14.5	8.5	23	2,300
Maya Bote (kha)	80	8	17	25	2,500
Chhan Kumari Bote	84	18	22	40	4,000
Mean	116	8	19	27	2,721
Minimum	40	3	4	12	1,200
Maximum	255	23	67	90	9,000

Source: RIDS, 2007

Production of fish in farm ponds clearly led to increased frequency of its consumption among the project households. This special item was normally consumed in various festivals. Besides, fish were also used to treat family guests. Total amount consumed was closely related to total amount produced. In Kathar, the amount of fish consumed by the households ranged from 4 to 135 kg, with an average of 38 kg (Table 4). By contrast, the same in Kawaswoti was estimated to range between 3 and 23 kg, with an average of 8 kg (Table 3). However, in both the sites, the households consumed roughly around a third to half of the total fish produced in their farm ponds. A large majority of the households also sold fish and augmented their income. The total amount sold was noted to be clearly related to total production. In general, around a third of the total fish produced was sold, with variation noted across the households. In Kawaswoti, average amount of fish sold per household was estimated at 19 kg (range: 4-67 kg), while the same was estimated at 77 kg (range: 20-340 kg) in Kathar (Tables 3 and 4).

Table 4

Fish and prawn production, consumption and sales in Kathar (Year 2)

		Fish				Prawn				
Participant	Pond area (m^2)	Consumed (kg)	Sold (kg)	Total prod (kg)	Income (NRs)	Stocked (No.)	Consumed (No.)	Sold (Kg)	Income (NRs)	Total Income (NRs)
Budhi M. Gurung	168	40	45	85	8,500	180	13	1.3	520	9,020
Susila Gurung	229	50	75	125	12,500	200	24	0.6	240	12,740
Ram Maya Gurung	280	25	42	67	6,700					6,700
Dil Maya Gurung	390	80	50	130	13,000					13,000
Bishnu M. Gurung	221	50	75	125	12,500					12,500
Jag Maya Gurung	75	30	28	58	5,800	85	4	0.4	160	5,960
Sita Thapa	262	35	71	106	10,600					10,600
Sagar Thapa	300	66	85	151	15,100					15,100
Sita Choudhary	378	25	25	50	5,000	215	24	1.1	440	5,440
Sunita Choudhary	315	35	50	85	8,500					8,500
Mangri Choudhary	696	135	205	340	34,000					34,000
Renu Choudhary	670	100	50	150	15,000	215	17	1.5	600	15,600
Sabitri Choudhary	120	23	21	44	4,400	135	16	0.3	120	4,520
Usha Choudhary	120	22.5	8.5	31	3,100	135	5	0.3	120	3,220
Bhagti Choudhary	160	40	45	85	8,500					8,500
Sauni Choudhary	121	30	5	35	3,500					3,500
Atoria Choudhary	161	20	30	50	5,000	125	14	0.5	200	5,200
Gauri Choudhary	351	35	40	75	7,500					7,500
Mansin Choudhary	288	45	35	80	8,000					8,000
Kabita Choudhary	175	25	25	50	5,000					5,000
Dhan M. Choudhary	396	40	15	55	5,500					5,500
Harikala Dahit	120	5	66	71	7,100	135	14	0.5	200	7,300
Bhikhani Choudhary	120	4	70	74	7,400					7,400
K. Choudhary	84	25	10	35	3,500					3,500
Umchi Choudhary	63	22	10	32	3,200					3,200
Hathani Choudhary	180	10	12	22	2,200	190	10	1.2	480	2,680
Maya Choudhary	80	25	8	33	3,300					3,300
Mina Choudhary	324	35	5	40	4,000					4,000
Akali Choudhary	85	10	10	20	2,000					2,000
Sukara Choudhary	72	25	12	37	3,700					3,700
Sani Choudhary	119	20	35	55	5,500					5,500
Laxmi Choudhary	176	45	26	71	7,100	190	10	0.4	160	7,260
Saru Gurung	120	80	10	90	9,000	130	15	0.4	160	9,160
Mean	225	38	39	77	7,748	161	14	0.7	283	7,852
Minimum	63	4	5	20	2,000	85	4	0.3	120	2,000
Maximum	696	135	205	340	34,000	215	24	1.5	600	34,000

Source: RIDS, 2007

Price of fish in local market in Kawaswoti and Kathar was roughly around NRs 100/kg. Estimation of gross household income from it was based on the total amount produced (kg) and average price (NRs 100/kg). Gross return from fish varied between Kawaswoti and Kathar, which was in line with the variation in total fish produced in these sites. Average gross return in the former was estimated to be NRs 2,721 (range: NRs 1,200-9,000), while the same in the latter was NRs 7,748 (range: NRs 2,000-34,000) (Tables 3 and 4). Besides, some of the households stocking prawns were also successful in making additional earnings by selling them in the local market (Table 4). Integration of prawns with fish gave additional returns and fish yields were not affected by it.

Considering the total production and return from fish-prawn culture, fish production in the project farm ponds were comparable to that elsewhere in the similar culture system relying mostly on on-farm inputs. Fish production can adequately be increased with the intensification of production systems by fertilizing ponds with chemical fertilizers. Marketing of fish and prawns was not a problem due to their very high demand in local market and even in the project villages themselves. Fish-prawn marketing cooperative members in both the sites were well prepared to increase fish production and also explore new markets in the coming years.

4.4. Cooperative development and strengthening

The FPMGs in both the sites have been developed into two community fish-prawn cooperatives in their Village Development Committees (VDCs). They have been registered as per the Cooperative Law of Nepal with Agriculture and Cooperatives Offices at the district level. The cooperatives have become functional since their establishment. They have been supporting, facilitating and leading the FPMGs members, including developing marketing linkages, and motivating and assisting individual FPMG members. The cooperatives have also been playing an advocacy role. Active participation of women members in fish production and marketing has contributed to narrowing gender gap in the community. Moreover, the cooperative members have been participating in discussions and meetings with local authorities, line agencies, other community members, and visitors from different organizations.

The project supported a long-term development of fish-prawn production and marketing through fish-prawn development fund (NRs 200,000/ cooperative). The number of women shareholders has increased to 63 and 44 in Kathar and Kawasoti cooperatives, respectively (Table 5). The members deposited their monthly group savings as their shares. These funds, together with the members' savings have been deposited in the cooperatives' bank accounts. The project provided partial subsidies on pond construction, fish and prawn seed, and pond inputs to the cooperative members. Their contribution was mainly in the form of labor and household resources. The cooperatives have already started lending as per their cooperatives rules. This has been a very effective mechanism for mobilizing local resources for sustainable fish-prawn production and marketing.

Table 5
Comparison of cooperatives in Kathar and Kawasoti (based on January 2009 updates)

	Women Fish Farming Cooperative, Kathar	Women Fish Farming Cooperative, Kawasoti
Cooperative registration (year)	2005-2006	2005-2006
Share holders	63 Women	44 Women
CFLI Capitalization fund (NRs)	200,000	200,000
Regular savings (NRs)	136,300 Interest (NRs): 35,190	65,000
Total capital (NRs)	361,490	265,000
Total Fish Pond (No.)	106 (186,135 m^2)	28 (4,617 m^2)
Annual fish production (kg)	25,000	1,000
Income from fish sale (NRs)	2,500,000	100,000
Cooperative Executive Committee	11 Members 2 Accountants	7 Members 2 Accountants

Source: RIDS, 2007

Women's participation in fish production and marketing not only improved household food security but also increased their access to and control over resources. Women would use incomes from fish and prawns to meet household expenses and also invest in their culture. The formation and management of cooperatives solely by women contributed to their empowerment as they could strongly feel ownership of their cooperatives due essentially to their active involvement right from their initiation to registration and management. Likewise, they developed knowledge and skills for organizational management (administrative and financial) and built confidence to actively participate in their own development activities.

4.5. Community-based development model

The CFPMP was designed as a community-based development approach in Nepal, where local groups were linked to the government district line agencies, academic institutions, banking institutions such as cooperatives and local NGOs (Fig. 3). It was developed through the mobilization of Tharu women, focusing on regular savings, fish pond construction, training and management, fish production and marketing. The project tried to establish community-based user groups to empower people to participate in planning and implementation of various development activities, emphasizing group cohesion and social harmony. It created an institutional base and established sustainable cooperative institution.

Fig. 3. CIDA Community-based programming approach.

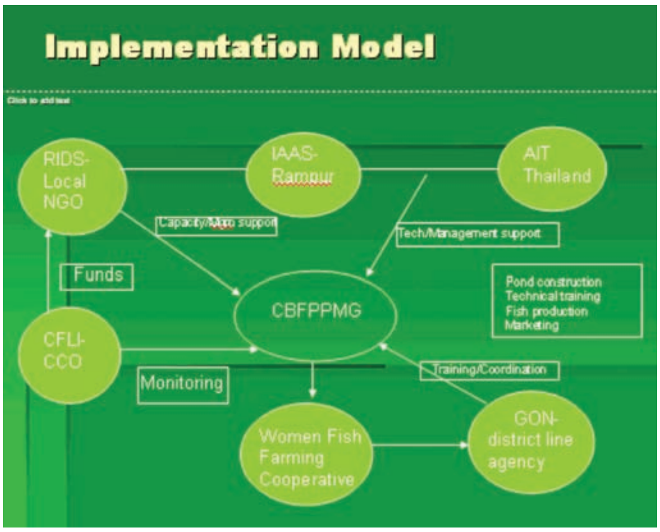

Fig. 4. Community-based project implementation model.

The EA (RIDS) and technical support agency (IAAS) together with local groups (FMPGs) coordinated and collaborated with the government line agencies such as Fisheries Development Center and Agriculture and Cooperatives Offices at the district level and the local governments (VDCs and District Development Committees (DDCs)). However, the linkages with the VDCs and DDCs for technical cooperation, fish farming promotion and development, and resource mobilization were found to be very weak, and hence need to be strengthened (Fig. 4). The project also enhanced capacity of the EA by providing training on project management, accounting, book keeping and reporting to its staff and executive board members.

One of the benefits of community-based approach is sustainability and the project emphasized the sustainability of its results. Farmers who joined the project are also expanding their pond areas and activities. Active participation of the community in all stages of the project, their resource contribution and institution building has ensured ownership and sustainability of the project. Adequate returns realized from fish-prawn production strongly suggest that participating households would expand their production system, while other households in the community would also start fish culture. The setting up of cooperatives essentially owned by women has adequately empowered them in organizational management. Cooperative management activities have been well institutionalized. All the participants have developed competency in fish culture and marketing with respect to pond management, feed preparation and feeding, seed purchasing and stocking, and marketing of fish. Moreover, most of the participants have realized that fish culture is much easy (in contrary to capture fisheries) and that it ensures fish supply for the household consumption all year round; enhances health of their family members through increased frequency of fish consumption; augments household income from fish sale; and helps reduce household expenditure on meat and fish.

5. Challenges and opportunities

This is a small pilot project to promote community-based small-scale fish-prawn farming aiming to improve nutrition and livelihood of disadvantaged Tharu community members, particularly women and children. There are several challenges to replicate this kind of initiative in various potential pocket areas throughout Nepal. They include: identification of potential small-scale fishery project areas and interested communities to start with some innovations; technical feasibility of mixing fish and prawn; technical knowledge on fish farming and resource availability; local resource mobilization; and increasing production from small-scale farming and marketing.

The results achieved from this project have shown that there is tremendous potential for socio-economic development by increasing household income through small-scale aquaculture involving rural women and disadvantaged communities. Such communities with their traditional skills in fish farming and acquired advanced knowledge from outside can substantially increase the productivity. Making use of the abundance water resources - which would go wasted otherwise, they can produce nutritional food for the household consumption and also generate income by selling the surplus. Collaborative efforts among the communities, NGOs, the government, donor/development partners, private sector, and academic institutions can bring significant changes in the lives of rural people through the promotion community-based small-scale aquaculture. Yet, there is a need for further investigation on small-scale aquaculture/fish farming in Nepal.

6. Conclusion

The project has demonstrated the success of fish-prawn integrated system in small-scale farming systems in Nepal for the first time. There exists enormous potential for the promotion of this model in most of the Terai districts of the country. Establishment of a mini- prawn hatchery and successful breeding of prawn at IAAS has been a significant achievement of this project. Formation of FPMGs and their subsequent development into cooperatives solely owned and managed by women members has notably contributed to women’s empowerment, which is another important achievement of the project. They are not only concerned about production of fish but also about its costs, returns and marketing as well as health and nutrition of their families. Likewise, they have been instrumental in encouraging their neighbors and relatives for fish farming. As the project participants are from traditional fishing communities (Tharu, Darai), their involvement in fish culture not only helped to meet their household fish demand but also contributed to aquatic resources conservation by virtue of reduced fishing pressure in streams, swamps and rivers.

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Small-scale aquaculture development model for rural Nepal

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Abstract

The majority of rural farmers in Nepal are small holders and their livelihood is based on agriculture. Three projects on small- scale aquaculture, with focus on women's involvement, were completed in Kathar and Kawasoti Village Development Committees (VDCs) of Chitwan and Nawalparasi districts, respectively during 2000-2007. Based on the experience from these projects, guidelines/ steps for the development of small-scale aquaculture in rural areas were drawn. They include: (i) selection of technically feasible site; (ii) identification of appropriate rural society/ ethnic group; (iii) formation of homogenous fish farmers' groups; (iv) registration of these groups with District Agriculture Office; (v) involvement of household heads (both male and female) in training and other activities; (vi) providing technical and input support for one culture cycle; (vii) organizing regular monthly meeting of fish farmers' groups to discuss on-going and upcoming activities, with an emphasis on women; and (viii) establishment of fish farmers' cooperative and its registration with District Cooperative Office. Small-scale aquaculture should be developed in clusters or groups and not in a scattered pattern. Emphasis on "one household-one pond" wherever possible provides an opportunity to form clusters.

Keywords: Aquaculture; Small-holder farmers; Rural livelihood; Woman's involvement; Nepal

1. Introduction

Small-scale aquaculture is the farming of aquatic organisms by small-scale farming households, using mainly extensive and semi- intensive husbandry for household consumption and/or income generation (Edwards and Demaine, 1977). It is further defined as part of subsistence farming with low or no input and with little or no routine management (Wilson, 2005). Small-scale farmers are resource-poor and big pond (>300 m^2) may face input limitation, causing low productivity (Bhujel et al., 2002a,b; Bhujel et al., 2004; Bhujel and Shrestha, 2007). The majority of rural farmers of Nepal are small holders and subsistence in nature. Farming is characterized by integration of crops with livestocks, and livestocks are mostly sold for cash income. Aquaculture is a relatively new farming activity in the country, although a number of ethnic minority communities across the country have traditionally made their living (partially/fully) from capture fisheries. Over the years, it has developed as the fastest growing food production sector in Nepal. However, local fish supplies have been extremely inadequate to meet the increasing demand for fish and fish products. The country imports such products in substantial quantities from India (Tiwari, 2009). Integration of pond aquaculture in existing crop-livestock-based farming system is believed to be effective in increasing local fish supply and diversifying livelihood options of small-holder farmers in southern plains (Terai) and mid-hill valleys, thereby increasing the resilience of rural livelihood.

Increasing food and nutrition security, augmenting cash income for household expenses and utilization of family labor are the major issues of the rural poor. The role of small-scale aquaculture in household food and nutrition security, income generation and empowerment of women and marginalized communities has been increasingly appreciated in recent years. Fish has been considered as "Living Cash" and a pond is "Savings Bank" because fish can be caught and sold whenever cash is needed (Bhujel et al., 2008). However, small-holder farmers will be vulnerable if new projects fail to cope with their daily livelihood, and hence such projects need to be implemented carefully so that the activities would continue and be sustainable beyond the project period. In this paper, we present outcomes of three small-scale aquaculture projects implemented in rural Nepal and attempt to suggest steps to be followed for the success of a small-scale aquaculture development project in the country

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2. Project implementation and outcome

Three projects on small-scale aquaculture were completed in Kathar and Kawasoti Village Development Committees (VDCs) of Chitwan and Nawalparasi districts, respectively during 2000-2007. These projects were: (i) Involvement of women in aquaculture to improve nutritional status and generate supplemental income for farm families (Women in Aquaculture - Phase I); (ii) Involvement of women in aquaculture with vegetable gardening to improve nutritional status and generate supplemental income for farm families (Women in Aquaculture - Phase II); and (iii) Community Fish Production and Marketing Project (CFPMP - Phase III) (Bhujel et al., 2002 a,b; RIDS, 2007).

2.1. Women in aquaculture - phase I (2000-2002)

This project was designed for small-scale farmers with the objectives of: (i) “one household-one pond” with an average size of 100-200 m^2 built near the house; (ii) woman member of household to have access to and control over the pond; (iii) fish produced in the pond mainly to be used for household consumption to improve family nutrition; and (iv) surplus fish to be sold to supplement household income. The project was initiated in 2000 at Kathar, Chitwan, Nepal - jointly by Institute of Agriculture and Animal Science (IAAS), Chitwan, Nepal and Asian Institute of Technology (AIT), Pathumthani, Thailand. It was funded by Women's World Day of Prayer (WDP)-German Committee.

The site selection was based on its appropriateness for pond construction, perennial availability of water (gravity flow canal water from river) and a fish-eating ethnic community known as Tharus as its inhabitants. Twenty-one households showed their interest to participate in the project. The project team carried out various activities on a regular basis, with the involvement of participating households. The sequential activities conducted were:

- Meeting was organized with both male and female heads of the participating households. This provided them a good understanding of the project and secured approval from them to be selected as project participants.
- Both the household heads were involved in training on fish farming and acquired relevant knowledge. This helped women to get support and help from their male counterparts as and when needed.
- Most of the ponds were constructed either by using own household labor or getting help from other households. The project supported 50% of the pond construction cost as calculated based on total labor use.
- Supply of fish seed to the participating households was supported by the project for the first year only. In the later years, representatives of the fish farmers were helped to procure and transport fish seed from seed center to the ponds so that they could do it themselves.
- Monitoring was done regularly during the culture period. Pond condition, fertilizer and manure application, and feed application were observed monthly during field visits and meetings.

The outcomes of the project are presented in detail in Table 1 (Bhujel et al., 2002a)

Table 1
Outcomes of Women in Aquaculture - Phase I (2000-2002)

Particulars	Kathar, Chiwan
Pond constructed (No.)	21
Pond size (m^2)	60 - 395
Total pond area (m^2)	3,683
Total fish production (kg)	1,096
Mean fish productivity (ton/ha)	2.98
Production range (kg/pond)	28.5 - 97
Total home consumption (kg)	436
Consumption range (kg/household)	10 - 45
Total fish sales (kg)	660
Sales range (kg/household)	9 - 67
Total supplemental income (NRs)	53,455
Supplemental income range (NRs/household)	630 - 6,030

2.2. Women in aquaculture - phase II (2002-2004)

After the completion of its first phase, the project entered in second phase (2002-2004), with the continued support from the donor. This phase focused on integration of fish farming with vegetable farming in the pond dykes, with the objectives of: (i) producing fish and vegetables using resources available on the farm; (ii) generating family income by selling the surplus ; and (iii) utilizing family labor (women) for the production.

The process followed was similar to that of Phase I. The project was extended to the adjoining villages of Kathar (Phase-I) and also to Kawasoti VDC of neighboring Nawalparasi district. In this phase, 56 new ponds were constructed. In addition, 21 on-going fish ponds of Phase I were also monitored. The detailed outcomes of Phase II are provided in Table 2.

Table 2
Outcomes of Women in Aquaculture - Phase II (2002-2004)

Particulars	Kathar, Chitwan	Kawasoti, Nawalparasi	Total
Total pond constructed (No.)	57	30	77
Pond size (m^2)	50 - 398	30 - 220	30 - 398
Total pond area (m^2)	8173	2667	10840
Total fish production (kg)	2712	534	3246
Mean fish productivity (ton/ha)	3.3	2.0	2.99
Production range (kg/pond)	5 - 205	7 - 35	5 - 205
Total home consumption (kg)	820	166	986
Consumption range (kg/household)	5 - 40	1 - 15	1 - 40
Total fish sales (kg)	1892	368	2260
Sales range (kg/household)	0 - 180	5 - 25	0 - 180
Total supplemental income (NRs)	227,040	44,160	271,200
Supplemental income range (NRs/household)	0 - 21,600	600 - 3,000	0 - 21,600

- Eight new ponds were constructed without any support from the project.
- In general, a third of the production was used for family consumption and the remaining two-thirds were sold for supplemental income.
- Vegetables (okra, beans, tomatoes, taros, ginger, cucurbits and turmeric) and fruit (bananas) produced in the pond dikes were not sold.

2.3. Community fish production and marketing project (CFPMP) - phase III (2004-2007)

CFPMP was developed as Phase III of the Women in Aquaculture project in the same sites as the previous two projects - Kathar, Chitwan and Kawasoti, Nawalparasi. The project focused on polyculture of carps/tilapia with freshwater prawn with the objectives of: (i) developing fish and prawn production through a cooperative network; and (ii) increasing household income and improving nutritional status of the community members, particularly women and children.

The majority of the participating households mobilized their household labor force to excavate farm ponds. CFPMP provided technical support in planning, layout and construction. Besides, the project also provided partial support to cover the costs of labor, fish seed and construction materials. Pond size varied with the variation in resource base (land and labor) and willingness of the participating households to convert their agricultural lands into fish ponds. All the households stocked fingerlings upon fertilizing their ponds for a few weeks after excavation. Fish species stocked included Tilapia, carps and freshwater prawns.

Table 3
Outcomes of Community Fish Production and Marketing Project - Phase III (2004-2007)

Particulars	Kathar, Chitwan	Kawasoti, Nawalparasi	Total
Total pond constructed (No.)	33	28	61
Pond size (m^2)	63 - 696	40 - 255	40 - 696
Total pond area (m^2)	7419	3242	10661
Total fish production (kg)	2557	762	3319
Mean fish productivity (ton/ha)	3.45	2.35	3.11
Production range (kg/pond)	20 - 340	12 - 90	12 - 340
Total home consumption (kg)	1258	227	1485
Consumption range (kg/household)	4 - 135	3 - 23	3 - 135
Total fish sales (kg)	1300	536	1836
Sales range (kg/household)	5 - 205	4 - 67	4 - 205
Total supplemental income (NRs)	156,000	64,320	220,320
Supplemental income range (NRs/household)	600 - 24,600	480 - 8,040	480 - 24,600

- About 30-50% of the fish produced were used for household consumption and 50-70% were sold for supplemental income.
- About 17 kg of freshwater prawns were harvested from the 12 ponds of Kathar, out of which 50% were consumed and the rest were sold.
- The possibility of carp/tilapia polyculture with prawn was demonstrated.
- Two women fish cooperatives were established.

3. Conclusion

The pilot projects implemented in Chitwan and Nawalparasi have been successful in demonstrating the viability of small-scale aquaculture systems in Nepal. Whilst Millennium Development Goals (MDGs) calls for halving the population living in extreme poverty by 2015, harnessing small-scale aquaculture development potential of Nepal could contribute significantly to meeting these goals. The results of these projects have shown that small-scale aquaculture can bring significant impact on household nutritional status.

About 30-50% of the fish produced were consumed by the households and the remaining was sold for supplemental income. Thus, small- scale pond aquaculture is an effective tool for improving household nutrition and generating supplemental income, thereby helping in poverty reduction.

Establishment of women fish cooperatives played key role in strengthening their organizational capacity. Hence, small-scale aquaculture can contribute greatly to women's empowerment. Replication of such projects is likely to benefit a large number of poor women farmers across Terai and mid-hill valleys of Nepal.

However, small-scale aquaculture should be developed in clusters or groups rather than scatterd. Emphasis on "one household-one pond" (wherever possible) provides an opportunity to form clusters. Formation of fish farmers' groups helps to establish linkage with government offices. It gives them power to demand services and supports. Formation of cooperative further strengthens the groups and individual farmers to be more equipped and to get supports from developmental organizations.

Based on the experience from the above three projects, an approach to the development and establishment of small-scale aquaculture in rural Nepal can be described as: "an aquaculture activity carried out by a family/ household as a component of its farming systems for increasing household nutrition through fish consumption and supplemental income from the sale of the surplus for the improvement of livelihood of resource-poor rural households". To achieve the goal of small-scale aquaculture as described above and for the successful implementation of such projects, guidelines/ steps have been developed (Table 4).

Table 4
Guidelines/steps for developing small-scale aquaculture in rural Nepal

1. Selection of technically feasible site;
2. Identification of appropriate rural society/ ethnic group;
3. Formation of homogenous fish farmers' groups;
4. Registration of these groups with District Agriculture Development Office;
5. Involvement of household heads (both male and female) in training and other activities;
6. Providing technical and input support for one culture cycle;
7. Organizing regular monthly meetings of fish farmers' groups to discuss on-going and up-coming activities, with an emphasis on household women; and
8. Establishment of fish farmers' cooperative and its registration with District Cooperative Office.

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Small-scale cold-water aquaculture in Nepal

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Abstract

Cold-water aquaculture is a recent development in Nepal. However, within very few years of technological development of rainbow trout (*Oncorhynchus mykiss*) farming, its popularity is sharply increasing around peripheral districts of Kathmandu valley. Earlier, the unavailability of fingerlings used to be one of the main impediments, which has now been solved through participatory breeding activities. Cold-water aquaculture with rainbow trout, a relatively high input-high output aquaculture, is developing rapidly in the northern hills of Nepal. At present, supply of quality composite pellet feed is one of the most advanced problems. Trout farming could be expanded further if this as well as the problem of networking for extension work could be resolved soon.

Keywords: Rainbow trout; Composite pellet feed; Participatory breeding

1. Introduction

Rainbow trout farming is a newly developed approach to fish farming in cold water regions. In the hills, cold water aquaculture is developing as one of the components of small-scale aquaculture. Nearly 85% of trout farms belong to this category according to the definition of NACA (2008) (Fig. 1). There are several definitions of small-scale aquaculture. According to NACA, small-scale aquaculture is a family-based enterprise, where fish are produced by involving family members of the fish farm owner regardless of the farm size, species reared and volume produced. This definition, however, has been further revised as: a family-based enterprise, where fish are produced by involving family members of the fish farm owner in common, leased, private or self-owned property regardless of the farm size, species reared and volume produced by family efforts Since this definition emphasizes on the family labor and skill, it is appropriate to include cold water fish - rainbow trout - farming into the category of small-scale aquaculture, although it is a relatively high input-high output system. In the present work, our aim is to give an overview of the status of rainbow trout farming in Nepal.

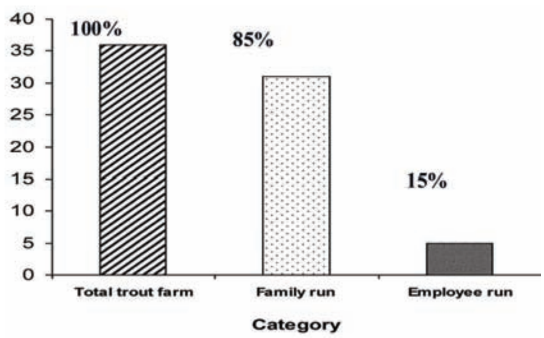

Fig. 1. Category of trout

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1.1. Introduction of rainbow trout in Nepal

Nepal is a mountainous country, which is rich in cold water streams, rivers and tributaries. To utilize these natural resources for the benefit of its people through the development of cold water aquaculture, salmonids were introduced in Nepal from the United Kingdom (UK), Japan, and India in the late 1960s and 1970s. The first attempt was made in 1969 by importing Atlantic salmon (*Salmo salar*) and Brown trout (*S. trutta*) from Kashmir, India; rainbow trout (*Oncorhynchus mykiss*) from the UK; and Sockeye salmon (*O. nerka*) from Japan during 1979-1980 but it failed due to inadequate technical know-how and skilled manpower. Later in 1988, rainbow trout was re-introduced from Japan. Approximately 50,000-eyed eggs were received at Fisheries Research Division (FRD) Godawari, Lalitpur (Nakagawa, 1998). The eggs were successfully hatched and reared and some of the fries and fingerlings were sent to Fisheries Research Center (FRC) Trishuli, Nuwakot.

1.2. Beginning of rainbow trout experimentation

Nepal Agriculture Research Council (NARC) developed rainbow trout farming technologies since 1988 after comprehensive studies at its Godawari and Trishuli fisheries research stations. Experimental studies were focused on feed ingredients, water quality, breeding, and fry nursing and rearing for development of a package of practices. Later, a participatory research program on trout farming was started in farmers' fields in nearby Kathmandu and Nuwakot. This approach was highly successful. Most of the farmers achieved the desirable results, creating higher demand for trout seed in the market.

2. Materials and methods

We performed a review and conducted a survey in six districts: Nuwakot, Rasuwa, Kathmandu, Lalitpur, Makwanpur and Sindhupalchowk, which was based on a semi-structured questionnaire and interview with farmers involved in trout culture. The survey was focused on different aspects of trout culture such as area covered, fingerling stocking number, hatchery and feed preparation facilities, quality and quantity of feed supplied at different stages of production, feed composition, source of feed ingredients, price of trout and number of individuals involved in its farming.

3. Support services to small-scale aquaculture

3.1. Nepal Agricultural Research Council (NARC)

Through its FRC Trishuli and FRD Godawari, NARC has been supporting rainbow trout farmers since 1998 on site selection, culture and breeding as participatory research program on their fields. High income generated from it farming has made trout one of the most wanted commodities among entrepreneurs in the cold mountain areas. It has been famous among the consumers as well due to its meat quality and taste. It is popular among all age groups as it does not contain "Y" bone and is easy to eat. As a result, demand for trout fingerlings for commercial farming has been on the increase. Few years ago, their unavailability was one of the major impediments. This problem has been solved through a participatory breeding program, in which seven private farms and two research stations were included as projects sites. The main aims were to (i) increase fingerling production; (ii) enhance capacity and technical skill in breeding, fry rearing and feeding; and (iii) produce robust seed for increasing production using the facilities of the farmers' own farms. The farmers were supplied with trout broods. Technical support was also provided in the areas ranging from brood stocking to nursing and rearing of fish. The farmers were trained in brood rearing, stripping, fertilization, incubation and larval rearing.

3.2. Japanese International Cooperation Agency (JICA)- supported Follow up project

Under this project, three private farms with hatcheries and nurseries (two in Nuwakot and one in Rasuwa districts) were supported for scaling up rainbow trout farming for the enhancement of livelihood of hill community in Central Nepal. Three private trout breeders were developed, and about 200,000 fry were produced and distributed by the end of the project. The follow-up cooperation from JICA reached poor farmers in the form of fingerlings supply, technical cooperation, training, demonstration and production of rainbow trout. Various stakeholders associated with trout farming were trained for better technological, managerial and marketing knowledge.

3.3. One Village One Product (OVOP) program

In 2006, Government of Nepal declared Rasuwa and Nuwakot as trout growing districts under OVOP program (2006/07), in which trout farming was prioritized to promote local farmers through cold water resource use and local tourism. The OVOP program was initiated with the aim of scaling up trout farming technology with private-public partnership (PPP).

3.4. Seed supply mechanism

Earlier, trout fingerlings were supplied to farmers exclusively from the two research stations. Later on, some private farms have been strengthened and in 2006 participatory breeding technology has been transferred to private sector. Now there are seven trout breeding farms - five in Nuwakot, one in Rasuwa, one in Sindhupalchowk and one in Makawanpur - producing 544,000 of seed in 2008 (Table 1).

Table 1
Privately-owned trout hatcheries

Year of establishment	Name of Trout Farm	No. of Female Brood	No. of Fry
2061	Fall and Trout Farm	151	150000
2062	Sri Man Lama Farm	71	30000
2063	Padam Lama Farm	132	60000
2064	Guni Farm	55	25000
2064	Himalaya Trout and Cold Water Pvt. Ltd.	77	75000
2064	Himalayan Trout Reserch Pvt. Ltd., Dhunche	103	80000
2064	Gopal Lama Farm	70	18000
2064	Kancha Lama Farm	22	14000
2064	Chitalang Farm	77	30000

3.5. Feed supply mechanism

Trout feed is prepared by mixing different ingredients in different ratios to meet their nutritional and energy demand. The young fish are fed on 45% crude protein (CP) content feed in the form of crumble, whereas the growing fish of over 50g are provided with 35% CP content feed. The major ingredients include shrimps, soybean, wheat flour, rice bran, mustard oil cake, vitamins and minerals. All the ingredients except shrimps, which are imported either from India or Bangladesh, are easily available. The feed conversion ratio (FCR) varies from 1.66 to 2.63 with an average of 2. This high FCR must have been caused by inclusion of low-protein or poorly digestible diets. Inclusion of high grade animal protein makes the feed expensive. Generally speaking, the feed must be growth effective on one hand and economically viable on the other.

Among the 36 farms presently farming rainbow trout, five prepared feed themselves, while the others were supported either by government or private farms. As the number of trout farms and fish production is growing year by year, the feed requirement is also on the increase. The total feed consumption was 135 kg in 1998 and 110,568 kg in 2007 (Fig. 2).

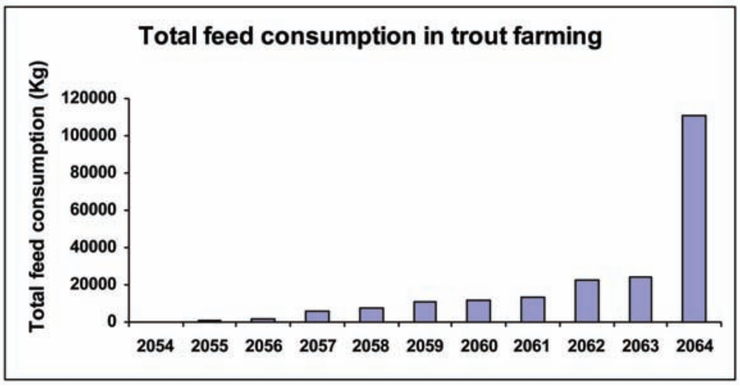

Fig. 2. Total feed consumption in trout farming (1997-2007)

4. Scope of cold water small-scale aquaculture development

Cold sloppy and terrain lands without any substantial agricultural use in the hills and mountains of Nepal having cold-water streams, tributaries and springs, and lying near roads and markets could be used for aquaculture development to enhance the livelihood of poverty-laden communities. Few species of native cold water fish are economically viable, but at present, farming technology is not well developed (Gurung and Basnet, 2003). Hence, different technological packages are required for economically high- value cold-water aquaculture development. Salmonids are considered to be the best fish for cold-water aquaculture development (Bardach et al., 1972; Huet and Timmermans, 1972; Shetty et al., 1989). Visualizing this fact, rainbow trout was introduced in Nepal. Trout prefers clean, cold and high-oxygen waters for its survival and growth, which are abundant in the country, particularly in the hilly and mountainous areas. At least 15 districts in the high hills and 40 in the mid-hills with abundant cold waters are suitable for its production. However, the former is more suitable for fry production and the latter for table fish production.

Technical inputs on cold-water fish farming could be made available from the two fisheries research stations in the country. In addition to rainbow trout, there are other economically high-value indigenous cold-water fish species, which can be developed for commercial production. In cold-water fish farming, substantially higher production can be achieved from limited space if water supply is abundant (Bardach et al., 1972; Huet and Timmermans, 1972). Trout can be the source of animal protein, food security, income and employment in the high- and mid-hills. Besides, it can also generate other opportunities related to tourism development. It has potential to provide equal employment opportunities to 5,000-6,000 men and women. Trout culture contributes greatly to soil and water conservation in the hills.

5. Constraints to commercialization of small-scale cold- water aquaculture

5.1. Poor feed quality and quantity

Supply of feed that is nutritionally rich and economically affordable for the poor farmers is very important for rural aquaculture development. Cultivation of rainbow trout requires absolute feed enriched with protein, carbohydrate, oil, vitamin and other important nutrient supplements. Till now, the feed requirement was fulfilled mainly from two sources: fisheries research centers and trout farmers using small-scale feed plants. Both of these sources have limited capacity and are unable to produce feed as required. Recently, the numbers of trout farms has reached around 36. The feed requirement of these farms is nearly 110.6 Mt in 2008 (personal communication with N.K. Roy, 2008). There are few trout farms which produce feed in their own farms. It is certain that with its present success in the country, trout farming would experience massive expansion in the future, demanding increased amount of feed. Therefore, to envisage higher production of trout, a commercial- scale feed plant is required. It can be predicted that in the next 5-10 years, the feed requirement would reach 1,000-5,000 mt/year. It is also expected that with the availability of feed, the farming practices will also be accelerated.

5.2. Small area coverage and low level of production

As mentioned above, there are two centers - FRD Godawari and FRC Trishuli - involved in trout research programs. Trout culture in private sector started since 1997 and presently there are 36 private farms - 22 in Nuwakot, five in Rasuwa, four in Sindhupalchowk, three in Kathmandu, one in Lalitpur, and one in Makawanpur districts - covering an area of 4,459 m^2 and producing 46,878 kg in 2007 (Table 2). During 2005-2007, the total production increased from 14,000 kg to 49,469 kg (Fig. 3). The production in private sector rose from 10,000 kg to 46,878 kg, while in the government sector, it remained the same for the first two years and a slight decrease was observed in the last year due to siltation and decreasing water volume.

Table 2
Status of trout farming (2007)

District	No. of Farmers	Area (m^2)	Estimated production (kg)
Nuwakot	22	2,351	28,543
Rasuwa	5	328	1,135
Kathmandu	3	438	4,000
Lalitpur	1	94	1,800
Sindhupalchowk	4	1,372	11,300
Makwanpur	1	75	100
Total	36	4,459	46,878

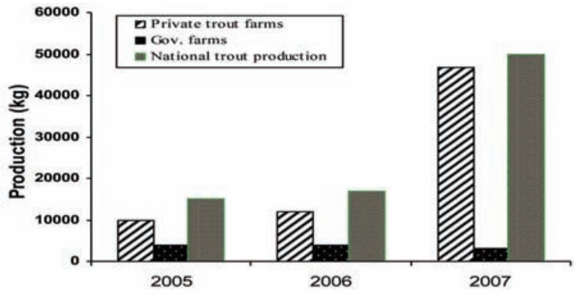

Fig. 3. Trend of trout production (2005-2007).

5.3. Inadequate human resource

Nepal lacks skilled human resource needed for trout farming. Although a bunch of farmers, few extension officers and few technicians were trained, skilled manpower is still nominal as the number of trout farmers is increasing day by day.

5.4. Weak extension mechanism

Extension mechanisms for trout production are weak.

5.5. Under-explored marketing possibilities

Marketing possibilities for trout have remained under-explored.

6. Conclusion

Most of the trout farms coming up in the hills belong to the category of small-scale aquaculture. Gradually, trout farming is self-sustaining due to transfer of seed production capability to private sector. The issues related to feed quality, extension network and legislation should be resolved to materialize the prospects of trout production in Nepal.

Acknowledgements

We are thankful to all those farmers who are presently associated with the participatory trout farming research as well as others for providing us with needed information. Our thanks are also extended to NARC, Directorate of Fisheries Development, JICA and Federation of Nepalese Chambers of Commerce and Industry for supporting scaling up trout farming.

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Development of aquaculture in seasonal water bodies: The Case studies of Tikouli and Chepang gholes in Chitwan, Nepal

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Abstract

Gholes are shallow seasonal water-logged areas in marginal lowlands. The area of gholes in Nepal is estimated to be about 12,700 ha. One of the national policy objectives is to develop extensive natural productivity-based carp polyculture techniques in gholes through mobilization of local communities for increased fish production and livelihood improvement. Currently, about 1,612 ha of gholes have been utilized for fish culture and the average yield is reported to be 1,300 kg/ha. The experiences exhibited in the gholes of Tikouli and Chepang in Chitwan have greatly encouraged the development of aquaculture in seasonal water bodies in the country. Tikouli and Chepang gholes are forest reserve inundated water bodies lying in buffer zone under local community forest. Both these gholes have been utilized in an eco-friendly manner by the locals with proper harmony maintained among other forest user groups. Tikouli ghole is managed by the main consumer group itself. On the contrary, Chepang ghole is managed by Chepang community recognized to be a poor and deprived segment within the larger local community. The Chepang community has also been supported by the local user community through a special stake provided for their overall development. Aquaculture techniques adopted by the local user community in Tikauli ghole is basically natural productivity-based extensive systems through open stocking of carps. The yield assessment needs to be computed using proper harvesting techniques. The consumer group has also initiated other economic entities such as navigation and eco-tourism through integrated and holistic management approach for enhanced livelihood and increased economic returns. The growth and changes, however, need to be assessed for actual impact and proliferation in a wider scale. In Chepang ghole, fish seed nursing management techniques have been adopted by the Chepang community with encouraging results. The livelihood of the community members has improved through their increased involvement in overall activities of Tikouli ghole management. The community members, particularly women, have been embraced by a goat raising and exchange scheme which has begun to show its impacts on their livelihood and capacity enhancement.

Keywords: Aquaculture, Seasonal water bodies, Aquatic resource conservation, Livelihoods

1. Introduction

Gholes are shallow seasonal water-logged areas in marginal lowlands, grossly overlooked for their utility. The area of gholes in Nepal is estimated to be about 12,700 ha, which constitutes about 1.6% of the total water area in the country. There is a great prospect of fish production in gholes. The overall utility of the fisheries sector is to support food security, enhance livelihood opportunities, and conserve and manage natural resources to achieve the goal of sustainable national development. One of the national policy objectives is to develop extensive natural productivity-based carp polyculture techniques in gholes through mobilization of local communities. Currently, about 1,612 ha of gholes have been utilized for fish culture and the average yield is reported to be 1,300 kg/ha. The government is supporting poor and deprived local ethnic communities, which are associated with fishery activities in gholes, through capacity enhancement and technological development.

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2. Tikouli and Chepang gholes

Tikouli and Chepang gholes are inundated water bodies of 15 ha and 2 ha, respectively, lying in the outskirt of Tikouli Buffer Zone Area of Chitwan National Park (Fig.1). The area is inhabited by Brahmins, Chhetris, Tharus, along with marginalized Chepangs, Darais, Kumals, Biswakarmas, etc. These deprived communities were earlier involved in fishing natural fish and other aquatic species (for example *Amphipnous cuchia, Clarias batrachus, Heteropneustes fossilis, Channa sp., Mystus sp., Labeo and Puntius,* and prawns, crabs and tortoises) available in these gholes for their livelihood. The gholes are frequented by birds like kingfishers, seasonal migratory birds such as cranes and water ducks, and wild animals, e.g., magar gohis, gharials and rhinos.

The establishment of Tikouli Buffer Zone Community Forest in 2052 B.S. affected the livelihood of the communities that were dependent on the gholes. The main consumer group of the community forest maintained and stocked Chepang and Tikouli gholes for open water fish farming based on natural productivity extensive systems. Chepang ghole was prepared for rearing fry, fingerlings and grow-out fish, while Tikouli ghole was maintained only for rearing fingerlings and grow-out fish. The management of Chepang ghole has been given solely to Chepang community with 80% share of benefits from the harvest for them and 20% for the main consumer group of Tikouli Buffer Zone Community Forest. Tikouli ghole, on the other hand, has been managed by the main consumer group itself. The Chepang community is supported by the main consumer group in terms of labor provision for cleaning, managing and harvesting fish in Tikouli ghole, and buying fingerlings reared in Chepang ghole.

Fig. 1. Tikouli and Chepang gholes.

3. Water quality parameters

Water quality parameters are almost similar in both the gholes with alkaline water containing dissolved oxygen ranging from 4.3 to 7.7 mg/L, depending upon the season (Table 1). Water temperature and other chemical parameters are conducive for warm-water fish and carp polyculture was practiced in these gholes.

Table 1
Physicochemical parameters of Tikouli and Chepang gholes

Parameters	Tikouli	Chepang
Air temperature (°c)	26.3 - 35.1	26.3 - 35.1
Water temperature (°c)	26.7 - 33.4	27.5 - 34.9
pH	8.1 - 8.7	8.3 - 8.8
Dissolved oxygen (mg/l)	4.3 - 7.2	4.0 - 7.7
Conductivity (µmhos/cm)	234 - 364	267 - 389
Total alkalinity (mg/l)	134 - 210	154 - 235
Total hardness (mg/l)	97 - 154	107 - 149

4. Fishery activities

Both these gholes have been utilized in an eco-friendly manner by the locals with proper harmony maintained among other forest user groups, the marginalized communities and the surrounding environment. Local communities were provided awareness trainings on conservation management; hoarding boards with conservation message were installed; and leaflets/posters were distributed. Trainings on fish farming in gholes were also provided to local people to enhance their knowledge. A visit program to Pokhara was arranged for both groups (the main consumers and Chepang community members) to acquaint them with cage fish farming in Phewa and Begnas lakes (Fig. 2). Fry nursing and rearing were started in private ponds under Mission Fishery Program of Directorate of Fishereis Development (DoFD). In this program, the government provided NRs 25,000/ha to initiate fish farming activities in the area. Fingerlings, financial assistance to maintain nursery bed in Chepang ghole and fishing gears like Mahajals and scoop-nets and other accessories were also managed to carry out fish farming smoothly.

Fig. 2. Visit program to Pokhara (Phewa lake).

5. Other activities

Outlets and walls of Tikouli ghole have been maintained and strengthened for their protection from flooding during heavy rain. Wooden boats were made in both gholes in close cooperation with local communities for clearing weeds and harvesting fish. These boats are also being used for navigation in Tikouli ghole to entertain local and foreigner visitors, and intensify economic activities (Fig. 3).

Fig. 3. Boating in Tikouli ghole.

6. Activities for women

A goat raising and exchange scheme was launched for the community members, in particular women, in which four pregnant goats were given to Chepang women for rearing as an alternative means of livelihood. In addition, a training program on sewing was arranged in three batches and sewing machines were also arranged in the initiation of local people.

7. Impacts of the activities

The impacts of activities in Tikouli and Chepang gholes are encouraging but not exactly similar. Tikouli ghole, as managed by resourceful forest user groups, became highly demonstrative, while Chepang community lagged behind, demanding reservation in resource reach to move ahead. Tikouli group was actively involved in developmental activities like boating, fund raising for the preparation of dams, Mission Fishery Program and nursery development programs in their private lands, and hotel business. On the other hand, Chepang group was involved in fishing, fry rearing and labor works in Tikouli ghole. More than 1.5 ton of fish was harvested from Tikouli ghole and about a ton from Chepang ghole. The size of fish is very appealing with a maximum of 9.0 kg after one year of stocking (Fig. 4).

Fig. 4. Fish harvested at Tikouli and Chepang gholes.

Fish reared in these gholes earned special brand as “Organic Fish” in the vicinity. There was high demand for them and they fetched high price in local areas, which ranged from NRs 200 to 250/kg, while the price of fish from other private ponds in the same area ranged only from about NRs 100 to 125/kg. The live large fish of these gholes were used as brood fish by fish growers. Fish nursing in private land under Mission Fishery Program was highly successful and the total earning reached more than NRs 300,000. One of the members of Tikouli group opened a restaurant close to the gholes, where fish is served as the main cuisine. Customers from Narayangadh, Hetauda, Birgunj and other local areas visit this restaurant regularly to enjoy the taste of the organic fish.

8. Constraints

The release of fingerlings in the gholes was far less compared to their sizes and was not based on standard scientific stocking rate. The presence of different predators like local fish, mugger gohis, gharials and visiting birds made yield assessment difficult. Harvesting was a huge problem due to heavy infestation of aquatic weeds and use of mahajals was not feasible either. It is necessary to develop proper management techniques to control the infestation of aquatic weeds. The yield assessment needs to be computed employing proper harvesting techniques, which incorporate the loss caused by the presence of predators. Due to the difficulty in harvesting, forest user groups have given harvesting in Tikouli ghole to professional fishermen from India at a flat rate of NRs 240,000. These professional fishermen have used drying up techniques to harvest fish (Fig. 5).

Fig. 5. Harvesting in Tikouli by professionals from India.

Contribution of small-scale cage fish culture to poverty reduction and sustainable development in Nepal

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Abstract

This paper presents current status and future scope of small-scale cage fish culture in Nepal, which is practiced mainly with plankton feeder fish, such as bighead carp (*Aristichthys nobilis*) and silver carp (*Hypopthalmichthys molitrix*), in floating cages in natural lakes and reservoirs. The most important characteristic feature of this type of fish culture is the absence of outside feed to cultivate plankton feeder fish, with the fish subsisting on plankton available naturally in water column. It is popular among a traditional fisher community living around lakes in Pokhara valley, which is known as Jalari or Pode, and among the families displaced by the construction of hydropower dam in Kulekhani, Makwanpur. In these water bodies, over 2,400 cages of approximately 117,350 m^3 with estimated fish production of 250 mt have been operated during 2007- 2008. Such a cage fish culture has been in operation since three to four decades in Pokhara and two decades in Kulekhani. The production rate has varied from 1.6 to 4.3 kg/m^3. The total annual production might be low contributing only 0.53% of the total fish production in the country in 2007. However, its social impact is incomparable as the cage fish culture sustains family job and provides income to buy food and clothing, and to support the education of the children. The cage fish culture in natural lakes in Pokhara and Kulekhani reservoir has been appreciated as one of the successful farming systems, contributing to mainstreaming the deprived fisher communities and the displaced. This practice is recommended for expansion in other lakes and reservoirs in the country, based on the inclusive doctrine of equal opportunity and sustainable development.

Keywords: Cage fish culture; Lakes and reservoirs; Social development; Social inclusion

1. Introduction

Cage fish culture in Nepal was started around 1975 using floating cages in lakes in Pokhara valley with the support of Food and Agriculture Organization (FAO) and United Nations's Development Programme (UNDP). The practice became successful and the support was extended. Later on, it was well perceived by International Development Research Centre (IDRC) and the technology was extended to Kulekhani (Indrasarobar) reservoir (Fig. 1) as well, where various other agencies such as Plan Nepal were also supporting the farmers. The development of cage fish culture in the country took place in the background of feasibility studies and intensive limnological surveys (Table 1).

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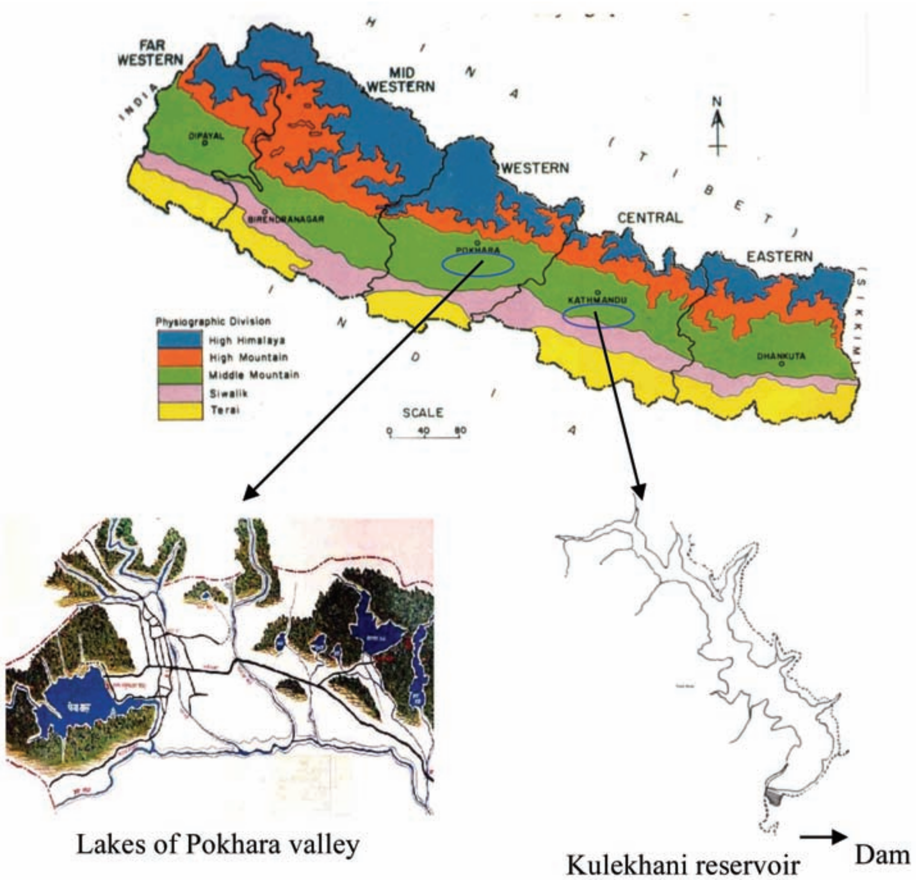

Fig. 1. Map of Nepal showing location of lakes of Pokhara and Kulekhani reservoir.

It was the FAO which first launched cage fish culture in Nepal (Gurung et al., 2005). The target group was an ethnic deprived, landless and so-called untouchable community known as Jalari or Pode living around lakes in Pokhara valley, which was entirely dependent on capture fishery. The organization extended its support further. Prior to the extension, it had set up certain guidelines to be followed. The cage fish culture initiated in lakes in Pokhara was one of the most successful projects (Gurung and Bista, 2003; Gurung et al., 2005). Following this, it was later developed in Kulekhani focusing on the resettlement of the displaced community during the construction of the Kulekhani hydropower reservoir (Gurung et al., 2008). The cage fish culture developed in Pokhara and Kulekhani is one of the most successful practices in alleviating poverty (Gurung and Bista, 2003; Gurung et al., 2005). These success stories demonstrated that despite its mountainous setting, aquaculture could be successful in Nepal, which is rich in water resources. Several hydropower reservoirs have been proposed for power generation in the future (Pradhan, 1987). These reservoirs could also be used for fish production to support people living nearby by providing food and nutrition. It is expected that the present work can set guidelines to planners for envisaging fisheries and aquaculture development program in the future reservoirs to create better opportunities for local communities. In this paper, we elucidate present status and future scope of cage fish culture in Nepal.

Table 1
Hydrographic and limnological features of lakes in Pokhara and Kulekhani reservoir (FRC Pokhara, 2005; Shrestha and Pandit, 2008)

Variables	Phewa	Begnas	Rupa	Kulekhani
Elevation (masl)	742	650	600	1,530
Area (ha)	523	328	135	220
Catchment area (km^2)	110	20	30	126
Water depth (m)				
Maximum	24	(10.0)	(6.0)	100
Average	7.5	6.6	3.0	60*
Volume of water (m^3)	393.2×10^5	179.6×10^5	32.5×10^5	-
Water temperature (°c)	16.5 - 30.0	16.5 - 31.0	14.5 - 27.5	12.2 - 24.9
Sechi disc visibility (m)	1.7 - 3.15	1.3 - 2.5	1.0 - 2.50	3.0 - 6.0
pH	7.6 - 10.2	7.2 - 10.2	7.6 - 9.2	7.6 - 9.5
Dissolved oxygen (mg/l)	5.4 - 9.3	5.2 - 9.1	1.8 - 8.4	5.9 - 11.7
Conductivity (µmhos/cm)	-	-	-	59 - 126
Chlorophyll a (µg/l)	0.0 - 25.8	0.0 - 20.0	0.0 - 74.5	2.7 - 20.7
Total nitrogen (mg/l)	0.0 - 0.81	0.0 - 10.3	0.0 - 0.64	0.32 - 0.41
Phosphate (PO_4-P) (µg/l)	0.0 - 50.0	0.0 - 70.0	1.0 - 10.0	51.0 - 64.0
Total phosphorus (mg/l)	0.0 - 0.014	-	0.017	0.08 - 0.11

* Minimum water depth at dry season

2. Suitable species for cage fish culture

Fish species that are suitable for cage culture varies considerably in their feeding habit, temperature tolerance and other characteristics. In most cases, cage fish culture is practiced with intensive feeding and high stocking rates for high economic benefits (Manob, 1979). However, cage fish culture in Nepal is of extensive type where fish are fed on naturally available plankton and external feed are not supplied. In such an extensive culture method, fish are stocked in low densities to avoid food consumption.

In Nepal, mainly two species of carps are popular for cage culture: bighead carp (*Aristichthys nobilis*) and silver carp (*Hypophthalmichthys molitrix*). This is perhaps due to their specialization of feeding on plankton in an extensive culture system. Production of fish in cages could be enhanced by intensive supplementary feeding but such a practice has not yet been adopted in the country for various reasons. Occasionally, other species are also stocked with bighead carp and silver carp such as rohu (*Labeo rohita*) as a biological cleaning agent of fouling in cages (Sharma, 1979). Recently, cage fish culture with grass carp (*Ctenopharyngodon idella*) in macrophyte dominated area of Phewa lake has become a promising enterprise among its fisher community.

An initial trial of growing rainbow trout (*Oncorhynchus mykiss*) in cages in lakes and reservoirs has been started in Nepal (Gurung, 2008; Bista et al., 2004). Studies have shown that trout farming in lakes and reservoirs of the mid-hills in winter could be one of the alternative opportunities for cage farmers to increase their income. Similar approach has been reported in many other countries such as the United States, where channel catfish are cultivated in summer, and after their harvest, rainbow trout are grown in the same cages in winter (Beem and Gebhart, 2000). However, at present, extension of rainbow trout for cage farming has been hindered by the poor access to fish seed and demand for nutrient-enriched feedlot, leading to eutrophication, specifically in the natural lakes (Bista et al., 2008).

3. Management practices of cage fish culture

Fish cages that are used in Nepal have been described in Sharma (1979), Rajbanshi et al. (1984) and Swar and Pradhan (1992). In the beginning, several types of readymade cages were imported from abroad, but now local fishermen have started weaving their own nets of desired mesh size and tailoring the cages locally. Nylon cages of varying mesh size are mounted on bamboo frames, which also serve as a float. Almost all the cages used in Nepal are of 50-62.5 m^3 (5x5x2- 2.5 m) because they are convenient for handling. However, a few large cages of 150 m^3 are also in operation. The voluminous cages are convenient for keeping fish before harvesting.

Management of an extensive cage culture is considered easy because feeding is not required. Stocking densities vary with the trophic status of lakes. Recommended stocking density in production cages (≥25 mm) during the late 1980s were 6 fingerlings/m^3 in Phewa lake, and 10 fingerlings/m^3 in Begnas and Rupa lakes. However, at present, 10 fingerlings/m^3 are stocked in Phewa lake as well, as eutrophication in the lake is progressing. In Kulekhani reservoir, where silver carp and bighead carp were stocked at 12 fish/m^3, the net fish production reached 5.27 kg/m^3 per year (Rai and Mulmi, 1992). Recently, stocking density has been adjusted to 8-10 fish/m^3 in the face of decreased productivity resulted from an enormous increase in the number and volume of cages in the reservoir (Wagle et al., 2009). Depending upon the type of plankton dominance and market, stocking structure usually constitutes 60% of bighead carp and 40% of silver carp, and vice versa. Usually, farmers purchase fry (3-5 g size) or fingerlings (10-15 g size) for rearing in cages from nearby hatcheries and nurseries. They first stock the fry into nursery cages (5-15 mm mesh) at 20-100 fish/m^3. When fingerlings attain approximately 20-30 g of body weight, they are transferred to production cages of ≥5 mm mesh.

In order to optimize production, it is essential to keep the cages clean to reduce mortality from inadequate food and dissolved oxygen. Sponges, algae and silt are common fouling agents in fresh water. Net fouling by fresh water sponge might negatively influence fish growth by reducing water exchange rate. A periodic cleaning is carried out by manual brushing in-situ or cages are removed, brushed, washed and sun dried. A routine cleaning of cages is recommended. The intensity of fouling depends on factors such as fertility of water, temperature, season and type of the net material. Generally, cages with smaller mesh size need to be cleaned more frequently. To lessen the human labor requirement in cleaning, low stocking of rohu is recommended (Sharma, 1979).

To grow from 5 g to 500-700 g, it may take 12-18 months at the stocking density of 8-10 fish/m^3. Fish in cages are harvested when they attain marketable size or when scope for their further growth is negligible. Cages are harvested in two ways: partially and completely. In the former, only a certain number of selected fish are removed. In such a case, harvested fish are usually the largest or the least healthy individuals. A complete harvest is advised when improvement in overall production is planned by replacing old stock with new fingerlings. Cages are restocked immediately after harvest.

4. Productivity of cage fish culture

Productivity of cage fish culture in lakes in Pokhara and Kulekhani reservoir has varied greatly over time (Table 2). Rupa lake had the highest productivity ranging between 5.0 and 7.4 kg/m^3 of cage per year from the late 1970s to the mid-1980s. Thereafter, productivity declined and fluctuated between 2.4 and 3.0 kg/m^3 of cage per year. Gradual deposition of silt in the lake due to landslides, floods, nutrient run-offs and heavy infestation with aquatic plants reduced the water level (IUCN Nepal, 1996; Rai 2000a,b), resulting in low productivity (Gurung et al., 2008). A seasonal decomposition of aquatic plants and resulting oxygen depletion caused the collapse of cage fishery and destroyed the livelihood of fisher families that were dependent on this (Gurung et al., 2010). Following the campaigns of Rupa Lake Restoration and Fish Farming Cooperative (RLRFFC) initiated in 2002, which were directed at weed removal and fish stocking, encroachment of vegetation on the lake margins was halted; its aquatic weeds came under control; and its fisheries improved. As a result, its productivity started increasing gradually and about 14 mt of fish have been produced from 5,850 m^3 of cages in 2008 (Table 3).

Table 2
Productivity estimates of cage fish culture in lakes in Pokhara and Kulekhani reservoir

	Production rate (kg/m³)				
Years	Phewa	Begnas	Rupa	Kulekhani	References
1979	5.5	3.8	7.4	-	Pradhan and Shrestha, 1979
1980	3.4	4.7	5.0	-	Wagle, 2000
1985	3.4	4.7	5.0	-	Swar and Pradhan, 1992
1989	-	-	-	5.27	Rai and Mulmi, 1992
1990	1.33	1.83	2.56	-	Sharma, 1990
1998	5.0	3.0	2.0	3.7	Wagle, 2000; Shrestha and Pandit, 2008
1999	-	-	-	1.3	Gurung et al., 2008
2000	5	2.2	3	1.5	Gurung et al., 2008; Wagle, 2000
2001	4.3	-	-	1.7	Gurung et al., 2005; Gurung et al., 2008
2002	4.4	-	-	1.4	Gurung et al., 2005; Gurung et al., 2008
2003	-	-	-	3.5	Shrestha and Pandit, 2008
2004	-	-	-	3.5	Shrestha and Pandit, 2008
2005	-	-	-	1.9	Shrestha and Pandit, 2008
2006	-	-	-	1.9	Shrestha and Pandit, 2008
2007	4.3	3.2	2.4	1.84	Shrestha and Pandit, 2008; Wagle et al., 2008
2008	4.3	3.2	2.4	1.62	Wagle et al., 2007
Average	4.1	3.3	3.7	2.4	

Phewa lake is becoming more productive as a result of nutrient enrichment. Urbanization is taking place rapidly in Pokhara valley in recent years. Consequently, development of tourism industry and intensification of agriculture practices in the watershed area of the lake may have laid to an increasing trend of eutrophication. Throughout the history of cage fish culture in the country, Phewa lake has had the highest average productivity of 4.1 kg/m³/year. The farmers have been able to produce 103.2 mt of fish from 24,000 m³ of cage in 2008.

Table 3
Distribution of cages in lakes in Pokhara and Kulekhani reservoir (2007-2008)

Location	No. of family	No. of cage owned	Volume (m³)	Estimated production (mt)
Phewa lake	90	600	24,000	103.2
Begnas lake	37	120	6,000	19.2
Rupa lake	53	117	5,850	14.0
Kulekhani reservoir	239	1,630	81,500	114.2
Total	419	2,467	117,350	250.6

Khudi Khola, the outlet of Begnas lake, was impounded by a dam in 1988. The damming increased the area of the lake from 224 ha to 328 ha. The newly inundated water in Begnas lake is not as productive as it was before. Productivity of cage fish culture in the lake dropped to 2.2 kg/m³/year for a few years after damming. However, productive status of the lake is now gradually restoring. Based on this, research efforts are being centered to reassess the stocking size, density and combination of plankton feeder fish. Productivity of cage fish culture in Begnas lake has been estimated to be 3.3 kg/m³/year and 19.2 mt of fish have been produced from 6,000 m³ of cages in 2008.

In the beginning of cage fish culture in Kulekhani reservoir, the productivity was relatively high (5.27 kg/m³/year), with a limited number of cages landed in the reservoir (Table 2). Since the inception, the number and volume of cages have increased rapidly and reached 1,630 cages (81,500 m³) in recent years. However, productivity has declined continuously from 3.92 kg/m³ in 1999 to 1.62 kg/m³ in 2008. Inadequate fish seed supply and increased number and volume of cages have been recognized as the major constraints to sustaining productivity of ever increasing cage fish culture in the reservoir (Wagle et al., 2009).

5. Effects of cage fish culture on environment

Increased agricultural activities, unplanned urbanization and development of tourism industry in Pokhara valley have begun to generate serious environmental threats to its lakes. These activities have resulted in increased signs of eutrophication such as algal blooms. At present, however, eutrophication of the lakes may have had a positive impact on the production of planktivorous carps, leading to the increased aquaculture (and fisheries) production from the lakes.

Although studies on the impacts (positive and negative) of bighead carp and silver carp culture on the environment have shown different results (Smith, 1985; Wu et al., 1979; Starling, 1993; Spataru and Gopheen, 1985), these impacts have been found strongly related to the intensity of production methods and scale of development within a lake or reservoir (Beveridge and Stewart, 1998). It is often blamed that cage fish culture activity in lakes deteriorates the lake environments (Oli, 1997). However, the present extensive fish cage culture helps remove the organic and inorganic nutrients.

Over the past three decades, cage fish culture in lakes in Pokhara and Kulekhani reservoir appear to have utilized increased nutrient inputs from sewage and fertilizers into fish production. The practice is probably contributing to controlling eutrophication in these water bodies. It may be removing 852 kg of Phosphorous and 6,415 kg of Nitrogen per year, at current fish production levels (Table 4). Thus, the utility of this activity has been very significant in maintaining the ecological balance in the lakes and the reservoir, and in their surrounding environments.

Table 4
Estimated removal of Nitrogen and Phosphorous from cage culture in lakes in Pokhara and Kulekhani reservoir (2008). Updated from Pradhan and Panth (1995)

Lake / Reservoir	Fish yield (mt)	Phosphorous removed[1] (kg/year)	Nitrogen removed[2] (kg/year)
Phewa	103.2	350.9	2,641.9
Begnas	19.2	65.3	491.5
Rupa	14.0	47.6	358.4
Kulekhani	114.2	388.3	2,923.5
Total[3]	250.6	852.0	6,415.4

1 Assuming P content of fish = 0.34% of harvested fish
2 Assuming N content of fish = 2.56% of harvested fish
3 Assuming P and N addition with fry/fingerling is not significant.

There are no disease problems, and hence no chemicals are used to treat fish. A salt solution (NaCl) is used as a dip treatment for fingerling before stocking them in cages. Such a treatment will not have any impact on the environment. Ultimately, there will be a finite “carrying capacity” for cage fish culture in the lakes and the reservoir, depending on the stocking densities and primary production. They have multi-purpose use, considering their values for different stakeholders. Expansion of cage culture is limited only to certain areas of the lakes and the reservoir. Although fish may require much water for filtering the plankton food, cages occupy <1.0% of the surface area of the lake/reservoir.

6. Communities involved in cage fish culture

Phewa and Begnas lakes are characterized by the involvement of artisanal fishermen - Jalaris or Podes - who are entirely dependent on fishing for their livelihood, using more conventional gears such as cast nets and local traps. In the early 1960s, the Jalari community was deprived of traditional agricultural lands, skills, jobs and incomes. A livelihood support program for their rehabilitation through small-scale cage fish culture was initiated in 1972 (Gurung et al., 2005). Rupa lake has a mixed ethnic community adopting cage fish culture. Small-scale fishery and cage aquaculture have today emerged as one of the important income- generating activities for them. The Jalari community comprised 77% of the 180 households that were engaged in cage fish culture (Fig. 2). Other ethnic communities that were involved in cage fish culture are Brahman and Chhetri (10%), Gurung (20%) and Magar (3%). To organize the local fishermen, mainly nomadic Jalaris, in a forum where issues on participatory fisheries management could be discussed, a lake-specific fishers association known as Rupa Matsya Byawasayi Samitee was established in 1990. The Samitee was later transformed into Rupa Lake Rehabilitation and Fisheries Cooperative (RLRFFC) in 2001, embracing 325 households as its share members, including cage fish operators.

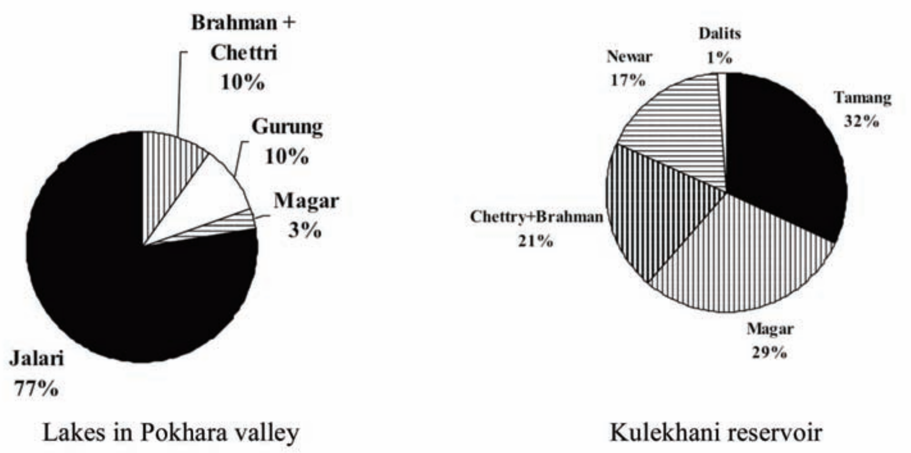

Fig. 2. Ethnic composition of the communities involved in cage fish culture in lakes in Pokhara and Kulekhani reservoir.

In Kulekhani reservoir, about 31.76% Tamang, 29.2% Magar, 20% Brahmin and Chhetri, 17.94% Newar, and 0.85% Kami, Damai and Pode are involved in cage fish culture (Fig. 1). Most of them had been displaced during the impoundment (Gurung et al., 2008). There are all together 239 families (Table 1), with 119 female and 120 male members, who are organized in 11 groups. Coordination and communication among different groups is facilitated by a federation (fishers association) represented by the leaders of the groups.

Small-scale cage fish culture is perceived as a gender disaggregated income-generating activity. Jalari women are playing a significant role in aquaculture and fishing, and earning their livelihood, besides performing household chores. In general, their contribution to cage fish culture, fishing and fish marketing has been estimated to be 41.3%, 27.6%, and 78.4%, respectively (Nepal, 2008). These women formed their own group and initiated cage fish culture in Phewa and Begnas lakes and are also playing the role of aquatic resource conservation activists. Among the 11 groups involved in cage fish culture in Kulekhani reservoir, four groups are exclusively comprised of women.

7. Agencies supporting cage fish culture

Cage fish culture in Nepal is only a recent development. Various organizations and agencies have been involved in promoting it in order to support the livelihood of the country's resource-poor and deprived ethnic communities.

- In 1972, floating cages were introduced in Pokhara by Japanese Overseas Volunteer Cooperation (JOVC).
- During 1975-80, Integrated Fishery and Fish Culture Project assisted by UNDP/FAO demonstrated the success of cage fish culture in lakes in Pokhara.
- In 1980, FAO - through Australian Food for Hunger Campaign (FFHC)) - further assisted cage fish culture in Pokhara. A revolving fund was established to provide loan to the adoptors of cage fish culture without collateral deposits.

- During 1985-88, an extensive limnological survey and feasibility study of cage fish culture in Kulekhani reservoir was carried out with the assistance of IDRC, Canada. Its outcome laid the foundation for the initiation of cage fish culture in the reservoir, which was targeted at the displaced community.
- During 1991-98, Japanese International Cooperation Agency (JICA) - through Natural Water Fisheries Development Project - assisted in the strengthening of fish seed supply in Pokhara.
- UK Department for International Development (DFID) - through Hill Agriculture Research Program (HARP) - assisted in the empowerment of Jalari women in Phewa and Begnas lakes by involving them in cage fish culture, adopting a group approach.
- Plan/Nepal supported the displaced community in Kulekhani reservoir by supplying cage net materials and other accessories.
- World Vision - through its local agency Swarup Nepal - supported women's groups of Begnas lake by providing them with cage materials, fish seed and training.

8. Major problems faced by cage fish farmers

Respective fishers associations/ cooperatives of the lakes and the reservoir have cited a number of problems that were encountered while practicing cage fish farming.

8.1. Problems associated with the shared ecosystem

Of particular interest and common to all fisher families in Pokhara valley is the problem of managing the capture fishery and cage fish culture, considering that it is a shared ecosystem. Long- term property tenure of cage fish culture area will enable fisher families to make further investments in cage aquaculture and lake resource management.

8.2. Poor access to cage net materials

Since readymade net cages or net materials are not manufactured in Nepal, the farmers solely depend on local dealers in Kathmandu who import them from abroad. The farmers claim that their durability and quality is inferior to that of the readymade cages and twines for making cages during the FAO/UNDP and Natural Water Fisheries Development Project (NWFDP) periods.

8.3. Short supply of fish seed

Inadequate fish seed supply has been recognized as one of the major constraints to sustaining the productivity of cage fish culture. The farmers entirely depend on the hatcheries in Terai region for the supply of fish fry in Kulekhani reservoir (Gurung et al., 2008). Post-transportation mortality (up to 70%) and contamination of carp fry with wild fish further trigger the problem of quality fish seed supply in the reservoir (Wagle et al., 2009). Although Fisheries Research Center Pokhara supplies fish fry in adequate number, the production of large-sized fingerlings that are suitable for stocking in production cages is insufficient because of the weak network of fish seed rearing at the community level.

8.4. Shortage of cage frame materials

Bamboo is the most popular material for making cage frames because of its availability even in remote rural areas. In a water- logged condition, it has a life span of two years, and hence farmers have to replace the cage frames every two years. Bamboo is not cultivated commercially but grown in a few bunches to meet general household needs in rural areas. With the increasing number of cages in the lakes in Pokhara and Kulekhani reservoir, and a short durability of bamboo cage frames, there has been a short supply and increased price of bamboo, raising the cost of cage fish farming.

9. Significance of cage fish culture in Nepal

Given the country's focus on poverty reduction in wetland ecosystem, the availability and quality of food produced in rural areas need to be enhanced through increased access to production resources, including ideal social capital, input supply, sustainable production methods and efficient markets. There are some 103 ethnic/caste groups in Nepal (CBS, 2006) of which 20 largely live on the banks of water resources, and are heavily dependent on the wetland products and services (IUCN Nepal, 2004). It has been estimated that about 6.6% of the 6,496,222 economically active populations in agriculture sector (CBS, 2006) are engaged in capture fishery. Despite the existence of a large number of wetland communities in the country, only 12.62% of the populations (CBS, 2006) are dependent upon fishing and wetland products for their livelihood. Their traditional occupations are not financially rewarding enough for sustaining their families (Gurung, 2003). In this context, introduction or expansion of cage fish culture practices, particularly those operating in lake and reservoir resources, could be an effective policy instrument to reduce poverty amongst the fisher and displaced communities.

Fig. 3. Womenís involvement in cage fish farming in Kulekhani reservoir.

Cage fish culture utilizes publicly-owned resources; requires small capital investments; and gives rapid returns to investments. Thus, it is a suitable option for resource-poor fisher families. An economic analysis of cage fish culture has shown that its net returns to total investments are up to 254.3%. Average net profits generated are estimated at NRs 77,082 (50.1% of income) and NRs 41,625 (31.9% of income) per year for a fisher family with an average cage holding of 250 m^3 in Phewa lake and 135 m^3 in Begnas lake, respectively (Wagle et al., 2009). Preliminary results of a socio-economic study of the Jalari community has revealed that with the adoption of cage aquaculture and recapture fisheries under the framework of community-based fisheries management in the two major lakes in Pokhara valley, its living standard - as indicated by access to a variety of social amenities and community services - has improved considerably over the past three decades (Wagle et al., 2007). Similarly, cage fish culture in Kulekhani reservoir provides an alternative source of livelihood to nearly 45% of the displaced families (Gurung et al., 2010).

There are several school-going children in fisher families practicing cage culture. Most cage owners have reported that incomes earned have been supporting their education. These cage owners who produce fish are the direct beneficiaries. The indirect beneficiaries include traders who are engaged in marketing, transporting and supplying cage materials, fingerlings, and fish, and restaurants operators. Therefore, the development of cage fisheries has been considered very important both socially and economically (Gurung et al., 2010).

Fig. 4. Cage culture site of Phewa lake, Pokhara

Cage fish culture has been contributing substantially to the empowerment of women. Women from the Jalari community in Pokhara and the displaced community in Kulekhani actively participate in all the activities concerning cage fish culture - ranging from attending meetings and workshops to fingerling transportation, fish stocking, boating, harvesting and marketing. On an average, they are taking part in about 41% of the works involved in fisheries and aquaculture, contributing as much as men (Nepal, 2008).

10. Conclusions and recommendations

Cage fish culture has offered the best economic option for improving the livelihood of resource-poor, deprived and nomadic Jalaris living around lakes in Pokhara and the community displaced by Kulekhani hydropower project. Aside from having economic importance, the practice is also beneficial from the ecological and social perspectives, and thus has become a promising intervention.

Generally, the cage fish farmers have experienced low productivity in the reservoir and variation in annual production in the lakes, which have influenced their economic status. The reasons behind these should be precisely evaluated and appropriate technologies for the improvement should be tested and recommended to the farmers.

Fish seed supply, particularly large-sized fingerlings, has remained one of the most critical elements to the sustenance/improvement of production and productivity. Community- based decentralized fish seed rearing mechanisms, such as nursing, rearing and trading networks, have proven to be a better catalyst for rural small-scale aquaculture development in Asia. In order to improve seed supply quantitatively as well as qualitatively, development of a decentralized fish seed rearing and delivery system is thus essential. It not only reduces cost and improves quality by avoiding long distance transportation of seed, but also creates employment and income.

Cage fish farming is relatively new in Nepal, and at present, it utilizes common property resources. Appropriate policies should be introduced and enforced to ensure that cage aquaculture remains a sustainable livelihood source for the rural resource-poor. There may be a need for regulation - both to maintain the feasibility of access to cage culture by the people and to keep production level within the environmental capacity. Present experience is also suggestive of the fact that in the future, fisheries research and development should form part of any hydropower development and lake rehabilitation programs for mainstreaming deprived and displaced communities and involving them in the task of nation building.

Key to influencing scaling up and sustaining cage fish culture for the rural resource-poor is to adopt policies that encourage stronger and more extensive linkages among farmers, researchers, and local and national development institutions. Through such linkages, dissemination of its impact could also be facilitated at the local and regional levels by using discussion forums.

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Low-cost small-scale cage culture with grass carp (*Ctenopharyngodon idella*) for generating higher income for the poor

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Abstract

Modern cage culture with filter feeders like silver and bighead carps was introduced in Nepal about three decades ago in lakes of Pokhara valley. Since then, the technique has spread across the country with varying degree of adaptation to local conditions. It has contributed remarkably to the improvement of living standards of the people, ensuring food security, creating additional jobs and augmenting incomes. Cage culture of carps retains its importance particularly in socio-economically disadvantaged areas. Currently, interest in traditional cage culture has revived and farmers are seeking other suitable species. A participatory pilot experiment was carried out to explore potential of cage culture with grass carp (*Ctenopharyngodon idella*), which is famous for being voracious; could utilize aquatic plants; and is a fast grower as well as fetches relatively high market price.

Fish with an average weight of 44.9± 4.10 g were stocked at the rate of 10 fish /m^3 in farmers' floating net cage of 50 m^3 having 15 mm mesh size. They were fed on adlibtum, with aquatic grasses - mainly hydrilla (*Hydrilla verticillata*) - removed daily from the same water bodies. Fish that attained the size of more than 500 g were transferred to cages with bigger mesh size (60 mm). Results showed that there was a great variation in growth and that 40.4% of fish attained an average final weight of 1.54 kg in a culture period of 480 days. The mean absolute daily weight gain and mean final yield were 3.11 g/day and 8.4 kg/m^3. The daily and monthly weight gains significantly (P<0.5) increased in the early culture period. The survival rate was 95% during the study period. It has been learned that with increased production and high price, expansion of cage culture with grass carp can enhance food security and nutritional status, and provide more income to rural people. Besides, removal of grass also improves the ecosystem of aquatic water bodies. Recent trend of its adoption suggests that cage culture with grass carp is becoming popular among farmers and possess further adoption potentialities.

Keywords: Cage culture; Grass carp; *Ctenopharyngodon idella*; Aquatic grass; *Hydrilla verticillata*

1. Introduction

Nepal is endowed with abundant inland natural waters. A large number of fisher communities are dependent on fishing in these water bodies for their livelihood. Phewa lake in Pokhara valley is one of the important natural water resources supporting the livelihood of a nomadic fisher community living around lakes known as Jalari. In the decades of 1960s and 1970s when fish catch declined due to over- fishing, the only source of Jalari's livelihood was threatened. To overcome this problem, Government of Nepal initiated a livelihood support program for the rehabilitation of this deprived community through small-scale fisheries and subsistence cage aquaculture in 1975. Planktivorous fish, such as silver carp (*Hypopthalmichthys molitix*) and bighead carp (*Aristichthys nobilis*), were mainly recommended to culture in cages in order to avoid eutrophication because lakes are primarily source of tourism industry. Nowadays, cage culture contributes substantially to the improvement of living standards of the people, ensures food security, and holds special importance in areas that are socially and economically backward.

Currently, the modern technique of cage culture with filter feeder fish species has spread across the country with varying degree of adaptation to local conditions. However, due to lack of appreciable ecosystem management, Phewa lake is changing and gradually progressing from mesotrophic condition in the early 1970s to one of eutrophic (Nakanishi et al., 1988; Rai, 2000). Nutrient (mainly Nitrogen and Phosphorus) enrichment from different sources (washing, agricultural run-off, pollution by sewerages and the like) is a major cause of eutrophication (Pradhan and Panth, 1995; Lamichhane, 2000; Hadwen et al., 2003). Current rate of eutrophication promotes the growth of aquatic weeds, which deteriorates water quality upon their death, obstructs light penetration and competes with phytoplankton for plant nutrients. In addition, it interferes with intended usage (Both fisheries activity and tourism industry require free access to boating,

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angling and recreation) as well as makes the water bodies unattractive. About 39 species of aquatic weeds of emergent, sub-emergent and floating types are recorded from Phewa lake. The sub-emergent type is prevalent with a high diversity of 23 species of which *Hydrilla verticillata* is abundant, and *Potamegeton octandrus*, *P. crispus* and *Vallisneria spiralis* are common associates (Shrestha, 1998). It is necessary to keep the weeds under control in one way or the other to protect more valuable aquatic resources. Several studies have suggested measures for alleviating the problem of aquatic weed (Jhingran, 1991; Khanna, 1990; Lewis, 1999). Besides preventive measures, biological control method is also considered an efficient and environmentally safe option. Biological organisms offer unique advantages for the management of aquatic weeds with potential for their conservation to useful protein product (fish flesh). The most promising biological agent for the problem of many sub-merged plants and some other aquatic weeds is grass carp (*Ctenopharyngodon idella*) (Lewis, 1999; Sutton and Vandiver, 1986). Previous studies with grass carp showed encouraging results in utilizing sub-merged weeds (Yamada et al., 1998).

Resource-poor farmers are always looking for cheap methods to carry out their aquaculture activities and utilization of grass carp in cages could be one of the means to minimize aquatic weeds and keep the cost low, as grasses are available abundantly in lakes. Moreover, grass carp is a fast grower as well as fetches higher market price than silver and bighead carps. Therefore, this study is designed with the purpose of utilizing dense population of aquatic weeds through small-scale cage culture with grass carp for generating higher income for poor communities.

2. Materials and methods

An experiment was conducted in Phewa lake in Pokhara valley during 2007-2008. Cages were fixed as per standard practices (Swar and Pradhan, 1992). Previously reared grass carp fingerlings weighing 44.9± 4.10 g were stocked at the rate of 10 individual/m^3 in farmers' floating net cage of 50 m^3, having 15 mm mesh size. Fish were fed on ad-libitum, with aquatic grasses removed daily from the water bodies. Cage cleaning was not necessary as the fish themselves browsed the net material while eating grasses. Fish attaining the size of more than 500 g were transferred to bigger cage with 60 mm mesh size after 180 days. Growth sample of 5% of fish population was observed monthly. Temperature was monitored daily. Cost benefit analysis was also performed (Pillay, 1993). Data were analyzed using stat graphics version 3.0 computer software.

3. Results and discussion

The growth pattern of grass carp in cage fed on aquatic grasses demonstrated steady increase in weight (Fig. 1). The results showed that the fish grew from an average weight of 44.9g to 1.5 kg in 480 days of feeding. The monthly weight gain significantly ($P<0.5$) differed in the early culture period. The mean absolute daily weight gain was 3.11 g/day and gross production averaged at 8.4 kg/m^3 (Table 1). Usually, in traditional practices of cage culture with planktivores at the same stocking density, fish become harvestable at 500-1,000 g in 12-15 months (Rai, 2000) and yield is 4.2-5 kg/m^3 (Gurung et al., 2005; Wagle et al., 2007) which indicates that grass carp flourishes and grows at a relatively rapid rate when sufficient amount of vegetation is available. The stocking size of 44.9 g maintained in this study was observed to have accepted grasses readily. An experiment conducted in tanks to determine the size of fish to utilize aquatic grasses showed that the grass carp of 10 g or below in weight cannot eat grasses effectively, while bigger fish (230 g) can utilize grasses effectively (Yamada et al., 1998). Fish have different adaptabilities to the variation in water temperature. In the present experiment in Phewa lake, the temperature varied from 17.5±05˚c to 31.3±0.250˚c which was considered optimum (Masser, 1997) for carp species.

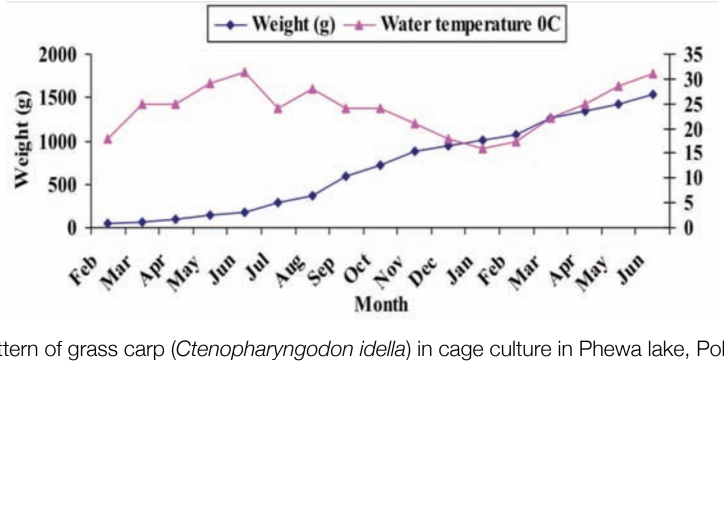

Fig. 1. Monthly growth pattern of grass carp (*Ctenopharyngodon idella*) in cage culture in Phewa lake, Pokhara, Nepal (2007-2008).

Table 1
Growth and yield description of grass carp (*Ctenopharyngodon idella*) in cage culture in Phewa lake, Pokhara, Nepal (2007-2008)

Description	
Size of cage (m^3)	50(5x5x2m)
Stocking rate (individual/m^3)	10
Total No. of stocking/cage	500
Individual weight of fish at stocking (g)	44.9± 4.1
Total weight of fish at stocking (kg)	22.45
Harvesting	
Individual weight at harvesting (g)	1540 ± 27.8
Net weight gain (g)	1460
Survival (%)	95
Gross production (kg)	416.83 (Sold:311.08+Stock:105.75)
Net production (kg)	389.8
Culture period (days)	480
Daily weight gain (g)	3.11
Mean yield (kg/m^3)	8.4

Feeding observation showed that grass carp preferred sub-merged plants, particularly hydrilla and soft tips of young tender plants. Many authors have stated that herbivorous macrophyte feeder fish have distinct preferences for plant materials to ingest (Edwards, 1980). In the present study, the daily grass consumption of fish was twice the weight of their body (Fig. 2). The high intake of aquatic grasses by the fish might be the results of high moisture content in them (Yamada et al., 1998), which considerably lowers net dry matter. Edwards (1987) reported that grass carp consumes large quantities to meet its nutritional requirement and the feeding rate of 174% of its body weight per day is typical. In China, it was reported that it consumed 40-70% of its own weight of grasses per day (Jhingran, 1991). The average survival rate was 95%, which was attributed to bigger fish size at stocking and availability of sufficient amount of feed. Large variation in the body weight gain among individuals was evident (Fig. 3). Such a discrepancy in growth is common among fish that rely on an aquatic vegetation (Masser, 1988), suggesting the need of frequent grading. Removal of larger fish reduces competition for food, allowing smaller fish to reach market size faster (Jhingran, 1991).

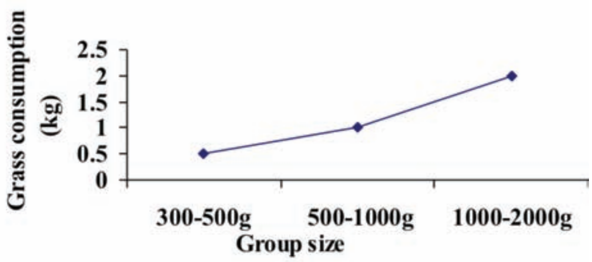

Fig. 2. Daily grass consumption in cage fish culture in Phewa lake, Pokhara, Nepal (2007-2008).

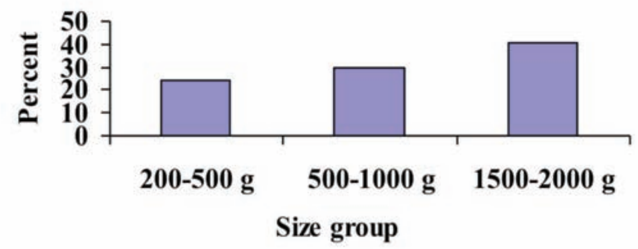

Fig. 3. Growth variation of grass carp (*Ctenopharyngodon idella*) in cage culture period in Phewa lake, Pokhara, Nepal (2007-2008).

Cage culture in Nepal is considered a lucrative practice because of its low cost of production. Table 2 gives some estimates on different costs incurred and returns obtained by the fish growers in Phewa lake. The cages depreciated in 15 years or more. The annual operating cost included costs for fingerlings, family labor, depreciation and interest. The net return on annual cost was NRs 27,632.40. Profitability analysis revealed that cage culture with grass carp is lucrative as indicated by the rate of return on investment and operating cost, which were 71.77% and 58.30%, respectively.

Table 2
Cost-benefit analysis of cage culture with grass carp (*Ctenopharyngodon idella*) in Phewa lake, Pokhara, Nepal (2007-2008)

S.N.		Total cost (NRs)
1.	Capital cost item	
	Cage 15mm (5x 5x 2m)	10,000.00
	Cage 60 mm (6x 6x 2m)	15,000.00
	Boat @25,000 (50% work)	12,500.00
	Bamboo (4)	1,000.00
	Sub-total	**38,500.00**
2	Annual operating cost	
a	Variable cost	
	Fingerlings cost (500 fingerlings) @ NRs 6.00 /fingerling	3,000.00
	Interest on variable cost (12%)	360.00
	Family labor 180 man days (3hrs/day) @ NRs 200.00	36,000.00
	Sub-total	**39,360.00**
b	Fixed cost	
	Depreciation on cage (Economic life 15 years)	1,667.00
	Depreciation on boat (Economic life 10 years)	1,250.00
	Depreciation on bamboo (Economic life 2 years)	500.00
	Interest on capital cost (12%)	4,620.00
	Sub-total	**8,037.00**
	Total operating cost	**47,397.00**
3.	Income (Gross revenue)	
	Fish sold 416.83 kg @ NRs180.00/kg	75,029.40
4.	Indicator	
	Net profit	27,632.40
	Rate of return on investment (NRs)	71.77
	Rate of return on operating Cost (NRs)	58.30
	Pay back period (Yrs)	1.24

Primary information revealed that 92.9% of the existing 70 households were operating cage culture with grass carp (Fig. 4). This high involvement of farmers implied that great potential was being realized from carp culture. However, expansion of cage seemed to be limited due to low supply of fingerlings and aquatic grasses, particularly in winter. Considering all the activities involved in cage culture, the participation of women and men was 40:60 (Fig. 5).

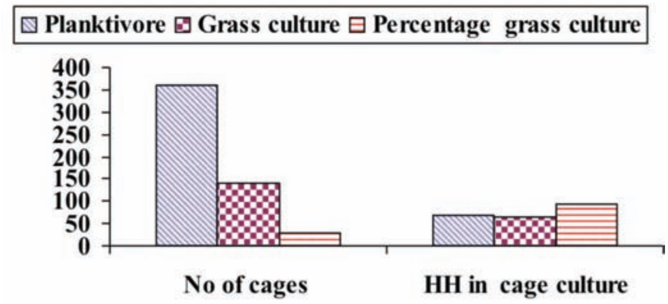

Fig. 4. Farmers' involvement in cage culture with grass carp (*Ctenopharyngodon idella*) in Phewa lake, Pokhara, Nepal, 2007-2008.

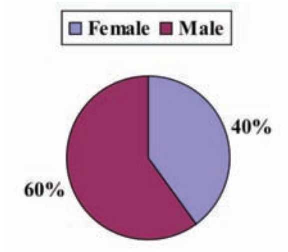

Fig. 5. Farmers' involvement by gender in cage culture with grass carp (*Ctenopharyngodon idella*) in Phewa lake, Pokhara, Nepal (2007- 2008).

4. Conclusion and recommendation

Expansion of cage culture with grass carp could enhance food security and nutritional status, and generate more income for rural people through increased production and high domestic market value. It also improves the ecosystem of aquatic water bodies by removing aquatic grasses. Recent trend of adoption suggests that cage culture with grass carp is getting popular among farmers and possess further adoption potentialities. However, it is necessary to understand that aquatic weeds are a basic component of a lake ecosystem. In an aquatic environment, some macrophytes are necessary because plant functions with other components of the ecosystem to help maintain an adequate environmental quality for fish production. It favors natural food production; enriches oxygen production; and serves as spawning ground as well as shelter for fish. Furthermore, most aquatic weeds of Phewa lake are ethno- botanically important, and posses food value for fish, water birds and humans. Fisheries personnel, therefore, should take the lead - in co-operation with local development authority and other concerned organizations - in making the farmers and local people aware of these and promoting a judicious utilization of aquatic weeds.

Availability of aquatic grasses as feed is the key factor to the success of cage culture with grass carp. It is suggested that the size of area infested with weeds in relation to the total area may be taken into consideration while deciding on increasing the number of cages. Utilization of natural feed such as aquatic weeds is considered environment-friendly. However, using external inputs like terrestrial grasses may receive wide controversy in the long run due to their possible effects on aquatic eutrophication in lakes from the unutilized portion and the wastes discharged by the fish. Thus, a careful planning is very important for the development of cage culture with Grass carp.

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Development of community-based fish seed rearing network for sustainable cage aquaculture in Kulekhani Reservoir, Nepal

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Abstract

Cage culture with silver carp and bighead carp was started in Kulekhani reservoir by Government of Nepal in the late 1980s to provide a means of livelihood to the people living in the vicinity, who were displaced by the construction of the reservoir. At present, 239 farmers organized in 11 groups are operating 1,630 cages (81,500 m^3) and producing 134 mt of fish. Despite the steady growth in the number and volume of cages, their productivity has declined continuously from 3.92kg/m^3 in 1999 to 1.84 kg/m^3 in 2007. Inadequate fish seed (fry) supply has been recognized as one of the major constraints to sustaining the productivity. The farmers entirely depend on hatcheries located in Terai region for the supply of fry. Post-transportation mortality (up to 70%) and contamination of carp fry with wild fish has further triggered the problem. Concerted efforts have been made to establish community-based networks by involving the farmers in all the three stages of nursing, rearing and production of fish seed. Their capacity was strengthened through a series of meetings, trainings and workshops. In their participation, nursery ponds were constructed, and nursery cages, hatchling and fry were supplied to their Fishers Association for producing fry and fingerlings. Although this initial effort would meet about 20% of the current fingerling demand, the establishment of local-level networks of seed rearing and distribution would foster entrepreneurship among these small farmers, allowing them to get involved as nursery operators, traders or sellers of related materials and supplies. Both government organizations and farmers community are recommended to play a greater role in strengthening community-based fish seed rearing and delivery networks in the reservoir area.

Keywords: Fish seed; Kulekhani reservoir; Nursery cages; Seed network

1. Introduction

Impounded in 1982, Kulekhani reservoir in Makawanpur district of Nepal is surrounded by approximately 126 km^2 of catchment area within the latitude of 270 23’ 25” to 270 41’ 31” N and the longitude of 850 2’ 46” to 850 16’ 16” E. The watershed area is situated in northeastern part of the district. The reservoir is approximately 42 km south from Kathmandu, the capital and linked to it with motorable pebble road, and about km north from Hetauda. Kulekhani reservoir is a small 220 ha water body situated in the mid-hills of Central Nepal at 1,430 m above the sea level (Fig. 1). The reservoir draws down up to 54 m during the peak season of power generation, leaving 220 ha of water surface area into 55 ha.

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Fig. 1. Map of Nepal showing location of Kulekhani reservoir.

It is the first man-made reservoir in the country, in which aquaculture development has been explored to provide a means of livelihood to the people living in the vicinity, who were displaced by the construction of the reservoir. This development program was initiated by Government of Nepal with technical assistance from the International Development Research Centre (IDRC), Canada in 1984. The initiative was visualized to assess the feasibility of a fisheries development program by gathering in-depth information on the limnological/biological parameters and also to help layout the foundation for the future reservoir fisheries development programs in the country.

Cage culture with silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*Aristichthys nobilis*) was started in Kulekhani reservoir in the late 1980s to provide a means of livelihood to the displaced people. The technology was developed in lakes in Pokhara valley, where it was successfully applied by the farmers. Since the inception of cage fish culture in the reservoir, the number and volume of cages increased rapidly and have reached 1,630 and 81,500 m^3, respectively in recent years. However, the productivity has declined continuously from 3.92 kg/m^3 in 1999 to 1.84 kg/m^3 in 2007. Inadequate fish seed supply (both in terms of quality and quantity) has been recognized as one of the major constraints to sustaining productivity of ever increasing cage fish culture. Although seed of the major cultured species are produced in large quantities in hatcheries in Terai region of the country, their poor quality and delivery mechanism are increasingly perceived as major constraints to maintaining the production rate of growing cage fish culture in Kulakhani reservoir. This paper, therefore, attempts to identify production trend of cage aquaculture, characteristics of current seed supply networks, and promising strategies for the rearing and distribution of quality seed to smallholders.

2. Methodology

Status of cage fish culture, and current seed demand and supply networks in Kulekhani reservoir were assessed. Farmers and local community members were interviewed. Data provided in various published sources were used to estimate fish seed demand, supply and stocking gap. Establishment of a community-based fish seed rearing network and development of rearing facilities were undertaken during 2006-2008 under "Cage Fish Culture Commercialization in Kulekhani Reservoir" project, which was supported by Nepal Agricultural Research and Development Fund (NARDF).

3. Community involved in cage fish culture

The total population of Kulekhani watershed was 36,187 in 1981, which comprised of Brahmin, Chhetri, Tamang, Magar, Newar and other ethnic communities (Bjønness, 1983). Among them, 500 families or approximately 2,100 people were affected by the construction of hydro dam (Gurung et al., 2010). About 31.76% Tamang, 29.2% Magar, 20% Brahmin and Chhetri, 17.94% Ne war and 0.85% Kami, Damai and Pode were involved in cage fish culture activities, and most of the families had been displaced during the impoundment (Gurung et al., 2010). At present, 239 farmers (119 women and 120 men) organized in 11 groups are practicing cage fish culture for their livelihood. Coordination and communication among the groups is facilitated by a federation (Fishers Association) represented by the leaders of the groups.

4. Growth trend of cage fish culture

The characteristic feature of cage fish culture in Kulekhani reservoir is sustainable production in ambient water productivity, using plankton feeder fish such as bighead and silver carp as main species (Swar and Gurung, 1988; Rai and Mulmi, 1992, Gurung et. al., 2005). In this system, per unit area of production remains low compared to intensive farming, as the fish rely only on natural food without feed input from outside (Rai and Mulmi, 1992).

The cage culture technology has been expanded enormously in the reservoir. With the effort made for its adoption, the number of participating farmers has reached to 239 in 2008 from merely five farmers in 1998 (Fig. 2). The number of cages at present is 1,690, which is equivalent to 84,545 m^3 of cage volume including 81,500 m^3 privately owned and 3045 m^3 government owned. Similarly, the number of cages operating in private and government sectors are 1,630 and 60, respectively. Relatively high productivity (≥3.5 kg/m^3) was persistent until 2004 when an increased volume of cage might have reached equilibrium with seed supply and the availability of natural foods. The productivity declined sharply in 2005 (1.9 kg/m^3) and has remained somewhat constant in the recent years despite the continuous increase in the number and volume of cages (Fig. 3).

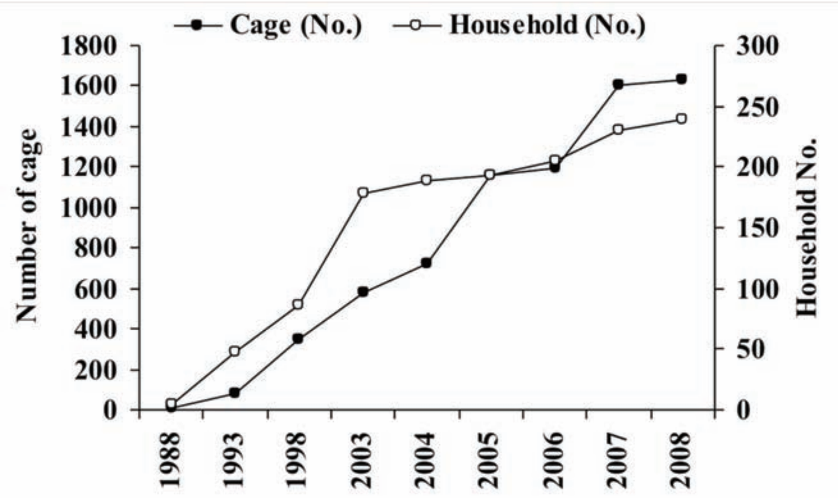

Fig. 2. Growth trend of adopter of cage fish culture and number of cages landed in Kulekhani reservoir.

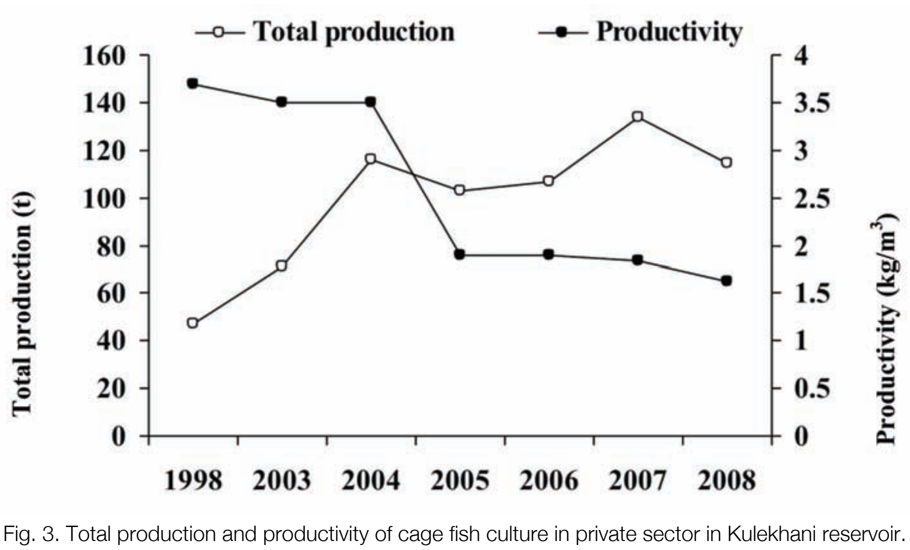

Fig. 3. Total production and productivity of cage fish culture in private sector in Kulekhani reservoir.

5. Fish seed demand and supply trend

Trend of seed supply to farmers suggests a rapid increase in its demand for cage culture in private sector. The sharp inclination for fry distribution from hatcheries implies its increasing popularity. This trend is also confirmed by the growing number of cages in the reservoir every year. However, the number of fry distributed to a production cycle has rarely met its demand since 1998 (Fig. 4). The highest stocking density was 9 fingerling/m^3 of cage in the year 2003 against the recommended density of 10 fingerling/m^3. In recent years, the stocking density never exceeds 7 fingerling/m^3 (Fig.5). The supply of fingerlings seems inadequate, which is why the farmers bring them by themselves from far distances, sometimes from Calcutta, India. They have realized that with sufficient supply of fingerlings they could increase production from cage culture and open water capture fishery.

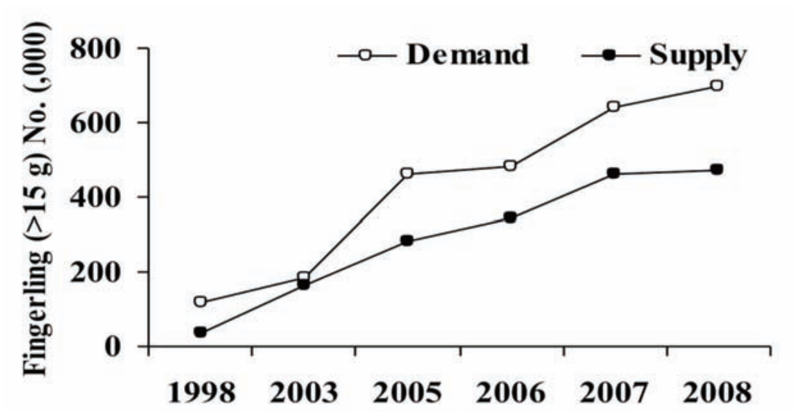

Fig. 4. Fingerling demand and supply in Kulekhani reservoir (The supply was calculated based on fry mortality during rearing in cages in different time periods as reported by the farmers).

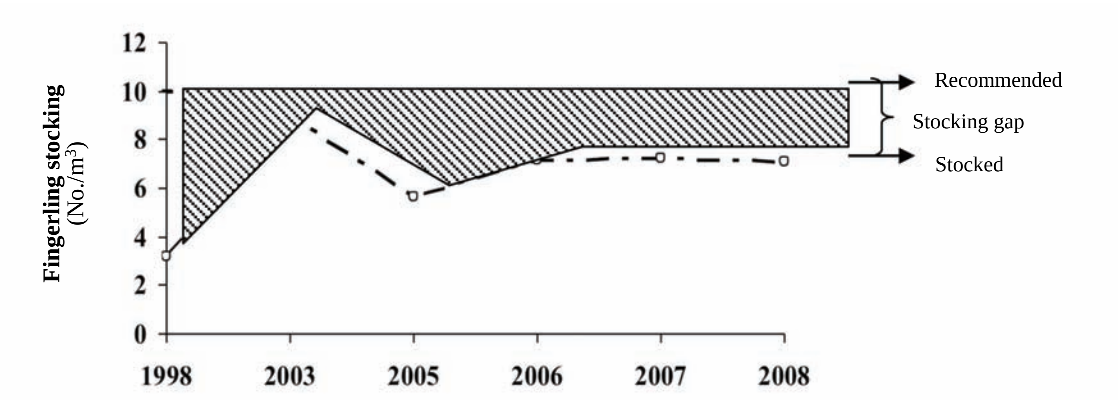

Fig. 5. Recommended and actual fingerling stocking density in production cages and the stocking gap in Kulekhani reservoir.

6. Source of fish seed and supply network

Right from the beginning, cage fish culture in the reservoir has been depending on fingerling supply from outside Kulekhani. Most of the fish seed (fry) come from government and private hatcheries in Terai region of the country. The nearest hatchery located in Terai corridor is about 50 km far from the reservoir. Fisheries Development Center (FDC) Kulekhani - in collaboration with the farmers - collects the demand for fry of 2-3 g for rearing in cages (Fig. 6). The demand is then placed with hatcheries but the commitments on their part are poor because of their resource constraint, poor communication and poor road network for transportation of fry during monsoon. Besides the supply from government farms coordinated by FDC Kulekhani, the farmers also purchase and transport fingerlings themselves from different locations of the country and India, mainly from Calcutta. Fish seed rearing and marketing networks by involving various stakeholders (cage operators, land owners and net suppliers) are poorly developed to support and sustain cage fish culture business in the reservoir.

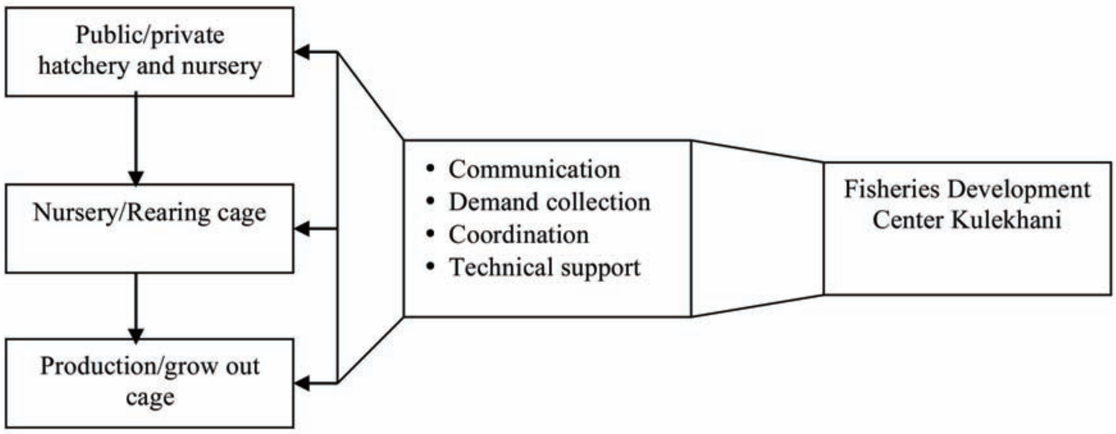

Fig. 6. Fish seed supply network in Kulekhani reservoir.

General complaints made by the farmers with respect to fish seed (fry) are related to fragile supply networks and inadequate capacity of the local community to get involved in seed rearing. The major problems faced by them are:

- Inadequate fish seed supply has been recognized as one of the major constraints to sustaining productivity of cage fish culture in Kulekhani reservoir. The farmers entirely depend on the hatcheries in Terai for the supply of fry. This has led them to over and under stock fingerlings in their cages during the years of surplus and scarcity, respectively.
- Despite the use of modern techniques in transportation (oxygenated polyethylene bags and open tanks), post-transportation mortality (up to 70%) of fry in nursery cages has been reported. With the onset of winter, a large number of fry is available to the farmers from late October to November. Fry mortality during rearing in cages has further been enhanced by decreasing water temperature in the reservoir, which has averaged 32.8±14.5% in the last two decades (Fig. 7).
- Contamination of carp fry with wild fish has further triggered the problem of quality seed supply. Accidentally, glass fish (*Chanda* sp) was transported along with the carp fry from Terai and introduced in the reservoir in 2003. This species has now been established in the reservoir and caused about 50% mortality among carp reared in cages with large-sized mesh (50 mm) (Shrestha, 2004). This species was known to have removed the scale of silver carp and bighead carp in the cages (Gurung et al., 2010). This problem has now been solved by raising fish in cages with small-sized mesh (25 mm). However, this practice might reduce the exchange of water containing plankton, which could result in slow growth of caged fish, as the exchange of organisms on which fish depend also get reduced.

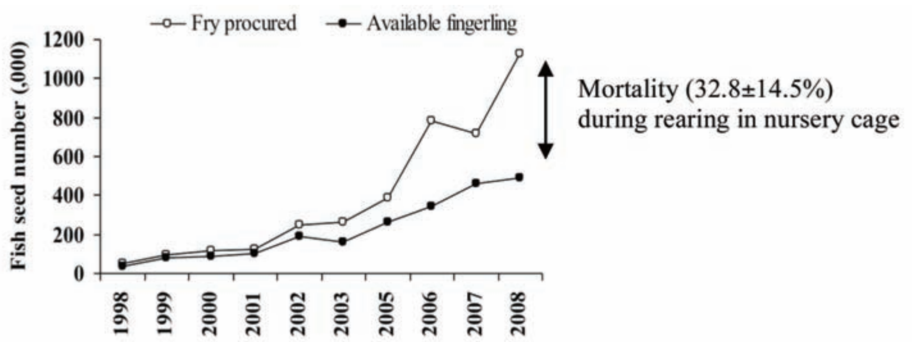

Fig. 7. Trend of fry procurement and fingerling production in Kulekhani reservoir.

7. Approaches to developing community-based fish seed rearing and supply network

Cage fish culture in Kulekhani reservoir is constrained by access to fingerlings but experience suggests that small-scale fish seed grow out system at local level can produce a big impact (Phillips, 2002). It has been widely accepted that community-based decentralized fish seed rearing mechanisms - such as nursing, rearing and trading networks - are a better catalyst for rural small-scale aquaculture development in Asia (Siriwardena, 2007). Fish seed networks - a web of physical and human connections producing and marketing fry and fingerlings - have been a major factor in the rise of inland aquaculture in Asia (Little et al., 2007). Fish seed networks are composed of groups of people producing and distributing fish seed and those marketing related supplies and services (Gregory et al., 1997). However, these networks are weak to support and sustain rapidly increasing cage aquaculture in Kulekhani reservoir. In order to improve seed supply both quantitatively and qualitatively in such areas, development of decentralized fish seed rearing and supply systems is essential. With the increasing concern on decentralized fish seed supply, small farmers in rural areas have opportunities to participate in this crucial aspect of cage aquaculture production (Edwards, 2000). Development of nurseries in physical proximity of fish growing areas not only reduces cost and improves 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).

A key aspect of any support for private sector seed networks, particularly in the hills, is a commitment to decentralized community approaches. In line with this, concerted efforts have been made to develop community-based fish seed rearing and marketing networks in Kulekhani reservoir under "Problems Assessment and Commercialization of Cage fish Culture in Kulekhani Reservoir" project during 2006-2008. The objectives of decentralized nursing and rearing of fish seed involving silver carp and bighead carp that are appropriate for cage fish culture and local level marketing network are to:

- improve seed supply (quantity and size);
- assure seed quality;
- reduce post-transportation loss of fry and fingerlings;
- reduce dependency of farmers on big/central hatcheries and nurseries for fry and fingerlings; and
- enhance capacity of local community for fish seed management and marketing.

In the beginning, capacity of the farmers in fish seed rearing was strengthened through meetings, trainings and workshops. Site selection for the construction of nursery ponds was made after several visits to adjacent farming community and analysis of its technical and hydro-physiographic suitability by a team of experts. With the participation of six farmers, eight nursery ponds (2500 m^2) were constructed (Table 1). Their area varied greatly depending upon the landscape, water source and land holding size of the farmers. These ponds were stocked with 900,000 hatchlings of silver carp and bighead carp procured from public/private hatchery located in Terai. After two to three months of nursing, the farmers were able to supply 150,000 fry (2-3 g each) to cage farmers.

Table 1
Number and area of nursery ponds constructed in Markhu and Chitlang Village Development Committees of Makwanpur district and their location

Location	No.	Area (m^2)
Chitlang	2	1,700
Shera	3	400
Kitani	2	250
FDC Kulekhani	1	150

There is a need to ease pressure on land in meeting the demand for large-sized fingerlings in Kulekhani reservoir. For this, an optimal use of nursery cages with 8-10 mm mesh opening has been suggested. Accordingly, 90 nursery cages (2,880 m^3) along with 60,000 fry have been supplied to Fishers Association for producing large- sized fingerlings (15-20 g) to be stocked in production cages. This will enable cage farmers to participate largely in local-level fish seed supply network. The association has been playing a key role in linking the nursery operators and cage fish growers. Supply channels of fish seed from hatcheries to cage farmers by involving different stakeholders, which is an outcome of the current efforts, are shown in Fig. 8.

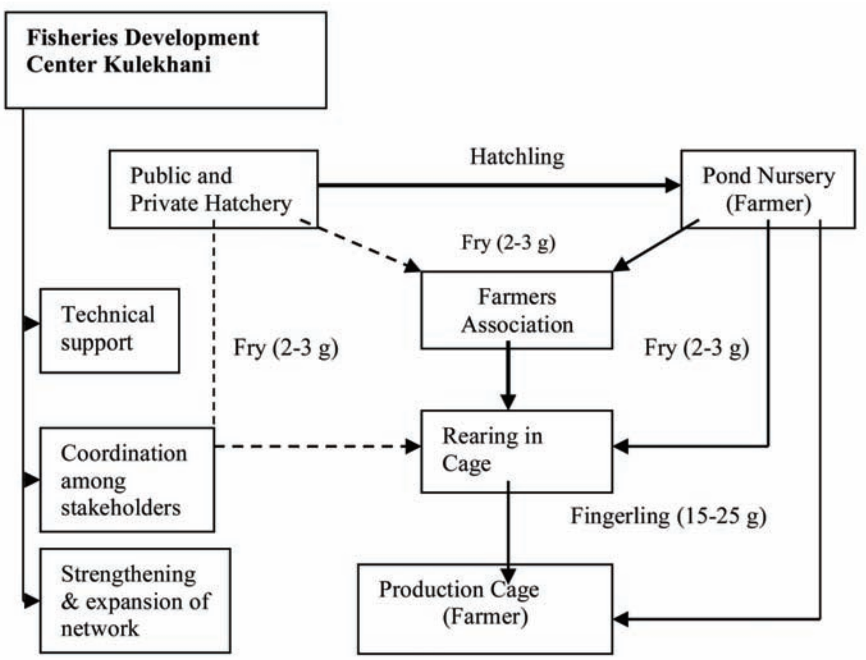

Fig. 8. Supply channels of fish seed from hatcheries to cage farmers in Kulekhani reservoir by involving different stakeholders (dotted arrow: weak linkage, thin: moderate and thick: strong).

Communication among relevant stakeholders (individuals, community and government institutions) on fish seed management has improved through knowledge sharing, networking and the introduction of participatory planning, implementation and monitoring approaches. Government-owned FDC Kulekhani would have a greater role in bridging all the stages (hatchery-nursery-rearing-production) of seed supply at present and expanding the networks in the future. Although this initial effort would meet 20% of the current demand for fish seed, the establishment of community-based seed rearing and distribution networks would be of great importance in terms of assurance, purity and reduced transportation mortality, and capacity building of local communities for sustaining aquaculture activities in poorly accessible hilly areas.

8. Way forward

The cage fish culture practiced in Kulekhani reservoir has been appreciated as one of the successful farming systems contributing to mainstreaming the displaced and deprived communities by enhancing their livelihood opportunities. However, fish seed supply, particularly large-sized fingerlings, has remained one of the most critical elements to the sustenance of production and productivity. Seed are transported to the reservoir from centrally-based hatcheries/nurseries located at a great distance. In the absence of local seed rearing networks, there is an attendant risk of gene pool mixing of fish stocks and spread of fish diseases (Phillips, 2002). Hatchling to fingerling rearing has had received only marginal attention from both public and private sectors in the reservoir area. In many countries, the processes evolved and adapted as a result of rural entrepreneurship (De Silva and Funge-Smith, 2005). The efforts made on the development of community-based fish seed rearing and supply networks could be catalysts for quality fish seed supply for cage fish culture in the reservoir. This model could be replicated to support small-scale aquaculture in other remote areas . Fish seed supply is an essential component of a value chain and its growth as an agribusiness will largely depend on private entrepreneurs. Seed networks enable entrepreneurship among farmers, allowing them to get involved as nursery operators, traders, or sellers of materials and supplies related to seed rearing and delivery (Little et al., 2007). Therefore, the government and relevant organizations should provide continued institutional support to enable more local people in Kulekhani area to enter seed nursing, rearing and supply networks.

9. Conclusion

Assessment of the status of fish seed supply for cage culture in Kulekhani reservoir has revealed that poor commitment on the part of hatcheries; heavy mortality of fry short after transportation and during rearing in winter; contamination of fish seed with wild fish; and weak linkage among various stakeholders have often limited seed stocking in production cages. Development of community-based fish seed rearing and distribution networks has potential to offer farmers opportunities to participate in seed management as a livelihood strategy, and a strong linkage among all the stakeholders of the networks is expected to combat the current seed shortage in Kulekhani reservoir. Nursing and rearing require low investments and modest skills, which makes it easier for the farmers to get involved in these activities. However, support from the relevant organizations in terms of seed money and training is considered useful.

Acknowledgements

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Investigation into fish mortality in cages in Kulekhani Reservoir, Nepal

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Abstract

Fish mortality in cages in Kulekhani reservoir, located in Makawanpur district of Nepal, resulted in tremendous loss to farmers during 2004-2005. In order to identify its causes, an experiment was conducted from May 2006 to April 2007 in the reservoir, which consisted of three treatments with six replications carried out in completely randomized design (CRD). Treatment allotments were of three different sizes of cages: 20 mm (T1); 35 mm (T2); and 50 mm (T3). Plankton feeder species and silver carp and bighead carp were stocked at the rate of 10 fish/m^3. The size of experimental unit was 8 m^3 (2 m x 2 m x 2 m). Monthly sampling and laboratory analysis of fish from 18 experimental cages were carried out to observe for fall-out of scales in the caged fish, parasites and diseases. An observatory experiment with carps and glass fish called *Chanda nama* was also conducted at Department of Aquaculture, Institute of Agriculture and Animal Science (IAAS), Chitwan. It was observed that the fish died of clinical sign of fall-out of scales from their body surface in four cages (66.66%) with 50 mm mesh size and two cages (33.33%) with 35 mm mesh size, and that non of the fish died in cages (00.00%) with 20 mm mesh size. The swarms of small notorious fish (exotic to the reservoir) *Chanda nama* were visible in abundance inside and around the cages with 50 mm mesh size and in lesser number inside the cages with 35 mm mesh size, and were absent inside the cages with 20 mm mesh size during the warm months of the study period. The glass fish showed active behaviors in warmer and passive in cooler months. These fish possessed thorny lips and appeared to be biting on the body surface of the caged fish which caused fall-out of scales among them and eventually their death in the cages where the glass fish could move freely in and out. Small mesh size prevented their movements and no sign of scale fall-out and death was observed among the caged fish. Visual observation in an aquarium at Institute of Agriculture and Animal Science (IAAS), Chitwan showed frequent attacks by glass fish to carp causing scrapping scales and wounds in their skin. Hence, using cages with small mesh size (20-25 mm) is recommended to prevent fish loss.

Keywords: Cage aquaculture; Cage mesh size; Behavior of *Chanda nama*; Reservoir fisheries

1. Introduction

Kulekhani reservoir was primarily constructed for the storage of excess water for electricity production during pick demand hours. It is a hydropower reservoir (max. depth 114 m), with water catchments from seven small hill streams (FDC Kulekhani, 2054 BS). Cage fish culture and open stocking of fish in the reservoir was initiated in 1988, and since then, significant amount of fish was being harvested each year (FDC Kulekhani, 2059 BS). However, an unexpected problem of fish mortality has started severely affecting the livelihood of the surrounding resource-poor farmers, who were actually marginalized by the construction of the reservoir as their agricultural lands were impounded and were bound to depend upon capture and culture fishery in the reservoir. The issue of fish mortality has remained unsolved since the last 3-4 years (2004 to 2007). This has created problem for the government as well as for the fisher communities of the reservoir site. Cage culture of planktivorous fish is one of the popular technologies of fish production in the reservoir (Shrestha et al., 2009). It has provided employment and additional incomes to the local fishers, and ensured supply of fish protein and livelihood for the marginalized farming households around the reservoir (FDC Kulekhani, 2060 BS). However, mass mortality of the caged fish has been occurring from 2004 to 2007, with a significant amount of fish loss every year. During these years, more than 50% of the stocked fish have died and many of the cages have become empty (FDC Kulekhani, 2060 BS). Since the reservoir (220 ha) submerged their agricultural lands, fish culture is the only option for their livelihood but the current problem of fish mortality has threatened their survival. If the problem is not solved, the sustainability of cage fish culture in the reservoir remains questionable. This research, therefore, aims to investigate the problem of fish mortality in Kulekhani reservoir and suggest mitigation measures for sustainable cage fish culture (Wagle et al., 2009).

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2. Materials and methods

An experiment consisting of three treatments with six replications carried out in completely randomized design (CRD) was conducted. Treatment allotments involved three different mesh sizes of cages: 20 mm (T1); 35 mm (T2); and 50 mm (T3). Plankton feeder species - silver carp and bighead carp - were stocked at the rate of 10-fish/m^3. Experimental unit was of 8 m^3 in size (2 m x 2 m x 2 m) and made of nylon threads. Monthly sampling and laboratory analysis of fish from the 18 experimental cages were carried out to observe for fall- out of scales in caged fish. Major activities included monitoring of diseases/parasites, pesticide residues and mortality among fish for a period of one year (May 2006-April 2007). A daily observation of fish in cages was made for mortality record, and moribund and freshly dead fish sample were regularly collected for laboratory analysis.

Watershed/catchment of Kulekhani reservoir was a famous intensive vegetable growing area, where heavy doses of pesticides to control insects/pests had been in use since a decade (ADO, 2002). In view of possibility of collection and deposition of some of pesticide residues in the reservoir and fish flesh through runoff water, sampling of fish for pesticide residue content in muscles was carried out quarterly (once in four month) for one year.

A visual observation was made in an aquarium at Institute of Agriculture and Animal Science (IAAS), Chitwan, in which silver carp and bighead carp were stocked. Glass fish called *Chanda nama* were also stocked in the same aquarium glass tank. The behaviors of glass fish towards silver carp and bighead carp were observed from outside the aquarium.

An analysis of pesticide residues in fish flesh was performed in Nepal Environmental & Scientific Services (P.) Ltd. Thapathali, Kathmandu. Based on a survey of pesticide uses in agricultural practices in the catchment/watershed, five groups of most commonly used pesticides were analyzed to find out whether their presence was at a significant level to cause fall-out of scales and fish kill.

3. Results and discussion

3.1. Pesticide residues

The depth of water just beneath the cages varied from 20 to 50 m in rainy and summer seasons, respectively (Shrestha et al., 2009). The concentration of pesticides on fish flesh in rainy season was reported to be as low as at 0.005 ppm or not even detected in some samples. Similarly, slightly higher concentration of pesticides (0.006 ppm and 0.007 ppm) was noted in winter and summer. However, in both the cases, the level of concentration was far too low to cause any clinical sign of fall-out of scales or fish kill in the water. Table 1 shows the pesticide concentration in fish flesh in Kulekhani reservoir.

Table 1
Pesticide concentration in fish flesh in Kulekhani reservoir

SN	Parameters	Fish Flesh Samples (lot-A) (I-Quarter)		Fish Flesh Samples (lot-B) (II-Quarter)		Fish Flesh Samples (lot-C) (III-Quarter)	
		Observed residue level (ppm)		Observed residue level (ppm)		Observed residue level (ppm)	
		Silver carp[1]	Bighead carp[2]	Silver carp[1]	Bighead carp[2]	Silver carp[1]	Bighead carp[2]
1	Cypermethrin	N.D. (<0.01)	N.D. (<0.01)	N.D. (<0.02)	N.D. (<0.02)	N.D. (<0.03)	N.D. (<0.03)
2	Endosulfan	0.005	N.D. (<0.005)	0.006	N.D. (<0.005)	0.005	N.D. (<0.007)
3	Deltamethrin	0.03	N.D. (<0.02)	0.03	N.D. (<0.03)	0.04	N.D. (<0.04)
4	Chloropyrifos	N.D. (<0.005)	N.D. (<0.005)	N.D. (<0.006)	N.D. (<0.006)	N.D. (<0.006)	N.D. (<0.006)
5	Dimethoate	N.D. (<0.001)	0.001	N.D. (<0.002)	0.002	N.D. (<0.003)	0.003

N.D.: Not detected ;
[1] : Pooled sample of 16 fish (one from each cage).
[2] : Pooled sample of 16 fish (one from each cage).

3.2. Fish mortality

Fall-out of scales and fish kill were observed in two out of three treatments. No signs of such incidents were noted in the cages with 20 mm mesh size. Some of moribund and dead fish were taken as sample for a laboratory investigation.

The following clinical signs were recorded:

- Scale fall-out from all over the dorsal side of body surface was observed.
- Scale fall-out was extended between bases of pectoral fin and caudal fin.
- Tip of the caudal fin seemed to have a sign of decaying.
- Infected fish were observed in slow motion.
- Gut examination showed an empty intestinal bulb and intestine.
- Loss of fish weight was observed.
- Fish parasites, namely *Trichodina* sp. and *Dactylogyrus* sp were found in the gills and mucus of some of the samples but the infestation level was very low.
- No clinical signs of scale fall-out and fish kill were observed in all the cages with 20 mm mesh size.

The findings clearly showed that the small-sized mesh (20 mm - T1) prevented the entry of notorious fish called glass fish inside the cages all together, while the medium-sized mesh (35 mm - T2) did this job partially and there was no prevention in the case of large- sized mesh (50 mm - T3) (Table 2).

Table 2
Cage mesh size and fish mortality record at harvest in Kulekhani reservoir

SN	Harvesting	20 mm (T1)	35 mm (T2)	50 mm (T3)	Total	Remarks
1	Cage with fish	6 (100%)	4 (66.66%)	2 (33.33%)	12	No mortality in 20 mm cages
2	Cage without fish	0 (100%)	2 (33.66%)	4 (66.66%)	6	Medium mortality in 35 mm cages
3	Total	6	6	6	18	High mortality in 50 mm cages

A swarm of glass fish was visible in and around the cages with 35 mm and 50 mm mesh size. The glass fish possessed thorny lips and appeared to have been biting on the body surface of the caged fish that might have been the cause of fall-out of scales and eventually death among them.

The analysis of pesticide residues in fish flesh in rainy, winter and summer seasons indicated that they were at a very low or undetectable level and that they could not have been the cause of mortality among fish in cages of Kulekhani reservoir. To cause any lesions/ulcers/wounds on external surface, the minimum concentration of pesticides should be >2-4 ppm (Thompson, 1998).

Since the glass fish were frequently attacking silver carp and bighead carp, they could have been the cause of scrapping scales and wounds in the skin of the caged fish. The very low concentration of pesticides detected in water was unlikely to cause of fall-out of scales and fish kill in the reservoir.

4. Recommendations

The following measures are recommended for the growth of cage fish culture in Kulekhani reservoir:

- Using cages with 20 mm or less mesh size
- Developing guidelines/norms for a sustainable cage culture in the reservoir
- Stopping the entry of glass fish and other exotic fish species (except for the recommended ones) that have capability of self breeding and multiplying into the reservoir
- Quarantine/screening of fish seed before stocking/releasing them into the reservoir/cages
- Monitoring the use of pesticides in the catchments and farm lands to prevent their unnecessary use

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Water quality pattern and natural food-based cage aquaculture in Kulekhani Reservoir

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Abstract

Kulekhani (or Indrasarobar) reservoir was built in 1982 for hydropower generation. It is situated at an altitude of 1,430 msl in the mid-hills of Nepal. The water in the reservoir is full in rainy season, with a surface area of 216 ha at the highest level. The water level draws down as dry season occurs, with the use of water for electricity generation to 55 ha at the lowest level. Drawing on the experience of extensive cage aquaculture practice of Phewa lake, cage and open water stocking of planktivorous fish such as silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*Aristichthys nobilis*), was started in this reservoir since 1988 and a significant amount of fish harvest has been obtained each year. This reservoir is well known for the growth of planktivorous fish. At present, 239 households have been involved in fish culture in 1,630 cages. Cage volume has increased to 81,500 m^3. Four years ago, there was a problem of fish mortality which decreased fish yield drastically. Later on, replacement with cages having smaller mesh size decreased fish mortality. In order to study the possible causes of mortality and stunting of fish, a limnological study was carried out to monitor monthly water quality parameters at 4 sampling stations of the reservoir during 20 May 2006-26 March 2007. The results showed that most of the parameters are in optimum range and fluctuated seasonally. It was also demonstrated that water quality parameters of the reservoir are not the critical factor to the mortality of the caged fish. However, the growth of fish has been affected which is directly linked with the limited availability of natural food in the cages. There might be two reasons for this: (i) exceeding carrying capacity leading to natural food limitation; and (ii) small mesh size blocking cage mesh and consequently creating fouling and limiting food circulation. Therefore, it is suggested that a study on carrying capacity of Kulekhani reservoir be conducted and mesh size of fish cages be altered seasonally.

Keywords: Cage aquaculture; Kulekhani reservoir; Water quality

1. Introduction

Kulekhani (or *Indrasarobar*) reservoir is situated at an altitude of 1,430 msl in the mid-hill region of Nepal about 70 km southest from Katmandu. The reservoir was impounded in 1982 by damming Kulekhani stream and its tributaries for hydropower generation. It has a catchment area of 126 km^2 (Rai and Bista, 2001). The water level in the reservoir fluctuates up to 54 m, making the surface area from 220 ha at the highest to 75 ha at the lowest (Rai, 1989). Kulekhani reservoir is well known for indigenous fish katle (*Neolissocheilus hexagonolepis*) and growth of exotic planktivorous fish silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*Aristichthys nobilis*) (Pradhan and Swar, 1988; Rai and Mulmi, 1992). Aquaculture development has been explored in the reservoir to provide a means of livelihood to people living in the vicinity, who were displaced by the construction of the reservoir. This development program was initiated by Government of Nepal with technical assistance from International Development Research Centre (IDRC), Canada in 1984 (Rai and Wagle, 2007). Cage culture using silver carp and bighead carp was started in Kulekhani reservoir on an experimental scale since 1988 and since then significant amount of fish harvest has been obtained each year (Shrestha et al., 2002). The technology applied was developed in lakes in Pokhara valley. Now there are 230 farmers (110 women and 120 men) involved in fish culture in the reservoir using 75,000 m^3 of cage volume for production, nursery and grow-out (FRDC, 2006/07). Recent studies have shown that there is also a great potential for cage culture of high value rainbow trout (*Oncorhynchus mykiss*) in winter (FRDC, 2006/07).

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During the last few years Kulekhani reservoir has been subjected to a range of stress factors caused by increased number and volume of fish cages, low rainfall in the catchment and the use of agro-chemicals in the surrounding vegetable pocket. Stunting fish growth and low yield have been the major problems to the cage fish farmers. At present, the volume of cages in Kulekhani reservoir has been increased to 81,500 m^3. Thus, the purpose of this study is to monitor the year round water quality in the reservoir and to predict its potential impacts on the cage fish culture and local biotic system.

2. Materials and methods

A limnological study was carried out at four different stations in Kulekhani reservoir from 18 April 2006 to 26 March 2007. Sampling stations were selected near the cage fish culture experimental site and the sampling depth was 15 cm below the surface water. Different water quality parameters were measured monthly at 0,700 to 0,900 h. In-situ water temperature and dissolved oxygen was measured using DO meter (Model: Orion). In-situ transparency and conductivity were measured by Secchi disk and SCT meter, respectively. For chemical analysis, water samples (from 15 cm depth) were collected from each station and brought to laboratory of Department of Aquaculture, Institute of Agriculture and Animal Science (IAAS), Tribhuvan University Chitwan, Nepal. The pH was measured by digital pH meter (WTW). For the biological oxygen demand (BOD_5), the samples were diluted; initial dissolved oxygen was measured by DO meter and the samples were incubated in dark for five days. Then dissolved oxygen was again measured and the initial and final difference was calculated. Soluble reactive phosphorous (PO_4-P) and total phosphorous (TP) were analyzed by ascorbic acid reduction method (APHA, 1985). Total ammonium nitrogen (NH_3- N) and total nitrogen (TN) were analyzed by Phenate method (APHA, 1985). Nitrite nitrogen (NO_2-N) and nitrate nitrogen (NO_3-N) were analyzed by diazotizing procedure (APHA, 1985). Total alkalinity and chlorophyll-a, were measured by sulfuric acid titration method and acetone extraction method, respectively (APHA, 1985). Total suspended solids (TSS) and total dissolved solids (TDS) were measured by filtering 100 ml water samples through GF/C filter and evaporating the moisture of both filtrates and suspended particles in 105˚c for 24 hours. The average water depth data of the reservoir were taken from the Electricity Office, Kulekhani.

3. Results

3.1. Water temperature

The water temperature changed seasonally in a regular pattern during the observation period, becoming the highest (24.9 ˚c) in July and the lowest (12.2 ˚c) in February (Table 1; Fig. 1). It decreased continuously from July, reached minimum (12 ˚c) in February and increased from March onwards (Fig. 1).

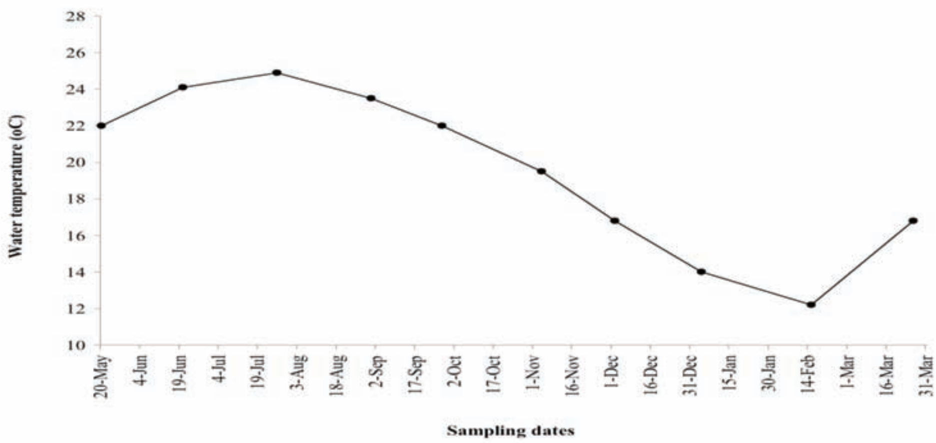

Fig. 1. Mean water temperature (˚c) in Kulekhani reservoir at different sampling dates during 20 May 2006-26 March 2007.

3.2. Dissolved oxygen

The dissolved oxygen fluctuated seasonally, ranging from 5.9 to 11.7 mg/L. The highest was recorded in June and the lowest in December (Table 1; Fig. 2). The fluctuation coincided with the precipitation and the surface algal die-offs.

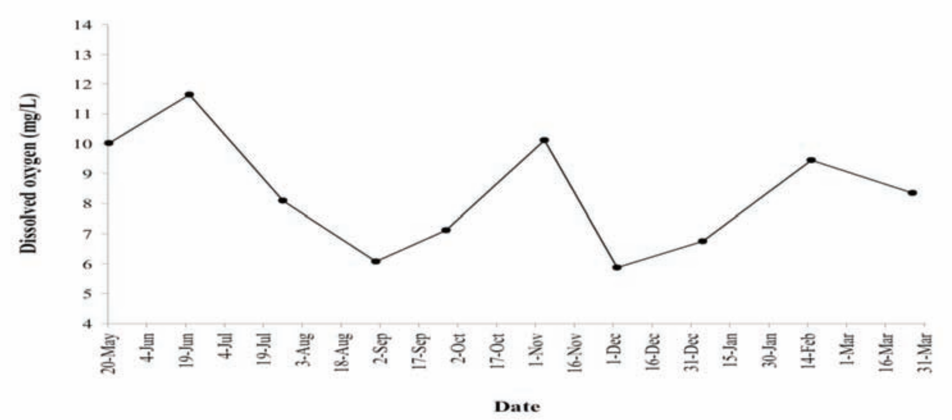

Fig. 2. Mean water dissolved oxygen (mg/L) in Kulekhani reservoir at different sampling dates during 20 May 2006-26 March 2007.

3.3. pH

The pH fluctuated from 7.9 to 9.5 depending on the season, remaining alkaline in all seasons (Table 1). It was the highest in March and the lowest in December/January. The pH was not much affected by the precipitation and other factors and remained mostly alkaline during the observation period.

3.4. Biological oxygen demand

The BOD5 ranged from 3.7 to 5.6 mg/l, with the highest in December and the lowest in August (Table 1). The fluctuation did not show clear seasonality.

3.5. Conductivity

The conductivity ranged from 58.8 to 125.8 - mos. It was the highest in May and the lowest in February (Table 1), which showed a cyclic high and low value depending on the concentration of the total dissolved solids.

3.6. Transparency

The Secchi disk reading showed high fluctuation ranging from 3.0 to 6.0 m. The highest transparency was recorded during December- March and the lowest during August-October (Table 1; Fig. 3). The fluctuation did not show clear seasonality.

Table 1
Monthly mean and range of water quality parameters in Kulekhani reservoir during 20 May 2006-26 March 2007

S.N.	Parameters	Mean	Minimum	Maximum
1	Temperature (°c)	19.6	12.2 (Feb)	24.9 (Jul)
2	Dissolved oxygen (mg/l)	8.4	5.9 (Dec)	11.7 (Jun)
3	pH	8.4	7.6 (Dec/Jan)	9.5 (Mar)
4	Conductivity (μmhos)	96.3	58.8 (Feb)	125.8 (May)
5	Transparency (m)	4.4	3.0 (Nov)	6.0 (Feb)
6	BOD_5 (mg/l)	4.8	3.7 (Aug)	5.6 (Dec)
7	PO_4-P (mg/l)	0.034	0.016 (Feb)	0.059 (Dec)
8	NH_3-N (mg/l)	0.083	0.037 (Feb)	0.152 (Aug)
9	NO_2-N (mg/l)	0.025	0.008 (May/Jun)	0.051 (Sep)
10	NO_2+NO_3-N (mg/l)	0.065	0.014 (May)	0.106 (Jan)
11	TP (mg/l)	0.151	0.064 (May)	0.216 (Dec)
12	TN (mg/l)	1.027	0.561 (May)	1.331 (Aug)
13	Chlorophyll-a (mg/cm^3)	8.49	2.67 (May)	20.72 (Sep)
14	Total alkalinity (mg/l $CaCO_3$)	57.2	50.1 (Sep)	65.2 (Mar)
15	Total suspended solids (mg/l)	145.7	47.5 (Sep)	980.0 (Aug)
16	Total dissolved solids (mg/l)	266.5	45.0 (Sep)	381.5 (Aug)
17	Water depth (m)	1510.2	1492.0 (May)	1525.8 (Nov)

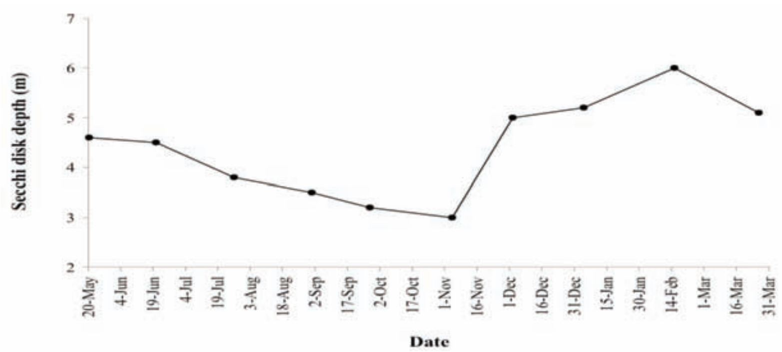

Fig. 3. Mean water transparency (m) in Kulekhani reservoir at different sampling dates during 20 May 2006-26 March 2007.

3.7. Soluble reactive phosphorous

The soluble reactive phosphorous varied seasonally from 0.016 to 0.059 mg/l. It was the highest in December and the lowest in June (Table 1; Fig. 4), showing slightly increasing trend over this period probably due to accumulation of nutrients in the reservoir from rainwater.

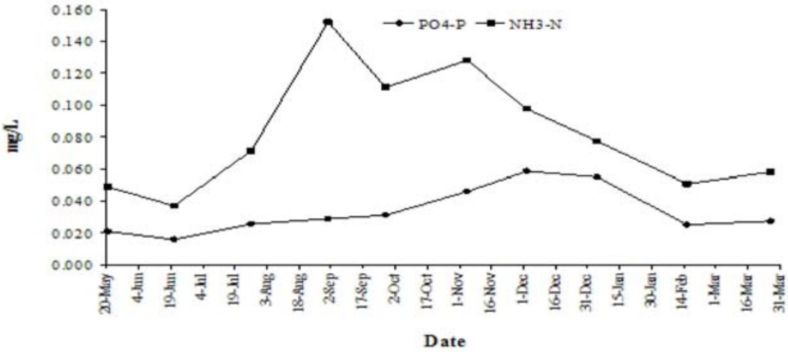

Fig. 4. Mean soluble reactive phosphorous (PO_4-P, mg/l) and total ammonium nitrogen (NH_3-N, mg/l) in Kulekhani reservoir at different sampling dates during 20 May 2006-26 March 2007.

3.8. Total ammonium nitrogen

The total ammonium nitrogen ranged from 0.037 to 0.152 mg/l, showing the highest value in August when dissolved oxygen concentration depleted and the lowest in June when the same increased (Table 1; Fig.4). The total ammonium nitrogen had a cyclic high and low value and the fluctuation did not show clear seasonality.

3.9. Nitrite nitrogen

The nitrite nitrogen concentration changed seasonally from 0.008 to 0.051 mg/l. It was the highest in September and the lowest in May/June (Table 1; Fig. 5).

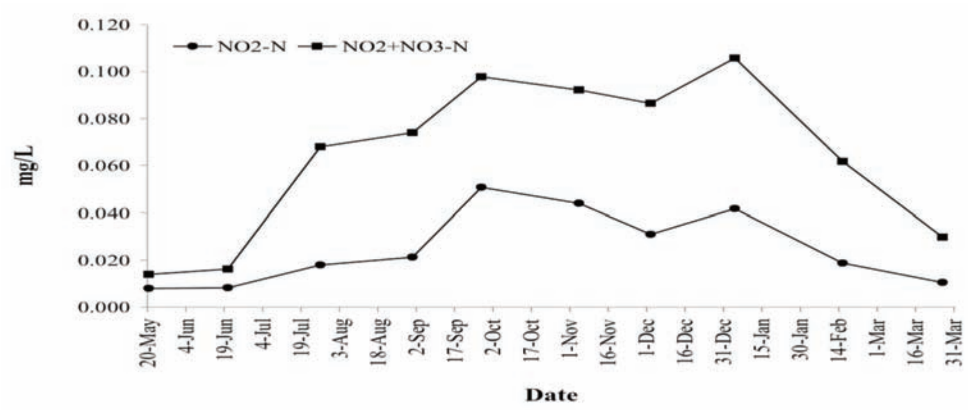

Fig. 5. Mean nitrite nitrogen (NO_2-N, mg/l) and nitrite plus nitrate nitrogen (NO_2+NO_3-N, mg/l) in Kulekhani reservoir at different sampling dates during 20 May 2006-26 March 2007.

3.10. Nitrite-nitrate nitrogen

The nitrite plus nitrate nitrogen concentration changed seasonally from 0.014 to 0.106 mg/L, showing the highest value in January and the lowest in May (Table 1; Fig. 5).

3.11. Total nitrogen

Total nitrogen varied seasonally from 0.561 to 1.331 mg/L, showing the highest value in August and the lowest in May (Table 1; Fig. 6).

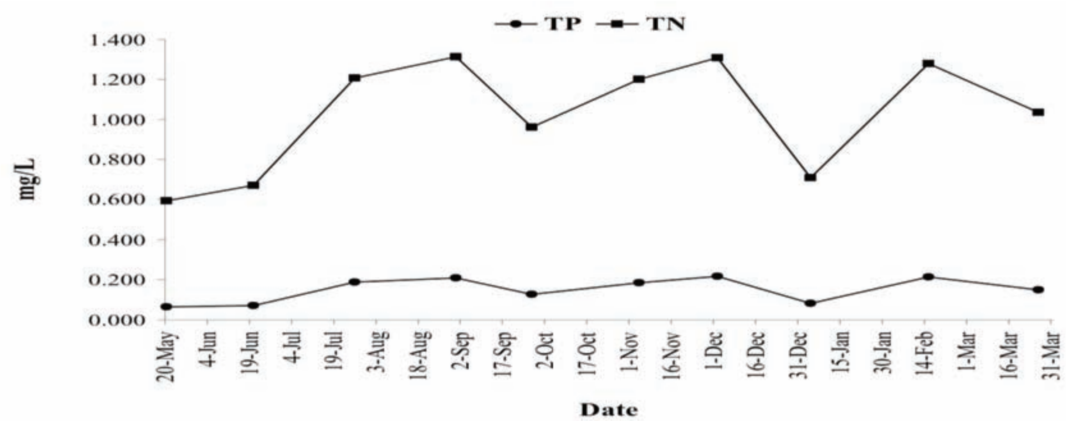

Fig. 6. Mean total phosphorous (TP, mg/l) and total nitrogen (TN, mg/l) in Kulekhani reservoir at different sampling dates during 20 May 2006-26 March 2007.

3.12. Total phosphorous

The total phosphorous varied seasonally from 0.064 to 0.216 mg/l. The highest value was noted in December and the lowest in May (Table 1; Fig. 6).

3.13. Chlorophyll-a

The chlorophyll-a was measured as an indicator of phytoplankton biomass. It varied seasonally from 2.67 to 20.72 mg/m^3, showing the highest value in September and the lowest in May (Table 1).

3.14. Total alkalinity

The total alkalinity varied from 50.1 to 65.2 mg/l $CaCO_3$ (Table 1). The variation did not show clear seasonality. It was the highest in March and the lowest in September.

3.15. Total suspended solids

The total suspended solids ranged from 47.5 to 980.0 mg/l, with the highest value observed in August and the lowest in September (Table 1).

3.16. Total dissolved solids

The total dissolved solids ranged from 45.0 to 318.5 mg/l. The highest was observed in August and the lowest in September (Table 1).

3.17. Water depth

The bottom level and maximum water holding capacity of Kulekhani reservoir is 1450 and 1530 msl, respectively. It fluctuated seasonally from 1492.0 to 1525.8 msl, showing the highest depth in November and the lowest in May (Table 1; Fig. 7). The water level fluctuated frequently due to the use of water in electricity generation; insufficient water sources to maintain the level in the dry season; and high precipitation during the monsoon.

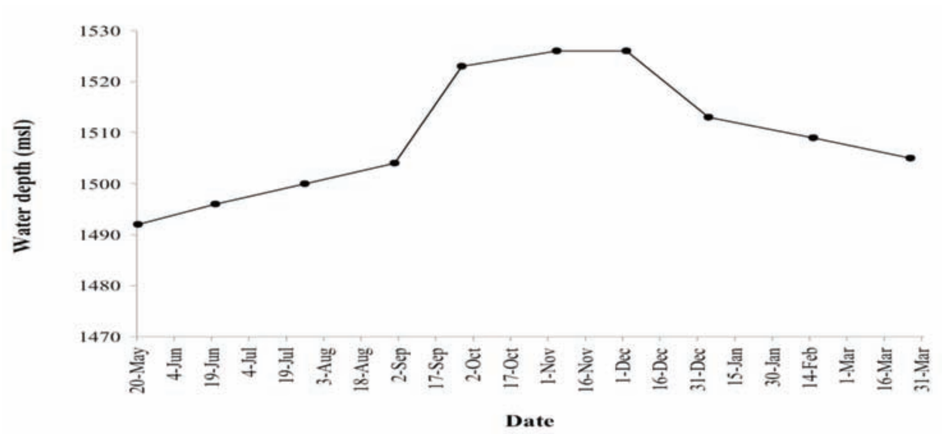

Fig. 7. Mean water depth (msl) in Kulekhani reservoir at different sampling dates during 20 May 2006-26 March 2007.

4. Discussion

Cage fish culture requires good water quality, and hence water properties strongly affect the choice of a water body and aquaculture site. Water quality parameters, such as temperature, dissolved oxygen, pH, and nitrogen and phosphorous compounds, should be within the range that provides life support and growth of cultured species (Lawson, 1995). The water temperature of Kulekhani reservoir varied from 12 to 17 ˚c in winter and from 17 to 25 ˚c in summer, which indicated good prospects of growth of silver carp and bighead carp in summer. The optimum temperature for the growth of rainbow trout is between 13 and 18 ˚c but good growth is attained between 10 and 20 ˚c. At 22 ˚c, severe heat stress begins, which is usually followed by death if exposure is prolonged. These temperature regimes indicated that trout culture in cages can be employed between November and March, as during this period, the reservoir has a suitable condition in terms of water temperature. Oxygen stress is the most frequently encountered water quality problem in cage fish culture. The concentration and availability of dissolved oxygen are critical to the health and survival of caged fish (Masser, 1997). The dissolved oxygen concentration in the present study - which ranged from 5.9 to 11.7 mg/l - fell into the desirable level for the optimum growth of carps and trout. The seasonal change in this experiment showed a similar pattern as measured by Rai (2000) in the same reservoir. Similarly, it was higher than those reported by Rai (1989) and Rai and Mulmi (1992) (3.3-7.7 mg/l). The pH is a measure of the relative acidity of water. The desirable range of pH for fish production is 6.5-9 (Boyd, 1990). The pH obtained in the present study (7.9 to 9.5) fell into the desirable level. Secchi depth provides an estimate of water clarity and is also a measure of productivity. It can be used to differentiate oligotrophic lakes (Secchi disk depth: 5.4-28.3 m) from eutrophic lakes (0.8-7.0 m) (Buyukcapar and Alp, 2006). In this study, the mean Secchi disk depth ranged from 3.0 to 6.0 m, which was far higher than those reported by Rai (1989) and Rai and Mulmi (1992) (1.2-3.4 m). A water body with 41-90 ppm total alkalinity has a medium to high productivity (Bennett, 1970). Similarly, Cole (1975) quotes alkalinities of 51-67 mg/l to indicate a very productive water body. The annual mean alkalinity of Kulekhani reservoir was observed 57.2 mg/l, suggesting that the reservoir can be categorized as productive.

Nitrogen and phosphorous compounds in water provide an estimate of nutrient availability in it and is a measure of productivity. It also provides an estimate of trophic status of water body. In this study, the mean concentration of total ammonium nitrogen, nitrate nitrogen, nitrite nitrogen and total nitrogen were 0.083, 0.040, 0.025 and 1.03 mg/l, respectively. Similarly, the mean concentration of soluble reactive phosphorous and total phosphorous were 0.034 and 0.151 mg/l, respectively. Since phosphorus and nitrogen are well known as a limiting factor to phytoplankton growth, the data obtained was marked in relation to the other nutrients and occurrence of phytoplankton concentration. The concentration of the photosynthetic green pigment chlorophyll-a in water is a proven indicator of the abundance and phytoplankton such as unicellular algae. It is also a commonly used measure of water quality (as a surrogate of nutrient availability). Chlorophyll-a concentration in the present study varied seasonally from 2.67 to 20.72 mg/m^3, with an annual average value of 8.49 mg/m^3. Based on the values of phosphorus, nitrogen, chlorophyll-a, and Secchi disk depth, Kulekhani reservoir still belongs to the category of eutrophic reservoir (Bronmark and Hansson, 1998; Lampert and Sommer, 1997). Filter-feeding fish cultured in cages and feeding only on naturally available food would probably have maximum growth and productivity in eutrophic water, with both adequate water quality and abundannt nutritious food (Bayne et al., 1991). However, increasing volume of cages and number of fish in the reservoir has affected fish growth.

The present study demonstrated that water quality parameters are not the critical factors to the mortality of fish in culture systems in Kulekhani reservoir. The current problem of decreased growth is due to the shortage of natural food, which is associated with the increased volume of cages and number of fish in the reservoir. Thus, an assessment of the carrying capacity needs to be made prior to the start of an extensive cage culture in Kulekhani reservoir.

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Assessment of culture practices and relative economics of African catfish, *Clarias gariepinus* in Chitwan, Nepal

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Abstract

In order to investigate the technical and economic viability of the existing culture systems of African catfish (*Clarias gariepinus*), which are expanding rapidly in recent years, a study was conducted in four Village Development Committees (VDCs) (Dibyanagar, Saradanagar, Mangalpur and Bhandara) and two municipalities (Ratnanargar and Bharatpur) of Chitwan district of Nepal for a period of 150 days (1 July-30 November 2006). A total of 144 catfish growers were grouped into three categories based on their farm size: small (<20 m^2), medium (21-100 m^2) and large (>100 m^2). A sample of 16, 6 and 8 catfish farms was drawn randomly and proportionately from small, medium and large category, respectively, for regular observation and data collection. The results showed that the farm size ranged from 11 to 427 m^2; the pond depth from 0.3 m to 1.5 m; and the stocking size of fingerlings from 4 g to 100 g. The pond depth and stocking size of fingerlings increased with the increase in farm size. However, the stocking density showed a reverse trend. The location did not have any effect on farm size, pond depth, stocking density and stocking size. As regards to the feed, broken eggs with dead embryo constituted the major (43%) part. Among the water quality parameters, the small ponds showed lower pH than the large ones. The transparency was higher in the medium farms, i.e., 18.5 cm and the temperature remained near 30 ˚c throughout the production period. The culture period, survival rate, growth rate, harvesting size and Feed Conversion Ratio (FCR) ranged from 156 to 166 days, 50 to 61%, 2 to 6 g day^{-1}, 254 to 602 g, and 2.5 to 3, respectively. The highest mean yield (16 kg m^{-2} $year^{-1}$) was recorded in the medium farms, followed by the small (14 kg m^{-2} $year^{-1}$) and large (9 kg m^{-2} $year^{-1}$) farms. Similarly, the maximum profit (NRs 455 m^{-2} $year^{-1}$) was recorded in the medium farms, followed by the small (NRs 283 m^{-2} $year^{-1}$) and large farms (281 m^{-2} $year^{-1}$). On the basis of location, the rural farms recorded higher profit (NRs 412 m^{-2} $year^{-1}$) than the urban farms (NRs 250 m^{-2} $year^{-1}$). The marketing channel showed that around 80% of the produce were sold to a single buyer, i.e., Namuna Matsya Farm in Chitwan, @ NRs 80 kg^{-1}, which were further sold to the consumers @ NRs 95 kg-1, with the market margins of NRs 15 kg^{-1}. The profits to Namuna Matsya Farm were NRs 14.5 kg^{-1} and NRs 13 kg^{-1} from the urban and rural ponds, respectively. Thus, the African catfish farming business in Chitwan district of Nepal was found profitable, contributing significantly to the household economy. There is also high potential for commercial farming of this species in the district. However, feed could be the limiting factor for its commercial expansion.

Keywords: Clarias gariepinus; Catfish culture; Chitwan; Catfish feed

1. Introduction

African catfish (*Clarias gariepinus*) is an indigenous species of Africa and is widely distributed throughout the world, mainly in Africa, Thailand, Indonesia, Singapore, Philippines, India, Bangladesh and Sri-Lanka. In recent years, the species has been introduced in Europe, Asia and South-America (Felix and de Graff, 2001).

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Natural habitats of this species are tropical swamps, lakes, rivers and floodplains. The species easily adapts to environments, where the water temperature is higher than 20 ˚c (de Graaf and Johannes, 1996). Biologically, it has all the attributes of a premier aquaculture species. Its ability to breathe by accessory organ; feeding on variety of feed-stuffs; good growth within a short duration; and ability to survive in poorly oxygenated water makes it possible to stock African catfish at a significantly higher density than any other species. These qualities have made it attractive for tropical and subtropical rural aquaculture. African catfish can be commercially grown in highly intensive conditions, where the production may reach several hundred metric tonnes a hactare of pond annually. As it develops the air-breathing organ, transportation of the fish of any age group over a long distance is not difficult. No special equipment is necessary to keep the fish alive in the market (Haylor, 1989). It has been one of the most popularly cultured fresh water catfish in South-east Asia. The growth of this species in ponds is relatively rapid, reaching the weight of 400-500 g in less than six months and providing yields of up to 7-15 t ha^{-1} $year^{-1}$ (FAO, 2003). As an air breather, it can be grown at an extremely high density (100 fish m^{-2}), with standing crop in pond culture reaching as high as 100 tons ha^{-1} (Muir, 1981). Under optimal conditions, cost-effective production in earthen ponds peaked at the level of 40 tones ha^{-1} $year^{-1}$ months and between 45 and 85 kg m^{-3} $year^{-1}$ months under high density tank culture at a feed conversion ratio (FCR) ranging from 0.95 to 1.3. The higher production levels have been obtained at the cost of higher FCR. The critical factors affecting the production are temperature, feed quality and ration (FAO, 2003).

2. Materials and methods

2.1. Time and place of the study

The study area was purposively selected in Dibyanagar, Saradanagr, Mangalpur and Bhandara Village Development Committees (VDCs), and Ratnagar and Bharatpur municipalities of Chitwan (Fig. 1). The reasons for this selection were the concentration of catfish growers in the areas, and the researcher's accessibility and budgetary/time constraints. The study period spanned from 1 July to 30 November 2005.

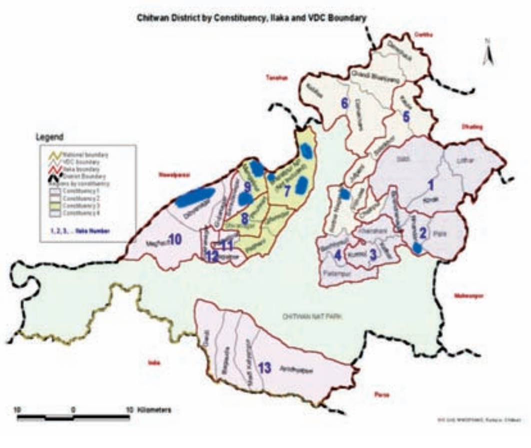

Fig. 1. Map of Chitwan district showing location of research sites

2.2. Selection of catfish farmers

A list of catfish growers was obtained from District Agriculture Development Office (DADO), Chitwan and Namuna Matsya Farm, Bharatpur, Chitwan. It was learnt that a total of 144 farmers having different sizes of ponds were operating both in urban and rural areas.

2.3. Categorization of farm and treatment decision

The catfish growers were categorized in the following three groups, namely small, medium and large, based on their farm size (Table 1).

Table 1
Distribution of catfish growers in Chitwan by farm size

Water surface area	No. of catfish growers
Small (1-20 m^2)	78
Medium (21-100 m^2)	27
Large (101 m^2 and above)	39
Total	144

Out of the 144 catfish growers, 30 were selected proportionately and randomly. Thus, 16, 6 and 8 farmers were included in small, medium and large category, respectively. The selected catfish growers were further classified into two groups, based on the size and location of their farm (Table 2).

Table 2
Distribution of sample catfish growers in Chitwan by farm size and location

Farm location	Farm size			
	Small	Medium	Large	Total
Rural	11	4	4	19
Urban	5	2	4	11
Total	16	6	8	30

2.4. Data collection

Visits were paid to the research site throughout the study period and data on water depth, stocking number, size and weight of fingerlings, culture period, survival rate, harvesting size, yield along with inputs and their respective cost were recorded in a pre- tested interview schedule. The catfish growers were requested to provide information on seed source, frequency, time and method of feeding, fish growth check-up and grading, water replacement, harvesting methods, etc. The inputs used in the calculation of production cost included land rent, pond, fence, electric motor and pumping sets, shallow tube-well, Rickshaw (tri-cycle), cycle, plastic can, buckets, balance, feed, seed, chemicals, wages, salaries, electricity, communication, fuel, transportation and their interests.

2.5. Water quality parameters

Data on water quality parameters such as pH, temperature and transparency were recorded each month during culture period from 8 am to 11 am by using digital pH meter, thermometer, and Secchi disk, respectively. The mean pH values were calculated by converting pH data to H^+ concentration. The mean H^+ concentration was converted to pH.

2.6. Data analysis

2.6.1. Production aspect

The complete harvesting of fish stock from each farm was observed and assessment of culture period, survival rate, harvesting size, growth rate, yield and FCR were calculated by using computer software packages.

2.6.2. Economic aspect

The total annual cost (TAC/m^2) was calculated by multiplying the quantities of inputs (land rent, pond construction, fence, electric motor and pumping sets, shallow tube-well, Rickshaw, cycle, feed, seed, etc) by their respective prices. Similarly, the total annual value product (TAVP) was obtained by multiplying the quantity of fish harvested in different production cycles by their respective prices. The mean profit (B) was derived by deducting the TAC from the TAVP, i.e., B= TAVP- TAC.

The marketing margins (per kg retailer's price - farm gate price) were calculated by deducting all the costs, including losses due to handling at all stages of marketing from the prices paid by the final consumers. The major cost items included were related to transportation and labor.

3. Results and discussion

Most of the catfish farms were started during 2003-2005. Out of the 30 selected farms, 17% were cemented and the rest were earthen ponds. The percentage of cemented tanks in small, medium and large farms were 14%, 20% and 33%, respectively, where bird, snake and frog predation was low as compared to earthen ponds. The mean farm size ranged from 11 to 427 m^2, with the mean water depth of 0.5-0.9 m., which were comparable (except for the small-sized farms) to those reported by (Uys and Hecht, 1985) (200-1000 m^2, with the mean water depth of 0.5 -1.0m). There were two different seed sources - (i) Namuna Matsya Farm and, (ii) dealers from India, supplying 40% and 60% of fingerlings, respectively. The percentage of the small, medium and large farms that purchased seed from the former were 43%, 50% and 25%, respectively, with the rest buying from the dealers. It is very interesting to note that around 75% of the large farmers stocked seed from the dealers, who were having the fingerlings with the average size of 4 g rather than from Numana Matsya Farm, which supplied large-sized fingerlings. The reasons could be their easy availability at home at a nominal price. The stocking density decreased from 59 fish m^{-2} to 17 fish m^{-2} as the farm size increased from 11 m^2 to 427 m^2), with the average of 32 fish m^{-2}. The stocking density ranged from 17 to 59 fish m^{-2}, which was higher than those reported by Rahaman et al., (1992) (2-10 fish m^{-2}) and Hecht et al., (1988) (10 fish m^{-2}).

As the feed, the fish growers mostly used poultry hatchery by- products, namely un-hatched and broken eggs, dead chicks, chicken and offal from slaughter houses, along with rice and wheat bran in nominal quantities, in which discarded eggs accounted for 43% of the total feed. Among the three types of farms, 76% of the fish growers fed twice a day (at 8-9 am and 2-3 pm) and 64% by making moist ball and the rest in an unmanaged form. Sixty percent of the farmers followed spot feeding method and the rest spread the feed over the ponds. The daily weight gain of African catfish in the ponds (2-6 g day^{-1}) was faster than that in outdoor cemented tanks (1.1-1.7 g day^{-1}) (Sethteethunyahan, 1998); an integrated pen-cum pond system (2.5- 2.6 g day^{-1}) (Yi et al., 2003); integrated cage-cum pond system (2.1- 2.2 g day^{-1}) (Lin and Diana, 1995); and in monoculture systems (1.5- 3.9 g day^{-1}) (Rahaman et al., 1992). The reasons could be the high quality protein-based feed (90%) and stocking of large-sized fingerlings (100 g). The survival rate of African catfish in this study (50-61%) was lower than those reported by Uddomkarn (1989), Sethteethunynhan (1998) and Ye (1991) (94-100%). This was probably due to the large variation in the stocking size (2-100 g) and cannibalism among the fish. The results showed that the percentage of removing uneaten feed from the feeding spots and exchanging water in frequent intervals were almost the same, i.e., 33%. As a result, chicken offal, egg paste and dead birds were observed in rotten forms in the water surface, making the water quality poor with 13 cm Secchi-disc visibility in most of the intensive feeding farms. The temperature during the culture period ranged from 29 ˚c to 30.4 ˚c, which was almost similar to the one (30 ˚c) reported by Rahman et al. (1992).

The net fish yield in this study (9, 14 and 16 kg m^{-2} $year^{-1}$ in large, small and medium farms, respectively) was lower than that reported by Rai and Lin (1999) (14.3-28.7 kg m^{-3}) in cages. The reasons could be the irregular, under as well as over feeding in poor water quality (huge deposition of uneaten and fecal materials on pond bottom), less fish grading practice (40%), fish diseases (26%), fish escaping in flood, cannibalism, and predation by birds, snakes and frogs. The FCR was the highest in the large farms, followed by the medium farms, which was poorer than the pellet feed reported elsewhere in the above integrated systems, i.e., Sethteethunynhan (1998) (1.2), Ye (1991) (1.5-1.7), Lin and Diana (1995) (1.9-2.2) and Yi et al. (2003) (1.3) but was comparable with those reported by Uddomakarn (1989) (2.8) and Mishra (2002) (2.8- 3.2).

The maximum mean profit of the medium farms (NRs 455 m^{-2} $year^{-1}$) was higher than that of intensive carp farming reported by Singh and Yadav (1996) (NRs 9 m^{-2} $year^{-1}$). The reasons could be the high fish yield (16 kg m^{-2} $year^{-1}$), which was supported by the short culture period (156 days giving 2-3 production cycles a year). The rural- based farms were more profitable than the urban-based ones, (NRs 412 vs 250 m^{-2} $year^{-1}$). The reasons could be the easier and more adequate availability of feedstuffs, cheaper labor and lower water management cost.

With regard to marketing, around 80% of the total fish produced in rural and urban farms were sold to Namuna Matsya Farm @ NRs 80 kg^{-1}, which were further sold to wholesalers in Narayangadh, Pokhara and Katmandu @ NRs 95 kg^{-1}, with NRs 15 kg^{-1} market margins. The profit to Namuna Matsya Farm from this business was NRs 13 and 14.5 kg^{-1} fish from rural and urban areas, respectively.

4. Summary of findings and conclusions

The study was carried out to identify the existing culture systems of African catfish (*Clarias gariepinus*) and its economic viability, under farmer-managed systems in Chitwan district, Nepal. The findings are summarized as follows:

- Most of the catfish farms were started during 2003-2005. The pond size ranged from 3 m^2 to 840 m^2, with the water depth of 0.3-1.5 m. The majority of the farms had single pond.
- The fish seed were supplied by two private parties, namely Namuna Matsya Farm in Chitwan and Indian dealers in the percentage of 40 and 60, respectively.
- The stocking density ranged from 5 fish m^{-2} to 208 fish m^{-2}, which decreased (from 58 fish m^{-2} to 17 fish m^{-2}) as the farm size increased (from 11 m^2 to 427 m^2).
- The stocking size of fingerlings ranged from 2 g to 100 g.
- The small ponds showed lower water pH (6.5) than the large ones (8.2). The other water quality parameters such as temperature and transparency during the culture period ranged from 26.6 ˚c to 32.1 ˚c and from 8 cm to 25 cm, respectively. Similarly, the color of the pond water was almost black in all the three categories of farms.
- Where an intensive feeding was in practice with limited exchange of water, a huge amount of organic load was found in the ponds in the form of unused feed and excreta, making the water color almost black. The feed used included chicken offal, broken, un-hatched and un-fertilized eggs, dead chicks and chicken, rice and wheat bran, maize flour, frogs, earthworms, small fish and brewery wastage. The main feed was broken eggs, which constituted 43% of the total.
- The culture period ranged from 60 days to 260 days, the mean being 166 days, 155 days and 158 days for small, medium and large farms, respectively.
- The survival rate of fish ranged from 16% to 93%, showing a great variation the mean being 52%. The highest survival rate was observed in the medium-sized farms, i.e., 56%.
- The harvesting size ranged from 75g to 1737 g, with the fish growth rate of 0.3 g day^{-1} and 9.8 g day^{-1} in the small and large farms, respectively.
- The annual yield ranged from 1 kg m^{-2} to 35 kg m^{-2} from one to three production cycles. The average yield was the highest in the medium farms (16 kg m^{-2} $year^{-1}$), followed by the small (14 kg m^{-2} $year^{-1}$) and large farms (9 kg m^{-2} $year^{-1}$), with the average FCR of 1:1.8.
- The average profit ranged from NRs 26 m^{-2} $year^{-1}$ to NRs 1,626 m^{-2} $year^{-1}$. It was observed the highest in the medium-sized farms (medium: NRs 455 m^{-2} $year^{-1}$; small: NRs 283 m^{-2} $year^{-1}$; and large: NRs 281 m^{-2} $year^{-1}$).
- The price of fish ranged from NRs 80 kg^{-1} to NRs 120 kg^{-1}, with 90% of the consumers paying NRs 95 kg^{-1}.
- The market margins were recorded higher in all the three urban- based farms (NRs 14.5 kg^{-1}) than the medium and large rural-based farms. It was almost the nil in the small rural-based farms.
- Around 80% of the total fish produced were purchased by a single buyer, 10% by retailers and the rest were consumed by the growers themselves. From the above findings, it can be concluded that the African catfish farming business in Chitwan, Nepal is profitable, making significant contribution to the household economy.

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Cage fish culture and capture fishery as dominant livelihood sources for fisher community in Pokhara Valley, Nepal: A socio-economic update

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Abstract

This paper aims to analyze socio-economic impacts of subsistence cage fish culture and small-scale capture fishery on a traditional fisher community - known as Pode or Jalari - living around Phewa (443 ha) and Begnas (328 ha) lakes in Pokhara valley, Nepal. The community adopted cage fish culture about three decades ago as an alternative source of its livelihood as the capture fishery was on the decline due to over fishing. There are about 134 households depending entirely on cage fish culture and recapture (catch of stocked fish) fishery in these lakes. At present (in 2007), about 720 cages, which are equivalent to about 30,000 m^3, are being used for producing about 122.4 mt of fish. Besides, the fisher households also share 58.8 mt from recapture fishery on an annual basis.

Economic analysis of cage fish culture in the lakes shows that the net return to total investment is 254.3% and the average annual net profit generated is NRs 77,082 (50.1% of income) and NRs 41,625 (31.9% of income) for a fisher household with an average cage holding of 250 m^3 in Phewa lake and of 135 m^3 in Begnas lake, respectively. Cage aquaculture and recapture fishery cumulatively share over 75% of the total annual income of the fisher households. With the adoption of cage aquaculture and recapture fisheries, the living standard as indicated by access to a variety of social amenities and community services has improved considerably over the past three decades. Improvement in the quality of life of the Jalari community is also evidenced by the low value (<30%) of Engel's coefficient, which is the ratio of expenditure on food to the total expenditure. In spite of this, the average income conceals the poverty of 30% of the fisher households. In order to improve the socio-economic conditions of these bottom households, subsidies on inputs used (fish seed and cage material) might be the only choice available in the short run. A comprehensive policy should be enacted to include entry regulation, upgrading fishing and cage culture operations, and development of additional employment opportunities.

Keywords: Cage fish culture; Capture fishery; Recapture fishery, Living standard; Socio-economic condition

1. Introduction

Of more than 20 million Nepalese currently living in rural areas, over 2.8 million depend on aquatic and fisheries resources to support their livelihood (CBS, 2006; IUCN Nepal, 2004). Most are subsistent, relying on one crop of cereal, indigenous fish and other aquatic resources, and a range of forest products. However, with a few exceptions, these most marginalized people are not financially able to sustain their families through their traditional occupations (Gurung and Bista, 2003).

A fragile fisher community - known as Pode or Jalari - living around the lakes in Pokhara valley are among such ethnic groups whose livelihood was entirely dependent on fishing in these water bodies. The Jalari community was traditionally deprived of agricultural lands, skills, jobs and income. Till 30-35 years back, most of its members had a nomadic life traveling from one lake, river and wetland area to another carrying a cast net for fishing to feed their families. In the early 1960s when fish catch declined in the lakes due to over fishing, the only source of Jalaris' livelihood was threatened. Hence, in 1972, a livelihood support program for the rehabilitation of this deprived community through subsistence cage aquaculture and small-scale capture fishery was initiated. In the beginning, only single 50-m^3 of cage was given to Jalaris in Phewa lake (Gurung et al., 2005). Since then, cage aquaculture grew at a steady rate and at present (in 2008), 30,000 m^3 of cages have landed in Phewa and Begnas lakes, producing 122.4 mt of fish and supporting the livelihood of 134 fisher households. Theese households have also been able to get 58.8 mt of yields from stocking and recapturing of fish in these lakes on an annual basis.

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2. Sites and methodology

Phewa lake is situated in the southwestern part of Kaski district (Fig.1) at 8.1° N and 82.5º E, and at 742 m above the mean sea level. The watershed area of the lake extends approximately 110 km^2 (Ferro and Swar, 1978), with the geometrical length of 17 km and width of 7 km. The total surface area of the lake is about 523 ha as reported in Rai (1998). However, Lamichhane (2000) has estimated the water surface area of only 443 ha, with the maximum depth of 23 m. Begnas (650 msl) is the second biggest lake fed by a perennial stream - Syankhudi Khola - with the catchment area of 10 km^2. The outlet of Begnas Lake - Khudi Khola - was blocked by a dam in 1988. The damming has increased the area of the lake from 224 ha to 328 ha. Its average depth has thus increased from 4.6 m to 6.6 m.

There are approximately 200 Jalari households in Pokhara (Nepal, 2008) and about 97 and 37 are living around Phewa and Begnas lakes, respectively. They are entirely dependent on the lake resources for their livelihood, and subsistence cage fish culture and small-scale capture fishery are their predominant livelihood activities since the 1970s. A socio-economic survey of these Jalari households was carried out in late 2006 and the site was re-visited in early 2008 to assess the impact of cage fish culture and capture fishery on their well-being. In 2006, 58 and 22 households from Phewa and Begnas lakes, respectively were interviewed to establish basic parameters such as household size, employment, asset/income and expenditure. These data were collected later again in 2008 as the productivity of fishery activities in these lakes varied which influenced the income of Jalaris (Wagle et al., 2007). Relevant secondary information was also gathered from Fisheries Research Center Pokhara, and respective fishers association of these lakes.

Fig. 1. Map of Nepal showing location of Pokhara valley.

3. Participatory cage fish culture and fishery management

Earlier mainly cast nets were employed for targeting indigenous fish species. The most common craft used was dug-out canoe. With the introduction of gill nets around the late 1960s, fish catches increased initially but began to decline after two years due to over exploitation. It became even harder for the fishermen to sustain their livelihood than it was before the introduction of gill nets. As a result of lack of appreciable management, the lakes were over- fished and environmentally degraded, threatening the biodiversity and livelihood of the traditional fishing community (Bhandari, 1992). There were quite a number of problems that the community could not solve on its own. These included: continuous resource depletion; persistent absolute and relative poverty; and space and resource conflicts. In order to cope with these problems, Government of Nepal initiated a livelihood support program in 1972 for the rehabilitation of this deprived community through subsistence cage aquaculture and small-scale capture fishery.

In order to organize nomadic Jalaris in a forum where issues on participatory fishery management could be discussed, lake-specific fishers associations known as Phewa Fish Entrepreneurs Committee (PFEC) and Begnas Fish Entrepreneurs Committee (BFEC) were established in 1990. Participatory approach to fisheries management refers to a customer-focused program where the targeted group participates in the entire process of learning about the situation, identifying problems, discussing alternatives, finding solutions, designing, implementing and evaluating activities, and disseminating results (Gurung et al., 2005). In line with participatory natural resource management, the PFEC and BFEC formulated code of conduct for gill net operation, cage fish culture in the lakes, marketing and loan repayment. The major strategies adopted were community mobilization for resource management and conservation, and fish stock enhancement through outsourcing.

4. Technical and economic background of cage fish culture and capture fishery

4.1. Cage fish culture

Cage fish culture in Nepal was first started in lakes in Pokhara in 1972 (Swar and Pradhan, 1992). It was targeted for poor people who could not afford large production input. It is an extensive type, where the caged fish rely on naturally available plankton and no external feed are supplied. Culture of plankton feeder fish in nylon or polyethylene knotless floating cages of approximately 5 m x 5 m x 2 m is a popular method of fish production in the lakes (Swar and Pradhan, 1992; Gurung, 2001). Cages with small mesh size (<25 mm) are preferred for rearing fingerlings, while cages with large mesh size (>35 to 50 mm) are stocked with >25 g fish (10 fish/m^3). Mainly two species of carps are famous for cage culture in the lakes: Bighead carp (*Aristichthys nobilis*) and Silver carp (*Hypophthalmichthys molitrix*). Fish are grown up to 500-1000 g before they are harvested. To grow from 5 g to market size of 500- 1000 g, it may take 12-18 months, depending on the trophic status of the water body.

The productivity of cages largely depends on the nutrient and plankton status of the lakes. Estimations made at different times have revealed that the productivity sometimes has reached 5 kg/m^3 and 4.7 kg/m^3 for Phewa and Begnas lakes, respectively (Gurung et al., 2005). However, the former has the average productivityof 4.3 kg/m^3/year, while the same for the latter is 3.0 kg/m^3/year (in 2008). The total number of cages in the two lakes is 720 (30,000 m^3) and estimated annual production is about 122.4 mt (in 2008) (Table 1).

Table 1
Present status of private sector cage fish culture in Phewa and Begnas lakes (2008)

Name of water body	No. of fisher households	No. of cages	Cage volume (m^3)	Annual production (mt.)
Phewa lake	97	600	24,000	103.2
Begnas lake	37	120	6,000	19.2
Total	134	720	30,000	122.4

The economics of extensive cage aquaculture in Phewa and Begnas lakes, where the stocked fish feed on only natural food, showed that the average net return to total investment was 254.3%. The average net profit generated was NRs 77,082 (50.1% of income) and NRs 41,625 (31.9% of income) for fisher households with an average cage holding of 250 m^3 in Phewa lake and 135 m^3 in Begnas lake, respectively. In a cost and benefit analysis, Swar and Pradhan (1992) showed that the net return of a five-cage system (250 m^3) would be feasible to sustain a fisher family. The present study has revealed that cage culture of carps in Phewa and Begnas lakes is still lucrative, having the net benefit of NRs 308.3/m^3 with promising prospects of further development (Table 2).

4.2. Open water capture fishery

Open water capture fishery was developed in Phewa and Begnas lakes with the introduction of gill net in the 1960s to support the livelihood of the wetland dependent Jalari community (Rajbanshi et al., 1984; Swar and Gurung, 1988). Fish catch increased initially but began to decline due to over exploitation of the native fish resources. In order to enhance the lake productivity, a restocking program was initiated in the 1980s with a number of exotic and native species. Exotic species such as silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*) and common carp (*Cyprinus carpio*), and native species like rohu (*Labeo rohita*), naini (*Cirrhinus mrigala*) and bhakur (*Catla catla*) - which do not recruit themselves - were stocked. The self-recruiting native species that formed the basis of the lake fishery were *Puntius spp*, *Cirrhina rewa* and *Barilius spp* (Gurung et al., 2005).

Table 2
Average cost, revenue and return (NRs) of cage fish culture in Phewa and Begnas lakes (2006)*

Cost and return	Cage/m^3	Caged fish/kg
Variable cost (fingerlings, hired labor, maintenance and interest on operating capital)	31.04	8.65
Fixed cost (depreciation of cage frame, net material, boat and facilities, and interest on debt)	46.09	12.80
Opportunity cost (family labor and interest on fixed capital)	54.54	15.15
Total cost	131.67	36.60
Gross revenue (fish sales)	440	110
Return		
Operating profit	408.96	102.24
Net income	362.87	86.40
Net profit (g)	308.33	73.40
Rate of return to capital investment (%)	434.10	
Rate of return to total investment (%)	254.29	
Ratio of net profit to variable cost	993.33	
Ratio of net profit to gross revenue	70.08	

* Cost and revenue figures are average of 40 production cages.

The total production from capture fishery is 38.8 mt and 19.3 mt, contributing 400 kg and 521 kg of fish per household in Phewa and Begnas lakes, respectively (in 2007). However, variation in annual catch is common, which corresponds to variation in the share of catch per household (Fig. 2A and 2B).

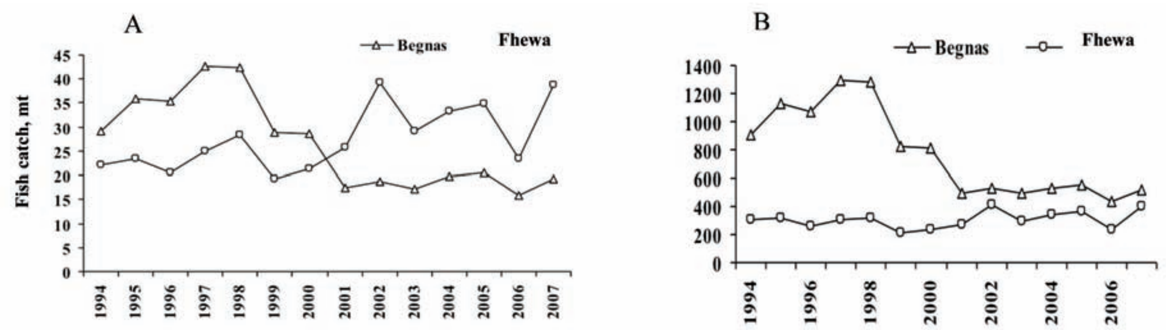

Fig. 2A. Annual yield from capture fisheries in Phewa and Begnas lakes (1993-2007) and B. Corresponding average yield per household.

Successful exploitation of a capture fishery depends not only on the quantity of fish caught, but also on the stability of fish supply (Silvert, 1982; Buijse et al., 1994). Its variable yield has direct consequences on the economic status of the fisher households, i.e., increased catches stimulate investments which, in turn, lead to increased fishing efforts. Therefore, fisher community of Phewa and Begnas lakes has commenced a conservation program to restore native species to their original state so that sustainable yield could be achieved. Participatory stock enhancement of high-value indigenous fish over traditional random stocking pattern of exotic ones has recently been initiated and regularized through mobilization and capacity building of users group and market strengthening for a long-term sustainable use of the lake resources.

4. Socio-demographic profile

The total population of Jalaris is 503 (97 Households) and 222 (37 Households) (Table 3), with a gender ratio of 0.96:1 and 0.83:1 (female:male) (based on Table 3) in Phewa and Begnas lakes, respectively. The household size in the former (6) is higher than that in the latter (5.2). Although over 54% of the fishermen have received some formal or informal education, the level attained is low, with most of them being only literate. It is highest among the young population in Begnas lake, where 12.6% have attained school- and university-level education.

Corresponding to the household size, households in Begnas lake have larger percentage of working members (78.3%) as well as higher gender ratio (male:female - 1:0.86) of the same (Table 4). The observed considerable differences in the percentage of working women in the two locations might be attributed to the availability of employment opportunities in family/neighbor-owned restaurants that are suitable for women in Begnas Lake.

Table 3
Number of households, population and education status of the fisher community in Phewa and Begnas lakes (2006)

Description	Phewa lake			Begnas lake		
	Male	Female	Total	Male	Female	Total
No. of Household			97			37
Population	256	247	503	121	101	222
Household size	2.7	2.5	5.2	3.3	2.7	6
Education (%)						
Illiterate	40.6	54.6	47.5	38.2	55.4	46.0
Literate	51.5	40.5	46.1	47.0	34.6	41.4
High school attendant	5.8	3.3	4.5	11.5	10.0	10.8
University attendant	2.1	1.6	1.9	3.3	0.0	1.8

The fishermen in Phewa lake have more production assets and the year of experience in the fishery business compared to their counterparts in Begnas lake (Table 5). More than 90% of the households in both the locations own fishing boats. However, a large variation exists in gill net - the dominant gear for fishing - holding (2-50 gill net per household). The fisher households in Phewa lake possess larger volume and number of production cages (250 m^3 and 5.3) compared to those in Begnas lake (135 m^3 and 2.7). The differences in the possession of the production assets among the households in the two locations have been well reflected in their income levels.

Table 4
Socio-demographic profile of the fisher community in Phewa and Begnas lakes (2006)

Description	Phewa lake	Begnas lake
Household size 1-2	7.9	10.8
3-5	50.0	54.4
6-8	26.3	24.3
9 and above	15.8	8.1
Average household size	5.2	6.0
Average No. of working member/household	3.9	4.7
Percentage of working member/household	74.3	78.3
Gender ratio of working member (male:female)	1:0.81	1:0.86

Most of the households are involved in more than one profession. Yet, all of them have adopted fishing - either capture fishery or cage aquaculture. About 83% of the total household heads in Phewa lake are involved in capture fishery, whereas 76% of them are involved in cage aquaculture (Table 6). Capture fishery (92%) and cage fish culture (86%) are even more dominant means of livelihood in Begnas lake. Among the other sources of livelihood of the fisher households in the lakes, agriculture and livestock; small businesses; and wage employment are remarkable. Similar trend of high involvement of economically active household members other than the heads in fish-related job is evident in the two locations. The young Jalaris in Begnas lake are tending to diversify their livelihood as indicated by their increased participation (25.3%) in small businesses.

Table 5
Production assets of the fisher community in Phewa and Begnas lakes (2006)

Assets/household	Phewa lake	Begnas lake
Experience in fishery and cage fish farming (years)	15.2	11.6
Boat (No./household)	0.96	0.92
Gillnet (No/household) (322 m^2 each)	18 (2-50)	17 (5-35)
Cages		
Nursery cage (No./household) (23 m^3 each)	2.5 (1-8)	1.6 (1-4)
Production cage (No./household) (50 m^3 each)	5.3 (1-16)	2.7 (1-8)

Figures in the parentheses are range.

Table 6
Distribution of heads and members of the fisher households in Phewa and Begnas lakes by occupation (2006)

	Phewa lake		Begnas lake	
	Head	Member*	Head	Member*
Fish- related job				
Cage fish culture	76.7	48.4	86	32.3
Capture fishery	83.6	44.6	92	49.7
Pond fish culture	5.3	2.6	5.4	2.2
Non-fishing job				
Agriculture (including livestock)	32.7	26.2	16.3	10.1
Wage employment (public, private and foreign)	28.6	24.3	21.4	18.7
Small business (hotel, resturent, shop and tourism)	9.5	5.4	13.5	25.3
Others (driving and boat operation)	4.8	4.0	5.4	3.6

* Percentage of economically active household members

6. Income

Income is one of the major indicators of socio-economic status. For the Jalari community, more than 75% of its income comes from cage fish culture and capture fishery, and the remaining from such sources as agriculture, wage employment (domestic and foreign), small businesses and others (driving, renting out boat, etc) (Fig. 3). The mean annual income is NRs 153,850.4 with CV 77% and NRs 130,623.2 with CV 63% in Phewa and Begnas lakes, respectively. This large variation in income is due to the heterogeneity in the additional occupations of the populations. In the total income, the contribution of fish-related jobs - which involve capture fishery, cage aquaculture and marketing of fish - 78.7% and 75.8% in Phewa and Begnas lakes, respectively. The contribution of cage fish culture (50.1%) to the total annual income of Jalaris in Phewa lake has increased remarkably in 2007 compared to 2005 (27.3%) (Wagle et al., 2007).

7. Expenditure

Expenditure represents the magnitude of household consumption which depends upon income. The mean annual expenditure of the Jalari community is NRs 88,655 and NRs75,468 with CV 102% and 76% in Phewa and Begnas lakes, respectively. Among the consumption items, food stands first accounting for more than 40% of the total annual expenditure (Fig. 4). The second largest expenditure belongs to household amenities in both Phewa (16.7%) and Begnas lakes (13.6). A significant amount is spent on education and clothing, which comprise more than one-tenth of the total expenditure each.

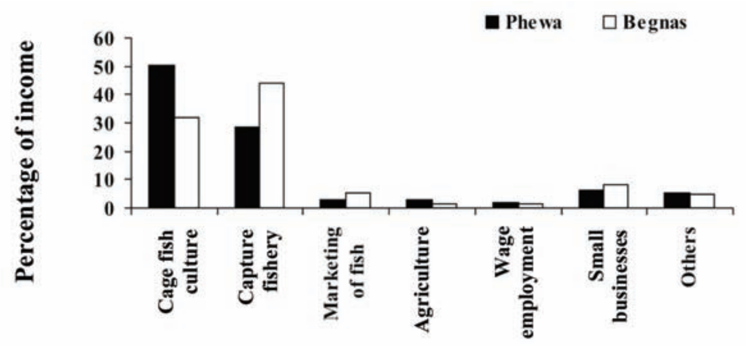

Fig. 3. Sources of annual income of the fisher community in Phewa and Begnas lakes (2007).

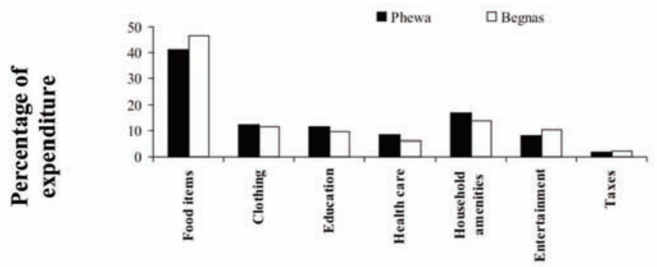

Fig. 4. Annual expenditure categories of the fisher community in Phewa and Begnas lakes (2007).

8. Livelihood outcomes

The living standard of the Jalari community in Phewa and Begnas lakes as indicated by the availability of social services and consumer durables are given in Table 7. Cage aquaculture and recapture fishery have shared over 75% of its total annual income. However, the average income has concealed the poverty of 30% of the fisher households. The standard of living of a household depends largely on its disposable income relative to its size as well as on the availability of public services and social amenities. The disposable income of a fisher household is the sum of its incomes from capture fisheries, cage fish culture and non-fishing actvities excluding the taxes. The disposable income of a Jalari household is not very different from its total income as the taxes are insignificant, which have ranged between NRs 1,660 in Begnas lake and NRs 1684 in Phewa lake. The tax at the rate of NRs 2.0 per kg of caged fish is paid to the respective fishers associations and at NRs 1.0 per kg of recaptured fish from open water to District Development Committee (DDC).

Alternative or rather supplementary to indicators of standard of living are the ownership of consumer durables and the private consumption expenditure. The preliminary results of this socio- economic study have revealed that with the adoption of cage aquaculture and recapture fishery under the community-based fisheries management structure, the living standard of the Jalari community as indicated by access to a variety of social amenities and community services has improved considerably over the past three decades. With the adoption of fisheries and allied businesses since the 1980s, most of the households (81.3%) in Phewa lake now own housing land, while 44.4% of the households in Begnas lake possess the same. A remarkable change in housing facilities has also been observed in Begnas lake, i.e., most of the thatched houses have been converted into either concrete or tin-roofed ones.

Table 7
Living standard of the fisher community in Phewa and Begnas lakes (2008)

Indicators	Phewa lake	Begnas lake
Income and savings		
Annual income (NRs)/household	153850.4	130623.2
Annual expenditure (NRs)/household	88655.0	75468.0
Savings (NRs)/household	65195.4	55155.2
Engle's coefficients (savings included in expenditure) (%)	23.6	29.2
Indicators of living standard (% household)		
Housing land	81.3	44.4
Concrete and tin-roofed houses	100.0	95.0
Access to potable water	100.0	93.2
Access to public health services	97.6	93.2
Use of water sealed toilets	21.8	10.1
Energy use (LPG gas and electricity)	94.6	53.8
Use of mass media (radios, televisions and newspapers)	83.2	75.3
Use of own automobiles	10.2	7.7

In 1980, water for more than 90% of the households was supplied from springs, lakes or other similar sources (Wagle et al., 2007). At present, over 90% of the households in both the locations have access to piped water (community water supply). Similarly, for cooking and lighting facilities too, most of the households earlier (in 1980) used fuel wood and kerosene (Wagle et al., 2007). A significant departure in terms of energy use (LPG and electricity) is evident in Phewa lake. The fisher community in Begnas lake, on the other hand, still relies on fuel wood for cooking because of its availability at low cost from the nearby community forest. Most of the households in both Phewa and Begnas lakes have access to mass media (radio, television, etc) and few also possess motorbikes.

With the increased income and improved livelihood, the fisher community has been able to send their children to schools. The level of formal education (literacy-compulsory first five grades) has increased to 46% and 41% in 2008 from 17% and 21% in 1980 (Wagle et al., 2007) in Phewa and Begnas lakes, respectively. In both the locations, some have attained education beyond high school and a few have even attended university.

Expenditure on food as a percentage of total household expenditure is another important indicator of standard of living. The poorer the family or the nation, the larger is the percentage of expenditure that goes to food - at the limit, a very low income may be spent entirely for the other biological needs. As income rises, the proportion of expenditure that goes to other less mandatory items such as clothing, transport, and education increases. According to Table 7, improvement in the quality of life of the Jalari community is also evidenced by the low value (<30%) of Engel's coefficient, with the Begnas fisher households the highest at 29.2% and the Phewa fisher households the lowest at 23.6%. Expenditure on food for the fisher households in Begnas and Phewa lakes is about equal, despite the considerable difference in the total expenditure and even greater difference in the income between the two.

9. Conclusions and recommendations

In order to understand the socio-economic conditions of the fisher community of Phewa and Begnas lakes, household income and expenditure levels and possession of facilities were analyzed. The income level and other indicators of well-being differ between the two locations. This could be due to the differences in the size of the production assets, quantity of fish caught and production from cage aquaculture. Another factor analyzed was the capability to be engaged in other occupations that, in turn, affects the wage rates. Although the fisher households in both the locations have the same level of educational attainment, those in Begnas lake are more skillful in operating non-fishing small businesses. However, the employment characteristics indicate low level of utilization of family labor in fishery and non-fishery occupations, and hence the presence of surplus labor in both the locations. To enhance income and living standard of the fisher community, measures to relocate some of the surplus labor should be investigated.

With the adoption of cage fish culture and capture fisheries, the income level and other indicators of well-being for the fisher community in Phewa and Begnas lakes have risen. However, the annual income is irregular due to the differences in catches and changes in the lake productivity. In the present context, the high level of profitability enjoyed by them need to be transfered into a meaningful and realistic savings scheme. There should be a policy to educate them about the further economic benefits that can be obtained in the long run. The lakes are the main attractions for foreign as well as domestic tourists in the country. Hence, policy of directing part of their savings into an appropriate area of the tourism industry should be implemented since in their villages, there is little opportunity for investment in sectors other than fisheries.

Unregulated entry due to the open access nature of the lake fishery resources will lead to overexploitation of such resources. The fisher households in Phewa and Begnas lakes lack incentives in the form of property rights to invest further in these resources. International experience strongly indicates that community-based management is unlikely to take off unless the communities have rights over the defined fisheries. Since the DDC charges tax on captured fish, long-term informal property rights to fishing and aquaculture area of the lakes should be awarded to the fisher community.

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Prospects of groundwater usage for inland aquaculture

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Abstract

Groundwater (GW) drafted in a huge quantity for irrigation has the potentiality to support aquaculture if dead storage of a meter is created in existing storage/transit ponds. In the state of Karnataka, India, tube/borewell water storage ponds (BWWSPs) - though exist in substantial numbers; are manageable by individual farmers; and have cumulative water spread area of few thousands of hectares - are underutilized by the sector. Prospects of BWWSPs for aquaculture was assessed by collecting documented information on the quantity and quality of GW, and number of BWs, and conducting survey on the number, nature and utilization of BWWSPs in selected Kolar and Bangalore Rural districts in Karnataka. Their potentiality for the state was extrapolated to prove that GW is qualified to be classified as a new inland fisheries resource and the term "Groundwater aquaculture" is coined.

Keywords: Groundwater aquaculture; Tube/borewell water storage ponds; Karnataka

1. Introduction

Groundwater (GW) resources do not figure in the classification of inland fisheries resources that normally include rivers, reservoirs, tanks and brackish water. Over the last few decades agriculture, but not inland aquaculture, has benefited largely by use of GW in India. GW was utilized for agriculture/horticulture so fast that it is now required to think of recharging GW artificially while it was under- utilized by fisheries sector, which is still aiming at structures viz., tanks, ponds, etc, meant for storage and recharging of GW. This study was undertaken with an idea that creation of a dead storage of about one meter in existing GW storage/transit ponds enables aquaculture with least investment.

India is the second wettest country in the world (1170 v/s world av. 870 mm). Its Gross Irrigation Potential of GW in 1950-1951 was only six million ha (mha) compared to 16 mha of Total Surface Water Systems. However, by 1990-1991, percent of Net Irrigated Area by Wells was 51, as compared to 42, by Canals (35.63) and Tanks (6.84) put together, with average GW development for the country being 45.54%. Irrigated areas contribute to 56% of agricultural production and 60% of food grains production (GoI, 1999: 476-7).

Though it is wise to adopt drip/sprinkler irrigation, power shortage in rural areas necessitates making of borewell water storage ponds (BWWSP) that are fully/partially earthen/stone pitched, at elevated place in farm (Fig. 1 and Fig. 2). GW is pumped into these ponds whenever there is power and drained through bottom outlets, sometimes resulting in complete drainage of pond. These ponds forms a unique man made ecosystem with GW being replenished based purely on irrigation needs. While borewell (BW) taps hard rock, tubewell taps sedimentary / alluvium for GW. However, as BW was the mainstay in the study locale, the term borewell (BW) is used here.

Fig. 1. Earthen bore well water storage pond

Fig. 2. Bore well water storage pond inlaid with stone blocks

Making use of this drafted GW for aquaculture is of course a daunting task, due to scattered presence and small area of BWWSP. Nevertheless, it also has advantages of rural small-scale aquaculture vis a vis higher productivity, integrated farming, improving nutritional and economic security of farmers.

2. Materials and methods

Documented information on BW / BWWSP was collected from 12 different government organizations of Karnataka State (Table 1). Presence of more number of BWWSP was the major rationale for selection of locale. The first three districts of Karnataka with more number of BW were: Kolar (72094), Tumkur (68272) and Bangalore Rural (57648) (DoES, 2006), coming coincidentally under the Agro- Climatic Zone-5 viz., South Eastern Dry Zone which includes five districts. Kolar and Bangalore Rural districts were selected for the study, as `Stage of GW development' were 195% and 171% respectively, compared to 110% of Tumkur district (DoMG and CGWB, 2005). Studies were conducted in the Taluks of Kolar and Nelamangala in the respective districts of Kolar and Bangalore Rural.

To estimate the aquaculture prospects of BWWSP viz, their number, dimensions, survey on 'Numbers, nature and utilization of BWWSP' was conducted in the two selected taluks, covering 10% of the villages (Kolar: 37/361 and Nelamangala: 25/243).

Table 1
List of Organizations in Karnataka State, India contacted for Information on Groundwater/ Borewell water storage ponds.

Sl. No.	Organization and it's Head	Address of the Organization
1	The Director Department of Fisheries	Visweswaraiah Towers, Bangalore - 560 01. Karnataka, India
2	The Director Department of Agriculture	Government of Karnataka Commissionerate of Agriculture # 1, Seshadri Road, Bangalore - 560 001, Ph: (080) 22212804, Fax: (080) 22212688
3	The Director Department of Horticulture	Government of Karnataka Lalbagh, Bangalore - 560 004 Ph: (080) 26571925, 26570181, 22283444
4	The Director Department of Minor Irrigation	K.R.Circle Bangalore - 560 001
5	The Karnataka State Remote Sensing Applications Centre	VI Floor, Multi Storeyed Building, Bangalore - 560 001
6	The Director Department of Rural Development and Panchayat Raj	Government of Karnataka Multi Storeyed Building, III Floor Bangalore - 560 001.
7	The Director Central Ground Water Board Ministry of Water Resources	Government of India 11th Main, 31st Cross, 4th Block, Jayanagar Bangalore - 560 011. Ph: (080) 26631336, 26630489, 26342704
8	The Karnataka Power Transmission Corporation Ltd.	Kaveri Bhavan, Bangalore - 560 001
9	The Director Department of Mines and Geology	Govt. of Karnataka, No.49, Khanija Bhavan Race Course Road, Bangalore - 560001., Ph: 080- 22269632/3
10	The Director Directorate of Economics and Statistics	Government of Karnataka 7th Floor, 1st Stage, Multi-storied Building, Dr. B. R. Ambedkar Veedhi, Bangalore - 560 001 Fax : 091-80-2353826 EPABX Nos : 091-80-2353829/830/832
11	The Secretary Irrigation Department	Govt. of Karnataka, M.S. Building, Dr. B. R. Ambedkar Road, Bangalore - 560 001, Ph.: (080) 2255524, 2255306 Fax: (080) 2092560 e-mail: secyirr@secretariat2.kar.nic.in
12	The Director The Karnataka Rural Water Supply and Sanitation Agency	Rural Development and Panchayat Raj Department, Government of Karnataka, II Floor, Cauvery Bhavan, Bangalore - 560 001 e-mail : agcensus@kar.nic.in,

3. Results and discussion

There is a general trend of increase in number of BW in all districts of Karnataka and area irrigated by them is consistently increasing from 19% in 1999-2000 to 32% in 2003-2004, sometimes even exceeding the role of canals (Table 2). This steep increase is attributed to free power supply, availability and awareness of BW technology even in remote villages and quick returns from investments on BW (DoMG and CGWB, 2005). However, the number of BW documented, i.e., 530370 (DoES, 2006) is about three times less than the number of irrigation pump sets energized, i.e., 1503028 (KPTCL, 2007).

There is no mention of groundwater body / BWWSP in any of the government documents referred, except for the Land Resources Information System of exploration by the Karnataka State Remote Sensing Application Centre, Bangalore, which mentions different levels of details of each water source / water body in Sinduvalli Grama Panchayat of Mysore district, Karnataka. The details of BW include diameter, depth, casing length, yield, failed / defunct and hand pump. Similarly, the details of 'BW Storage tank' include with/without water, lined/unlined, shape and dimensions (pers. comm., 2007).

Quality of drinking GW analyzed in 71% villages (33,667 / 47,309) of Karnataka during summer 2000 include some chemical parameters of importance to aquaculture viz., Turbidity, Conductivity, pH, Total Dissolved solids, Total Hardness and Alkalinity (KRWSSA, 2004). However, except for pH, the permissible limits for drinking purpose are in excess of what are considered desirable limits for aquaculture. 4.61% of samples (Total No. samples: 1,54,491) belonging to 11.68% of villages recorded pH range of 0.25-11.42, inferring that pH needs to be corrected here for doing aquaculture. Similar information on Total Hardness (601-8600 ppm) and Alkalinity (601-12065 ppm) are useful to avoid the affected villages for aquaculture.

Survey conducted on `Numbers, Nature and Utilization of BWWSP in the two taluks of Kolar and Nelamangala using the format as at Annexure-2 revealed that average number of BW per village in the Zone is 29 (Table 3). Deeper aquifers are being extracted (161 m), more so in Kolar than in Nelamangala (177 v/s 146 m). The situation of increasing stage of development of GW, in spite of being 195% and 171% respectively in Kolar and Nelamangala taluks (DoMG and CGWB, 2005), is indicated by the average higher depth of 225 m for the deepest BW and an annual average of 23% failure to strike GW.

Daily average number of hours of three phase power supply, required to run submersible pumps, in summer is just 4.5, substantiating the need for BWWSP. The observation is reinforced by the Minor Irrigation Census 2000-2001 recording that minor irrigation schemes like shallow tube wells and dug wells in Nelamangala Taluk are underutilized (25.78% and 5.94% respectively), due to inadequate power (KDoMI, 2007). Power cuts in rural India found a mention by the World Bank which state that unreliable power means more than necessary exploitation of GW when power is available and installation of electric pumps of higher than necessary capacity (WB and MWR, 1998).

Not all borewells have ponds. A 64% of them have ponds and rest manage without them by pumping into a pond being filled in by another borewell (29%) or due to adoption of drip irrigation (22%) or due to lesser water requirement vis a vis less land holding / irrigated land (20%). Other options for not having a BWWSP viz., "there is good power supply", "there is good yield of bore well water" and "there is good supply of both power and bore well water" got negligible responses.

The BWWSP are mostly earthen (80.30%) followed by stone inlaid ones (19.70%). It was observed that more BWWSP near to stone quarries are inlaid with stone slabs/blocks. Area of each BWWSP varies greatly depending on type of soil, total area of the farm, cultivated area, type of irrigation (flood/channel/drip/sprinkler irrigation), GW yield, type of construction of pond (fully/partially earthen/stone pitched) and local weather conditions. The BWWSP are small (Av. WSA: 155 m^2) and shallow (Av. depth: 1.46 m) and are largely unused for aquaculture (97.84%), resulting in under-utilization of an existing, but unclassified, resource.

Total estimated potential water spread area (PWSA) of BWWSP in Karnataka is 5300 ha [Total no. of BW in Karnataka, not the no. of irrigation pump sets energized X Average % of BW having water storage ponds, in decimals X Av. WSA of BWWSP (m^2) = 5,30,370 X 0.6427 X 155.48 m^2= 5299.83 ha]. As it was observed during the survey that all BWWSP were with water, the presumed 95% of PWSA offers an effective WSA of 5035 ha or 0.005 mha, comparable to the area of brackish water (0.008 mha) of Karnataka and hence qualifies to be classified as an Inland Fisheries Resource. There are good prospects of aquaculture in these groundwater / BWWS ponds, for the nutritional and economic benefit of rural masses. Considering the significant aquaculture potential of groundwater for benefit of large number of small farmers, a term "Groundwater Aquaculture" is worth coining: "Groundwater Aquaculture is the set of all activities related to culture of lotic and lentic biota in groundwater storage or transit structures irrespective of nature or primary purpose of such structures with or without bottom dead storage, for better utilization of groundwater".

Table 2
Source wise Percentage Area irrigated from 1999-2000 to 2005-2006

		Percent Area irrigated													
		Net**							Gross*						
Sl. No.	Source of irrigation	1999-2000	2000-01	01-02	02-03	03-04	04-05	05-06	1999-2000	2000-01	01-02	02-03	03-04	04-05	05-06
1	Canals	39.00	36.57	35.22	31.53	31.18	33.63	35.65	40.68	38.35	37.13	31.05	31.58	35.31	38.32
2	Tanks	9.64	9.88	9.49	7.47	6.17	6.27	6.36	8.67	9.29	8.93	7.13	6.05	5.82	5.74
3	Wells	18.74	18.12	18.70	18.27	16.42	15.14	12.75	18.03	17.52	17.58	18.34	16.22	14.36	12.06
4	Bore wells	18.90	20.40	22.39	30.08	32.47	31.28	32.47	19.52	20.81	23.15	31.33	32.74	30.92	31.89
5	Lift irrigation	3.59	3.58	3.62	4.12	4.89	4.86	3.66	3.85	3.66	3.54	4.11	4.79	4.81	3.5
6	Other sources***	10.13	11.45	10.58	8.53	8.87	8.82	9.11	9.25	10.37	9.67	8.04	8.62	8.78	8.49
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100

* Area irrigated more than once, ** Area irrigated only once, *** Include: Spring, Pick up, Seepage water, Nala, Pond, Kunte, River, Drain water, etc. Compiled data from: Annual Season and Crop Statistics Reports, Directorate of Economics and Statistics, Government of Karnataka, Bangalore

Table 3
Inferences from the Survey on Numbers, Nature and Utilization of Borewell water Storage Ponds in Kolar and Nelamangala Taluks
[No. of villages sampled in Kolar and Nelamangala taluks were 10% of the villages, i.e., 37/361 and 25/243 respectively]

Sl. No.	Inferences	Locale in Kolar Taluk	Locale in Nelamangala Taluks	Average of the two Taluks
1	Average No. of Bore wells/BW Storage ponds in a village	29.97 / 16.70	28.12 / 20.48	29.04 / 18.59
2	Average depth of bore well (m.)	177.16	146.20	161.68
3	Average Depth of deepest bore well in the region (m.)	245.00	206.00	225.50
4	Average % failure to strike water during the last year	30.43	16.80	23.61
5	Average % of the total number of bore wells having storage pond	55.72	72.93	64.27
6	Reasons and Percentages of the total number of bore wells, for not having storage pond			
6a	Drip Irrigation	25.79	18.32	22.05
6b	Morethanoneborewellpumping into one storage pond	11.98	47.12	29.55
6c	Land holding/Irrigated land is less	6.51	34.55	20.53
7	Make of bore-well water-storage ponds and their percents			
7a	Earthen	72.51	88.08	80.29
7b	Stone	27.49	11.91	19.70
8	Average Water Spread Area of a storage pond (m^2)	151.76	155.20	155.48
9	Average depth of a storage pond (m.)	1.48	1.45	1.46
10	%of total number of storage ponds used for fish culture*	2.75	1.56	2.16

* In none of the bore-well water-storage ponds surveyed, fish seed rearing was practiced.

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Resource use and dependency on wetlands: A study of the Jalari fishing community of Phewa Lake, Nepal

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Abstract

The wetlands are highly significant in providing communities around the world with valued benefits and functions. Many communities, especially fishing, entirely depend on the wetlands for sustaining their livelihood. The ethnic Jalari fishing community is one such example, having its substantial presence around Phewa lake, Nepal. The lake is situated in Pokhara valley of Kaski district, with rich biological diversity which supports the livelihood of Jalaris and many others. This study is an attempt to understand the livelihood of Jalaris and the role of fisheries (capture fisheries and cage fish culture) in their livelihood.

Both participatory rural appraisal (PRA) and rapid rural appraisal (RRA) tools were employed to collect information for an in-depth study. The use of an ethnographic approach enabled the reconstruction of a background of the community. Also with the help of the DFID [UK Department for International Development] Sustainable Livelihood Framework, it was easier to structure the study under different livelihood capitals, strategies, vulnerabilities and outcomes. The livelihood outcomes primarily emphasize the contribution of fisheries in the household income and income distribution within the community. Lorenz curve and Gini's coefficient were used to measure the income variability in the community.

Fisheries in Phewa lake have proven to be highly beneficial in sustaining the livelihood of the Jalari community. The findings showed that its natural, physical and financial capitals were fully utilized, while human and social capitals still needed to be enhanced further. Lack of education was evident in the community. Capture fisheries and cage fish culture both contributed significantly to the household income but the share of the former was higher compared to the latter. Although cage fish culture played a significant role in reducing income inequality of the households, and thereby reducing poverty, it was still not their important source of income. Their inability to utilize human and social capitals reduced the options of diversifying their livelihood. Diversification of livelihood is thus observed very significant not only to reduce their total reliance on the lake but also to decrease the stress on the lake and to maintain the existence of the Jalari community.

Keywords: Ethnic fishing community; Livelihoods; Capture fishery; Cage aquaculture

1. Introduction

Wetlands are highly significant in providing communities around the world with valued benefits and functions. Wetlands -- both coastal and inland -- are important reservoirs of aquatic biodiversity, providing ecological and economic services which are known for their recreational, educational, scientific, aesthetic, spiritual and cultural values. Covering an area of 7430 km^2 almost 5% of the total land area of the country (147,181 km^2), the wetlands of Nepal are a habitat to a number of aquatic plants and animal species (FDD, 1992) and are exclusively freshwater in nature. Different types of wetlands occur in Nepal of which -- 0.7% is lakes, 0.2% reservoirs, 1.6% marshy lands, 0.7% village ponds, 43.7% paddy fields and 53.1% rivers (FDD, 1992). Although the most extensive and visible wetlands are the rivers, which are estimated to be 6000 across the nation, the major concern of the study here is the lakes and the local fishing community dependent on them.

Communities, especially the fishing, are entirely dependant on the wetlands for sustaining their livelihoods. The Jalari fishing community is one such community, having its substantial presence around Phewa Lake. The lake is situated in Pokhara Valley of Kaski district of Nepal, with rich biological diversity which supports livelihood of many, including fisher folks. An in-depth study of this community was carried out to: (1) understand the existing livelihood status of the Jalari community; (2) explore the contribution of income from cage fish culture to the Jalari household economy; and (3) examine the variability of income from fisheries and their degree of dependence on the lake.

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The study dwelled on three major research questions: (1) To what extent does capital asset determine the well being and sustainability of the livelihood? (2) What are the relative contributions of different sources of fisheries to the household income and how do they vary amongst the household? (3) Are the livelihood strategies changing in order to enhance the community?

2. Research and methodology

The study area was located on the banks of Phewa Lake - the largest in Pokhara Valley, which is 200 km west of Kathmandu. The community is found to be located along the stretch in the north - western bank of the lake between urban and rural settings. The stars in Fig. 1 indicate the area where household survey was conducted.

The Jalari community was selected due to various reasons. The fishermen are occupational, who depend on the lake to secure their livelihoods. Two types of fisheries are practised in the lake - capture fisheries and cage fish culture. They are situated not so far from the urban settings where different diversified forms of livelihood strategies could be adopted.

Both PRA and RRA tools (Chambers, 1992) were used to collect information for the study. The methods were informal interviews with key informants, participant observation, semi-structured household (HH) interview, focus group discussion and resource map making. The use of different types of methods helped in triangulating or in other words in crosschecking the validity and reliability of the data collected. The use of an ethnographic approach enabled to reconstruct a background on the community. Also with the help of the DFID Sustainable livelihood Framework (Allison and Horemans, 2006), it was easier to structure the study under different livelihood capitals, strategies, vulnerabilities and outcomes. The livelihood outcome emphasizes mainly on the contribution of fisheries to the household income and income distribution within the community. Lorenz curve and Gini's coefficient (Bellu and Liberati, 2005) were used to measure the income variability in the community.

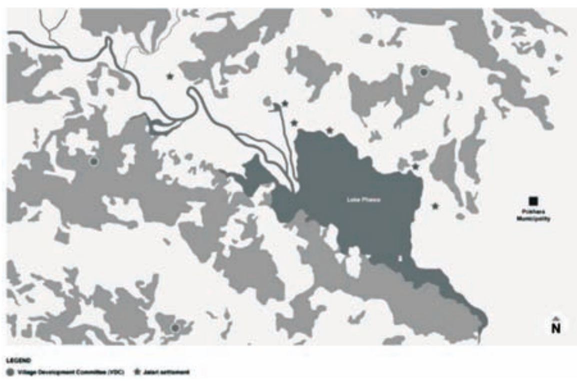

Fig. 1. Map showing the Jalari settlements where the study was conducted. (Map adapted and modified from Government of Nepal Survey Department, 2005)

The Jalari settlements were homogenous in nature and were randomly distributed between Pokhara Sub Metropolitan City (PSMC) and Sarangkot Village Development Committee (VDC). Therefore, systematic sampling technique (Kothari, 2004) was employed to collect data, selecting the first household randomly and the remaining at fixed intervals, i.e., every second fishing household in the area. Two households from the PSMC and 21 households from Sarangkot VDC were sampled for the research. The total sample size considered for the research was hence 23 households (n=23). The data was collected from September 2007 to March 2008.

3. Results and discussion

3.1 Patterns of wealth and poverty in Jalari community

The interesting features revealed from the study was that the rich and medium-income class groups did not differ hugely in their average possession of the five key assets but the poor one was deficit of land, livestock, number of cages and education. The study correlated with Wagle et al., 2007 which also showed that livelihood of the Jalari fishing community has changed and improved over the past few years. The rich and medium-income households had been able to trade up their assets by accumulating them, for instance, by buying land and livestock. Some of the Jalari households were benefiting from fisheries by investing their income generated from capture fisheries and cage culture in other types of sources of income, which consequently led to increase in wealth. The study directed to the point that relative wealth was associated with diversification in income-generating activities. Households with other sources of income such as labour work in Gulf countries and livestock keeping were found to be wealthier than those without other sources of income. Also, their ability to diversify income generating activities was strongly linked with education level of the household head. Out of 23 household heads, 30.4 % had some level of school education. Also very important to note was the lifestyle each household had adopted. Most of the households invested their surplus income in leisure activities rather than other occupations.

Pokhara city where Phewa Lake is situated is emerging out as a major tourist hub in the nation. Various forms of income-generating activities such as handicrafts making, carpentry and construction were observed during the field work. However, the Jalari community was not able to identify any other occupations besides fishing and their perception of not being involved in these newer or other activities was notably referred to such causes as their ethnicity, skill and occupation as traditional fishers and lack of education. Besides, their wealth, lifestyle and social capital also played a vital role in not developing their interest towards the adoption of other occupation. Committee such as Phewa Fisheries Entrepreneurs Committee, Mothers Group and Fathers Groups formed under Fisheries Research Centre (FRC) were able to build up a tradition of norms, reciprocity and trust in the community. The groups were not able to introduce other income-generating activities in the community though as in Bangladesh where, with the help of micro credit scheme formed by women fisher folks, many were now involved in small-scale fish farming, poultry rearing, vegetable farming and traditional handicraft making (Ruhi et al., 2006). This study exhibited that the social groups formed lacked necessary contacts, education and experience to access funds. Hence, it is not the number of groups that are formed or norms that are set up but is the quality of the groups that are formed which matters (Lanjouw et al., 2001). If social capital is not able to fulfil in its entire dimension, the community often fails to conduct in a viable way.

3.2. Jalari, fisheries and Phewa Lake

For Jalari community, fisheries in Phewa Lake have proven to be very significant in generating income and employment. The contribution of capture fisheries is significant compared to cage culture (Table 1). Eighty three percent of the household income was from capture fisheries and only 17 % from cage culture.

Table 1
Annual income of sampled household according to income sources in NPR and proportion of income

Income source	Minimum	Maximum	Total	Average	Proportion of income (%)
Capture fisheries	0	138370	908102	39573	83
Cage fish culture	0	19248	185686	8073	17
Total income	3972	157618	1095854	47646	100

It was also observed that there existed large variability in the total household income with only capture fisheries but with the inclusion of cage fish culture, income inequality was found to decrease. This was also illustrated with the help of Lorenz Curve (Fig 2) and Gini Coefficient.

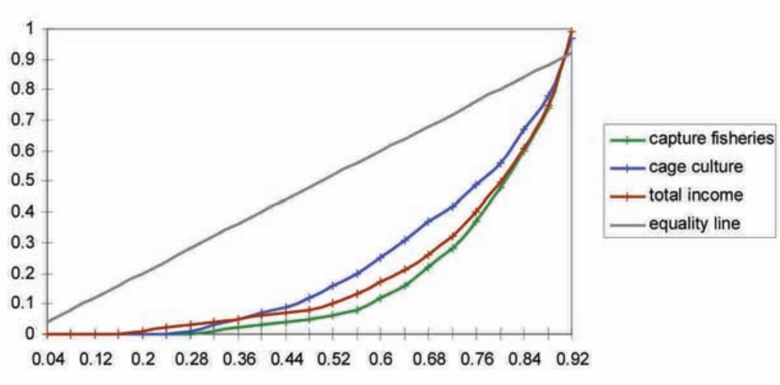

Fig. 2. Lorenz curve with and without capture fisheries and cage fish culture

The inner curve towards the line of equality is the Lorenz curve with cage culture income distribution while the two outer curves are the Lorenz curves with total income and capture fisheries income distribution. Also, the Gini coefficient of the fishing community was 0.64, indicating a high level of income inequality among the households. Poverty can be induced in a community with increasing income inequality (Sharma, 2004). Gini coefficient for the total households, when cage culture income was excluded, was even higher 0.69. Thus, it can be said that inclusion of cage culture in the total household income helped in reducing the income inequalities among the households. The Gini coefficient calculated for cage culture was 0.56 which is lower than that for capture fisheries and total household income. Capture fisheries fulfilled the household demand on a daily basis whereas in the long run, cage fish culture had opened out ways of diversifying the income sources, resulting into reduction in poverty. Some of the key points that explained cage fish culture as a poverty reducing factor could be as follows:

1. Non-requirement of land and easy accessibility to Phewa Lake which acted as strength for the landless Jalari;
2. Low capital investment and working capital requirement;
3. Cooperative use of labour resulting into high returns irrespective of number of cages;
4. Although the risk to cages from sedimentation and landslides was rated high, small and a few number of cages were relatively easy to clean and repair;
5. Cage culture fitted well with the existing coping strategies. Higher investment in fingerlings could be made during high income, building on the existing strength of the natural food availability and the fishing skill of the community;
6. The risk of disease outbreak was unknown so far; and
7. High market demand for fish.

Similar potential contribution of aquaculture to the rural development has been observed in countries like China, Vietnam and Indonesia and also in parts of Africa (Edwards, 2000). One of the interesting patterns that were noted in the study was that cage fish culture contributed significantly to the reduction of income inequality. Wealthier households with more number of cages were expected with large income, inducing more income variability in the community. Possible explanations for this could be that with increase in number of cages, the cost for labour, maintenance and fish fries also increased. Although environmental vulnerabilities in general were outweighed with the explanation that small cages could be easily removed and repaired, it was unfeasible for the households to have around 10 to 20 cages. Richer households mostly had cages of this number and with such frequent environmental hazards as noted during the study, cost of maintenance was more than income generated. However, it should be noted here that the number of rich households having more than 10 cages was only 3 so concluding remarks based on such a small sample size cannot be made.

The Jalari community can be taken as a community within nature where fisheries from Phewa Lake has provided them with economic benefit but at the same time was governed by environmental constraints or vulnerabilities. The community and the lake are intricately linked with each other. For this reason, the Jalari community has been trying to protect and restore the lake in its form but often lacking in such endeavours as other resource users also has an equal stake on it and they seldom participate in such projects. Lack of proper communication and coordination with other community members and social barriers in the form of strong caste discrimination had added to their complexity in protecting the lake, which if continued, could endanger the community itself. The Jalari community thus needs to break out from their ethnic isolation and exploit possibilities brought in by urbanisation and tourism development in order to lead a sustainable life. Local economic development policy with equal emphasis on the conservation of the lake counting Jalari as equally important member of the society needs to be formulated and strengthened. This calls in for a coordinated approach among all the stakeholders of the lake. Poverty alleviation is primarily taken as a task of national government and government-owned FRC has been able to enable the poor, socially excluded and vulnerable fishing community like Jalari. Nevertheless, somehow there exists a weak implementation of local policy that needs to be addressed. On the one hand, the Jalari needs to free themselves from seclusion (as only fisher folks) and on the other; the government should help in encouraging them in adopting available basket of choices.

4. Conclusion

The study of Phewa Lake and the fishing community showed that the values and functions of the lake have not been understood well. The objective of Ramsar Convention of utilizing wetlands in a sustainable way has been carried out by the Jalari community only through fisheries. But other wetland services provided by Phewa Lake have seriously been undervalued. Fisheries is not the only source of living available in the areas around Phewa Lake; animal husbandry, agriculture, cottage-based industries in mini scale can also be easily adopted. There is a need of diversification in their current livelihood strategies as described by Ellis and Bahiigwa (2003) as described diversification as 'the process by which rural families construct a diverse portfolio of activities and social support capabilities in their struggle for survival and in order to improve their standard of living'. Hence, diversification in the household occupation is necessary for the Jalari community as it not only broadens the sources of their income but also reduces the stress on the resources they are heavily dependent on and their reliance on fisheries as the only source of income. The findings also showed that natural, physical and financial capitals were fully utilised in the community while human and social capitals still remain to be further enhanced. Lack of education was evident amongst the Jalari community. Wealthier households were committed to build human capital and were purchasing physical assets. They were also devoting more time to other productive activities and academic pursuits. The poor were more dependent on only one type of income source (mainly capture fisheries), lacked education and were unable to diversify their livelihood strategies. The relative proportion of net incomes from capture fisheries and cage fish culture clearly indicated how significant was the contribution of the former to the household income but at the same time it also showed large variability among the households. With only capture fisheries, the richer were getting richer and poor continued to be poorer, indicating growing differentiation within the community. But Lorenz curve and Gini coefficient provided a clear insight on how inclusion of cage fish culture in the household income could reduce the inequality in income in the community.

Poverty in the Jalari community can be seen as a result of combination of interacting social, economic and environmental factors and processes. Some of which are: (i) heavy rainfall and unsustainable agricultural practices in surrounding areas leading to landslides and heavy siltation in the lake resulting in low fisheries output; (ii) ethnic isolation created by the community themselves; (iii) caste discrimination within the society in which the community resides; (iv) low level of education and skill; (v) inability to diversify their activities; and (vi) lack of credit markets. Therefore, the study highlights the need for an integrated approach to development aiming at alleviating poverty among the Jalari households through enactment of local development policy, creation of their access to opportunities and decision-making in the management of common pool resources (Phewa Lake), and promotion and encouragement of their participation in educational activities and environmental hazard prevention. Besides, a joint effort is also required to break the social discrimination so that Jalari can equally enjoy the benefits provided.

Of paramount importance is the development of the ability in the community itself to effectively mobilise and enhance their existing capitals. Hence, the Jalari households have a rich and varied livelihood portfolio with displays of infinite resources from Phewa Lake. The essential element here is to bring in change in pattern of livelihood activities which would enable each and every fishing household to enjoy the valued functions of the lake.

5. Outlook

The proposed methodology for data collection and its analysis proved to be doable in the chosen study in the sense that the researcher could execute all the steps presented. The used of proposed methodology for data analyses, DFID Sustainable Livelihood Framework and economic analyses using Lorenz curve and Gini coefficient provided desired and detailed insights in the study. However, livelihood analyses itself is a vast array of subject which could have been specifically dealt. Some challenges and limitation could also be identified in the sample and its size. Since the population of the fishing community itself was small (only 63 households), the sample size (n=23 household) might not have been adequate for carrying out statistically significant tests or for explaining income variability. Constraints in data collection were also one of the challenges faced during the study.

More research needs to be carried out on the socio-economic uses of wetlands as well as their distribution in Nepal. So far, only a few exist which also limited the present study. There is also a need for study on the income variability, including Lorenz curve and Gini coefficient on fisheries or aquaculture as after carrying out this study it was found that data required for comparative analysis of fisheries and income variability was scarce and inadequate at both national and international levels. More studies were found to have focussed on forest and agricultural resources and very little information on fisheries is available in the case of Nepal.

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Differential productivity and income from small-scale pond aquaculture in the mid-hills of Nepal

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Abstract

Aquaculture, through its integration into farming systems, has been promoted in the mid-hill region of Nepal with an ultimate objective of assisting rural households to improve and diversify their production, nutrition and income sources. Aquaculture in ponds has been practiced for a long time in the lowlands of the country but is poorly developed in the hilly region due to its topographical limitation and poor technological intervention. An assessment of the adoption, utilization and economic performance of small-scale pond aquaculture technology in the hilly region was made from a survey of 12 fish grow-out farms in Kaski and Tanahu districts in 2008 to determine its productivity and profitability and to identify major production constraints. Economics of pond aquaculture were analyzed, particularly technology, and cost and return. Almost 42% of the studied farms were no more than 0.14 ha with 2 ponds (small farms) and only two farms were above 0.50 ha with 6 ponds (medium farms). The pond efficiency per unit area in fish polyculture system was greater for the small farms, producing higher yield (3.5 ton/ha) compared to the medium farms (2.5 ton/ha). The small farms also expended higher cost than the medium farms but at the same time realized higher annual net profit , i.e., NRs 155,100 vs. 80,100/ha. With the present technology, farm size and stocking rate were proved to be two important determinants of output. Price efficiency analysis demonstrated that the stocking rate could be increased with advantage, as it was positively correlated with the profit. Intensification and expansion of small-scale pond aquaculture in the hilly region require removing/lessening the present constraints of quality fish seed and other inputs. The government should, therefore, provide support to the resource-poor fish farmers by establishing a decentralized fish seed nursing and distribution network.

Key words: Farming system; Pond efficiency; Intensification; Quality fish seed

1. Introduction

Poverty reduction and improvement of the livelihoods of the poorest of the poor has always been one of the major goals of development programs in Nepal and is also a major objective in aquaculture development program. Aquaculture has become one of the fastest growing food production industries in the world, with significant contribution to food security and poverty reduction (ADB, 2005). Integrated agricultural activities for diversified production of food grains, vegetables, fruits and livestock in small-scale is a unique characteristic of average farmers in Nepal. Small-scale fish farming is an additional component of some farmers in mid-hill region. Aquaculture - through its integration into farming system - has been promoted in hill region, with the ultimate objective of supporting rural households to diversify the production, nutrition, income and employment sources. Although aquaculture in ponds has been practiced for a long time in lowland areas, it is poorly developed in hill region due to topographical limitations and poor technological intervention. Advancement of fisheries and aquaculture development was step up when about two dozen fish hatcheries were established in public sector in different ecological regions of the country during 1960-65 (Gurung, 2003; Swar and Nepal, 1998). Despite government efforts, very few farmers are practicing pond fish culture and rice-fish culture in the hills (Shrestha et al, 2003).

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Beset of the pressure of increasing food demand in the region, overwhelming concern of aquaculture is to increase food production either through expansion of area or intensive culture. However the strategy of aquaculture extension by means of larger ponds (>1000 m^2 size) may exclude the resource poor farmers (Shrestha, 2004). Most of the farmers in hill area cannot afford to construct such a large pond in their limited land resource. On the other hand, constraints, such as poor aquaculture extension delivery system, weak technology transfer mechanism, lack of supply of quality fish seed as per the demand of the farmers, limited qualified human resource, (Karki, 1998; Rai et al., 2002) are to be addressed on a priority basis. In fact, some past efforts have focused especially on terai region. The aquaculture production in mid-hill districts of Nepal was only 1.3%, out of total 22,545 metric ton fish produced from pond culture in 2007 (DoFD, 2007). Although the production is low due to several constraints, small-scale rural aquaculture has been considered a good support for livelihoods of mid-hill people by means of income and employment generation. The small-scale aquaculture activities in the mid-hill districts started to be practiced by few farmers has been concentrated more in and around the Pokhara and Kathmandu valleys. It indicates that the extension of area and technology would be supportive to enhance standard of living of the people in hill districts. However, there is a requirement of suitable policy and strategy for warm-water aquaculture in hilly areas and information are not adequate to be acquainted with present status and future scope. This study attempts to analyze the profitability of small-scale aquaculture and then identify the production constraints for future policy and up-scaling of the technology.

2. Materials and methods

A case study of 12 fish grow out farms was carried out in Kaski and Tanahu districts of mid-hill region, Nepal in 2008. Economics of pond fish production, particularly the aspects of production technology, cost and returns were assessed and analyzed by the farm size. Among the 12 farms, eight and four were grouped into two categories of <3000 m^2 and 3000-10000 m^2 sized, respectively and results were presented as performance of small and medium farms (relative term). The case study included interview with farmers and on-site observation of pond aquaculture to establish basic parameters, such as level of technology, asset/income, expenditure and the constraints. Analysis of farm costs, income, returns, profits, rate of returns and ratios were considered as follows:

Operating profit = Gross revenue - Total variable cost
Net income = Operating profit - Total fixed cost
Return to land capital and management = Net income - Family labor
Return to capital and management = Return to land capital and management - Land use cost Net profit = Gross revenue - Total cost
Rate of return to capital investment (CI) = Return to capital and management/Total fixed cost + Total variable cost) x 100
Rate of return to total investment (TI) = (Return to land capital and management/Total cost) x 100
Ratio of net profits to variable cost = (Net profit/Total variable cost) x 100
Ratio of net profits to gross revenues = (Net profit/Gross revenue) x 100

3. Results

Among the total of 12 fish farms, eight were categorized as small-scale farms (<3000 m^2). Five (62.5%) of eight farms had area of below average, no more than 1400 m^2 with one or two ponds. Out of four medium farms, only two (50%) had above 3000 m^2 area with average six number of ponds (Fig. 1, Table 1).

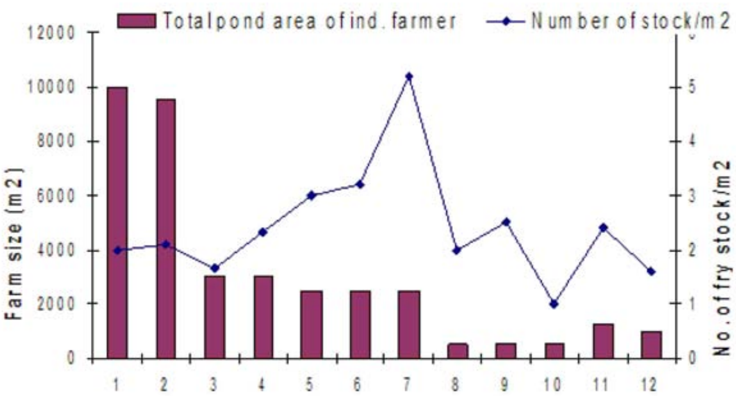

Fig. 1. Total pond area of individual farmer and number of fry stocked.

Major aquaculture system adopted in these farms was carp polyculture with 3-7 and 4-8 species for small and medium farms (relative term), respectively. Species used to culture in hills were chiefly: Common carp (*Cyprinus carpio*), Rohu (*Labeo rohita*), Naini or Mrigal (*Cirrhinus mrigala*), Bhakur (*Catla catla*), Silver carp (*Hypophthalmichthys molitrix*), Bighead carp (*Aristichthys nobilis*) and Grass carp (*Ctenopharyngodon idella*). All farmers had earthen- bottom ponds except few with concrete walls to control seepage, reduce annual maintenance cost and prevent from predators.

Available resources used by the farms and their production performances have been presented in Table 1. Production per hectare in small farms increased as stocking rate became higher. Average stocking density (number/m^2) was 2.6 and 2.0 respectively for small and medium farms with the range of 1-5.2 fish/m^2 (Fig. 1). Pond efficiency per unit area was greater for smaller farms and they produced higher yield (3.5 ton/ha) compared to medium farm (2.5 ton/ha). Feed conversion ratio (FCR) was lower, 1.2 and 1.3 respectively for small and medium farms and it might be attributed to the higher stock composition of grass carp. Kitchen waste also was applied as feed and farm yard manure (FYM) has been used to fertilize the pond. Small-scale farms have used higher amount of fertilizer than medium farms. As there was no calculation of area for FYM application, similar amount was used, even though the ponds varied in size. Small-sized ponds therefore bear higher amount of FYM as an advantage of integrated agriculture system. Survival rate for small farms was observed slightly higher (65%) than that for medium farms (58%). However, recovery or survival was low in both cases due to the practice of stocking very small fry in the ponds. Although the small farm expended higher cost - Rs. 406300 in comparison with Rs. 244800/ha for medium farm, the annual net profit from them was also realized higher compared to medium farms, NRs. 155100 vs. 80100/ha (Table 1).

Total culture period was reported almost the same in both cases - 9-10 months. In the socio-economic aspect, average family size was similar; however, home consumption was higher (80.0 kg/year) in medium-scale farm holder families in comparison with small-scale (57.5 kg/year).

Table 2 describes the detailed investment, with cost for farm operation and returns status of the small- and medium-level farms. The analysis indicates that the cost of investment was 28% higher, whereas profit remained 48% higher in small-scale farms compared to medium-scale farms. Total cost per square meter was NRs. 40.63 and 29.28 respectively for small and medium-scale farms where net profit remained NRs. 15.51 and 8.01 respectively. Results proved that the small-scale farms are more efficient than medium-scale ones.

Table 1
Summary of average technical and cost benefit facets of fish production and productivity of small- and medium-scale aquaculture farms in the mid-hills of Nepal, 2008

Descriptions	Small-scale farms (<3000 m^2)	Medium-scale farms (3000-10000 m^2)
Respondents (no)	8	4
Av. water surface area (m^2)	1400	6500
Av. number of ponds	2.0	5.8
Fish stocking density/ha (no)	26000	20000
Fish stocking size (g)	1.6	2.4
Fish production/ha (kg)	3510	2490
Av. wt. of fish at harvest (g)	600	600
Estimated recovery (%)	65	58
Total feed used/ha (kg)	4605	2885
Feed conversion ratio FCR (kg)	1.3	1.2
FYM (fertilizer) used/ha (kg)	5476	1231
Total lime used/ha (kg)	65	276
Family labor used/ha (man-hrs)	6000	2000
Cost for family labor/ha (NRs)	123000	30500
Total cost/ha (NRs)	406300	292800
Gross income/ha (NRs)	561400	372900
Net profit/ha (NRs)	155100	80100
Operating profit/ha (NRs)	430500	244800
Feeding frequency	1.3	2.0
Cultured species (no)	3-7	4-8
Total culture days	270-300	270-300
Cropping intensity (time/year)	1	1
Farmers experience (year)	2-20	2-22
Home consumption fish (kg/year)	57.5	80.0
Family size	6.0	6.3

NRs = Nepalese Rupees

Almost all farmers reported that the availability of quality fish seed (species, size and time, and distribution network) was a serious bottleneck and that there also prevails wide differences in seed cost among public and private nurseries. Ingredients for supplemental feeds tend to be of variable type, quality and quantity and typically dependent upon by-products available in the farm. This was the second major constraint to the enhancement of the productivity of small scale aquaculture. Aquaculture training/education was also the demands of fish farmers for improving their technical know how.

Table 2
Average costs and returns of small- and medium-scale aquaculture farms in the mid-hills of Nepal, 2008 Costs in Nepalese Rupees (US$ 1= NRs 78 in present value)

Descriptions	Small-scale farms		Medium-scale farms	
	<3000 m^2	per m^2	3000-10000 m^2	per m^2
Total number of farms	8		4	
Average water surface area (m^2)	1400		6500	
A. Capital cost				
1. Land	0		0	
2. Pond construction	85938		325000	
3. Water supply	2375		20375	
4. Net, Transportation, Plastic pipe, etc	2188		7750	
Sub-total	**90501**	64.65	**353125**	54.33
B. Fixed cost (F)				
Depreciation of ponds	4297		16250	
Depreciation of irrigation	119		1019	
Depreciation of facilities	438		1550	
Interest on fixed capital (12%)	10860		42375	
Sub-total	**15714**	11.23	**61194**	9.42
C. Operational/variable cost				
1. Fingerlings	3132		9700	
2. Feed	9468		35575	
3. Medicine (Salt)	0		69	
4. Fertilizer (FYM)	770		800	
5. Lime	194		3923	
6. Electricity/gas	0		2700	
7. Hired labor	1500		19850	
8. Transportation	463		3175	
9. Maintenance cost	1750		2750	
Sub-total	17277		78542	
10. Interest on operation cost (12%, 6 months)	1037		4712	
Sub-total of variable cost	**18314**	13.08	**83254**	12.81
D. Owned inputs (Opportunity Costs)				
Family labor	17225	12.30	19850	3.05
Land use (marginal land)	5625	4.02	26000	4.00
Sub-total	**22850**	16.32	**45850**	7.06
E. Total cost	**56878**	**40.63**	**190298**	**29.28**
F. Gross Revenues Fish production	**78588**	56.14	**242370**	37.29
G. Returns				
Operating profit	60274	43.05	159116	24.48
Net income	44560	31.83	97922	15.07
Return to land capital and management	27335		78072	
Return to capital and management	21710		52072	
Net profit	**21710**	15.51	**52072**	8.01
Standard deviation	(±11606)		(±13561)	
H. Rates of return (%)				
Rate of return to CI	63.8		36.0	
Rate of return to TI	48.1		41.0	
Ratio of net profits to variable cost	118.5		62.5	
Ratio of net profits to gross revenues	27.6		21.5	

4. Discussion

Small-scale aquaculture in Nepal has been practiced by using technologies adapted to locally available and limited resources of households, which is similar to “rural aquaculture” defined by Edwards and Demaine (1997). Although most of the lands and topographical areas in the mid-hills of Nepal are poor, farmers reported a good potentiality of rural aquaculture development in the region on the basis of their experiences. The price efficiency analysis has demonstrated that stocking rate can be increased with advantage as it is positively correlated with profit. With present technology, sizes of farm/pond and stocking rate have been proved to be two important determinants of output. However, medium-scale farms have experienced more scarcity of these input materials. Lower FCR in this study is attributed to the higher stock composition of grass carp, where grass supplied as a feed has not been calculated. Additional reason of lower FCR might be use of kitchen waste as feed and frequent application of FYM to fertilize the ponds. Small-sized ponds, therefore, bear higher amount of FYM as an advantage of integrated agriculture system. Lower recovery or survival in both cases is attributed to stocking of very small fry in their ponds, where rearing pond is necessary to stock the large-sized fingerlings for higher survival rate.

Farming system should be in direction of semi-intensive utilizing indigenous knowledge of management and locally available sources of low-cost inputs (feed ingredients, fertilizers, etc). Semi-intensive systems are more appropriate for rural aquaculture to satisfy the needs of small-scale farming households and poor consumers (Edwards and Demaine, 1988). Only small-scale farms are not adequate to enhance aquaculture; medium-scale farms should also be benefited with good profit to improve people's source of income and level of nutrition (animal source protein). Presently, it is not easy to acquire fish seeds, feeds and other necessary inputs for aquaculture in the mid-hills except in and around Kathmandu and Pokhara valleys; integrated agriculture-aquaculture farming system should be promoted as a possible alternative. Such combination as rice-field kitchen garden and fishpond can be believed to offer farmers a more stable livelihood than cultivation of rice alone or rice and another commercial crop (Wigzell and Setboonsarng, 1995; Gurung, 2003). Both fish seed sales and rice-fish farming can benefit from improved nutrition through access to improved aquaculture. Encouraging policies and support system can go a long way to empower such entrepreneurs to perform a vital role in rural aquaculture (Little et al., 2007). A network of decentralized seed distribution with marketing mechanism and education jointly seem most necessary for conquering the present constraints to aquaculture development in the mid-hills of Nepal.

5. Conclusion and implications

Analyses indicate that the costs of investment as well as operation in small-scale farms are higher than those in medium-scale farms; however, the profit per unit of water surface area is higher. It implies that the small-scale fish farms operating in an integrated agriculture system are more efficient than medium-scale farms in mid-hill region of Nepal. Unavailability of quality fish seed has been one of the major constraints to aquaculture development. Hence, decentralized seed-supply mechanism and network should be established at a community level. As the agriculture in the region is complex with multi-disciplinary and integrated nature of farming system, extension and delivery of advanced technical knowledge and introduction of suitable species for intensive rural aquaculture is also an additional requirement of the farmers. Therefore, appropriate policies for easy access to required materials and financial support at subsidized prices along with education should be enacted to promote the aquaculture, which would be a reliable additional option for nutrition and income for resource-poor people in rural areas.

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Incidence of fish diseases and management practices in Nepal

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Abstract

In the recent past, small-scale aquaculture has taken speedy momentum in Nepal, attracting rural people for employment, income and nutrition. With this, diseases in fish have become a great concern, affecting sustainable development of aquaculture. Spontaneous occurrences of diseases in fish ponds have been reported throughout the country. Among all pathogens, bacterial and mycotic diseases are potentially harmful to most of farmed fish. Among bacterial pathogens, *Aeromonas salmonicida*, *Staphylococcus aureus*, *Pseudomonas fluorescence*, *Flexibactor sp*, *Vibrio parahaemolyticus* are of common occurrence. The ubiquitous fungus *Saprolegnia* sp and *Aphanomyces invadans* affect wide range of fish species, while *Branchiomyces* is another filamentous fungus which obstructs blood vessels in gill filaments. White spot disease in fish caused by protozoan ciliate *Ichthyophthirius multifiliis* is one of the most common and troublesome fish pathogens. Other protozoans associated with cultivated and non-cultivated fish are *Trichodina* sp, *Epistylis* sp, *Myxosoma* sp, *Apisoma* sp, *Costia* sp or *Ichthyobodo* sp. Among monogenetic treamatodes, *Dactylogyrus* sp and *Gyrodactylus* sp are dangerous, as they sometimes cause serious infections, while digenetic trematode *Diplostomum* sp is reported in *Catla* and *Labeo*. *Bothriocephalus* sp and *Caryophyllaeus* sp are common tapeworms, affecting carps and other fish. Among nematodes, *Procamellanus mahendrai*, *Atracits emilii* and *Hedruris bryllosi* have been reported. Leeches, which includes *Helobdella stagnalis*, *Hemiclepis marginata*, *Glossiphonia complanata* and *Erpobdella octoculata*, cause considerable damage to the host. Parasitic crustacean comprises fish lice (*Argulus*) and anchor worms (*Lernea*). Argulid parasitism is considered one of the most serious threats to farmed fish.

Prevention of diseases in fish is accomplished through good water quality management, nutrition and sanitation. Chemotherapy is a major means of controlling many of them. Simple and effective treatments are available for many parasitic and fungal diseases. Formalin (15-25 ppm) is widely used against ectoparasitic protozoa and dye malachite green (0.05-0.1 ppm) is a potent fungicide. The methylene blue @ 3ppm is recommended effective against protozoan for ponds and aquarium. Trichlorfon at 0.25mg/l and formalin at 15- 50mg/l as therapeutic measures are effective to control *Trichodina* sp in fry and *Agrulus* sp in brood fish. Antibacterial are widely used in the treatment of bacterial diseases but where they are in regular use, problem of resistance has become widespread, including multiple resistance. Chemical Diptrex @ 0.5-0.8 ppm is used to control monogenetic trematodes. Similarly, Di-n-butyl tin oxide mixed in fish feed @ 0.28% and fed @ 3% of body weight of fish has been proved quite effective against cestodes. Generally, lime (CaO @ 500 kg/ha), potassium permanganate ($KMno_4$ @ 2-5 ppm), formalin @ 15 - 25 ppm, common salt (NaCl @ 1-5% for dip), acetic acid and copper sulphate ($CuSO_4$ @ 0.25-1 ppm) are commonly used for pond treatment. Careful manipulation of aquatic environment and fish health management has significant potential for limiting pathogenic effects from many of ectoparasites. Control of microbes and parasites is still far from being satisfactory and further research is needed.

Keywords: Bacterial pathogen; Protozoan parasites; trematode parasite; Parasitic crustaceans

1. Introduction

Fishery has a great potential and at places, is the backbone of the agriculture sector. It is important as fish are the source of low-cost animal protein. For the development of aquaculture in Nepal, programs were launched in 1950s but they were intensified only in the last two decades. As soon as this intensification program was started, fish diseases emerged as a major problem, which caused significant loss of cultivated fish.

The first incidence of fish diseases in Nepal was reported in cultivated carps in 1965. Various incidences were reported from different parts of the country in 1967. Similarly, in 1970s, increased incidences along with intensified fish diseases were recorded, particularly with the introduction of polyculture and integrated fish farming system. Since then, several species of parasites have been reported in fish, causing serious economic loss in production.

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The incidences of parasitic infection were reported in different regions - from as low as Terai (100m above sea level) to as high as Rara (Mahendra) Lake region (3000m above sea level). Although parasitic infections were present in the fish farms throughout the year, they were found to be intensified especially during the breeding season of warm water fish. It usually occurs in the spring and summer seasons when the metabolic activities of parasites are at greater extent (Shrestha, 1982). On the contrary, epizootic ulcerative syndrome (EUS) occurs during winter. This disease usually occurs in the overcrowded ponds and causes heavy mortality if constant supervision is not carried out. Up to 65% of mortality of fry was reported by the Fisheries Research Center in Pokhara which can, indeed, be categorized as serious. Such a heavy mortality was a resultant of compound effects of environment, occurrence of parasites and fish health management practices (Bista et al., 2001).

A number of stress factors - such as low dissolved oxygen; temperature and pH variations; nutritional deficiencies; overcrowding and aggression from other fish; and handling and waste loading occurring especially in artificial confinement - result in immunosuppressive fish which are more susceptible to disease organisms. Out of the above mentioned stressors, low dissolved oxygen is a frequent cause of fish mortality in ponds during the summer season. With crowding of fish in culture facilities, outbreaks of diseases become rather common as ammonia levels are increased. Moreover, when compared to natural systems, in artificial system there is increased concentration of hosts resulting in increased chances of infections (Thoney and Hargis Jr., 1991).

Although there are several problems caused by viruses, bacteria and fungus, greater losses are caused by protozoa, helminthes and crustaceans parasites. A comprehensive knowledge of fish pathogens is a prerequisite for strategic planning and successful execution of fish health management. Hence, an attempt has been made here to review different diseases among fish and their management practices in the country.

2. Types of fish diseases

There are two broad categories of diseases that affect fish health:

2.1. Infectious (diseases caused by pathogens)

2.1.1. Viruses and bacteria

Viruses: Viral diseases among fish are suspected in the country. They are difficult to diagnose because there is no special laboratory facility to test them.

Bacteria: Bacterial diseases are widely distributed in the country and are responsible for heavy mortality of both cultivated and non-cultivated fish. Bacterial diseases were observed in Rainbow trout (*Oncorhynchus mykiss*). It was presumed that the trout were suffering from Furunculosis or ulcer in Fisheries Research Centre at Trishuli and Godawari. Later on, the disease was confirmed as tail and fin rot in trout. It was controlled by administrating sulfamerazine or tetracycline in the feed of yearling and adult trout (Rayamajhi, 1998).

External bacterial infections of the skin or gills, particularly those due to Myxobacteria (*Myxobacterioses*), are a major problem in trout culture. In 1993/94, reports regarding most of the trout being affected by such bacteria were published.

In the fiscal year 1996/97, a collaborative research project was initiated on bacterial disease among fish. The predominant aerobic bacterial flora were isolated from pond water, aquatic insects, aquatic plants and slime, skin gills, intestine and diets of fish. The following bacteria were reported from different species of fish (Rayamajhi, 1998; NACA/FAO, 2002): *Aeromonas salmonicida*, *Staphylococcus aureus*, *Pseudomonas fluorescence Flexibactor sp* and *Vibrio parahaemolyticus*.

Bacterial ulcer is one of the common diseases occurring in cultivated carps, cat fish and non-cultivated fish. Infectious abdominal dropsy has also been reported among brood fish. Similarly, species-specific bacterial eye disease which causes blindness in common carps has also been reported (Jha, 2002).

2.1.2. Fungal infections

Although mycotic diseases of fish are widespread, they rarely cause any significant problems. These (fungal) infections are usually external and mostly caused by *Saprolegniaeceae*, *Saprolegnia* and *Branchiomyces*. These fungi are implicated in mycotic infections and are considered just to be secondary invaders following physical and physiological injuries brought about by rough handling and/or attack by primary pathogens. Fish eggs and fingerlings are mostly affected by fungus *Saprolegnia*. *Branchiomyces* is another filamentous fungus which obstructs the blood vessels in the gill filaments. In this disease, the affected gill filament becomes grayish-white at later stages. *Aphanomyces* infection of fish is also common in Nepal. In this fungal infection, just external damage to the skin occurs. Yet, it might often be the ultimate cause of death in affected fish.

Among all the fungal diseases, EUS caused by *Aphanomyces invadans* is the most devastating, affecting the majority of fish species (Lilly et al., 1998; Jha and Shrestha, 2003). The first outbreak of EUS occurred in February 1989 in Eastern Terai of Nepal (Phillips, 1989) which caused significant loss of standing fish crop of farmers. A loss of 17.2% of total fish production due to initial outbreak was reported and economic loss from fish mortalities was estimated at about NRs 30 millions (US$ 550, 000) (ADB/NACA, 1991). A study carried out in Kapilvastu district of Western Nepal revealed that the average prevalence of EUS was 6.5%, irrespective of fish species - susceptible or resistant. The study further showed that fishpond management practices played a vital role in its occurrence (Dahal et al., 2005). Recently too, EUS has been reported from tropical areas of Chitwan and Nawalparasi districts of Nepal and Naini and Bhakura were shown highly affected by this disease. The economic loss from EUS in these districts was estimated to be around US$30,000 (NACA/FAO, 2009).

2.1.3. Protozoans

Protozoans represent one of the most important groups of pathogens negatively affecting the health state of both cultivated and non-cultivated fish. There are a number of protozoan parasites that have long been recognized as causative agents of severe pathogenic diseases. White spot disease caused by protozoan ciliate Ichthyophthirius multifiliis is one of the most common and troublesome fish pathogens. It was detected in common carps (*Cyprinus carpio*) and Gold fish (*Carrasius carrasius*) in Kathmandu valley in 1967. After the breeding season of common carps, the water temperature generally ranges from 20 to 25 ˚c. This is particularly when epizootic hazards generally occur. Being an important pathogen, this parasite and its host relationship have been the subject of numerous studies (Paperna, 1991). This was first reported as an epidemic in hatcheries where all the hatchery ponds were dried and disinfected to control the disease (Shrestha, 1982). More recent occurrence of this disease was reported in Central and Western Nepal (Mishra, 2005).

Trichodina is another dominant protozoan appearing throughout the fish larval rearing period. A review of the epidemiology of *Trichodina* in culture facilities at different development regions of the country revealed that this parasite was associated with Chinese carps and common carps (Rayamajhi, 1998; Bista et al., 2000). Other protozoans associated with cultivated carps and non-cultivated fish are *Epistylis sp*, *Myxosoma sp*, *Apisoma sp*, *Costia sp or Ichthyobodo sp*. (NACA/FAO, 2002; Rajbanshi 1978).

The data base regarding protozoan impact is fragmentary since species identification is rarely practiced by fish health specialists in the country. A loss of fish fry caused by Trichodina sp. alone in Pokhara Valley was estimated between 1.8-15% of the total fry population (Bistha et al., 2001). There is a possibility of occurrence of other protozoans like *Eimeria* sp and *Henneguya* sp.

2.1.4. Helminths

Monogenea: Among monogenetic treamatodes, *Dactylogyrus* and *Gyrodactylus* can sometimes be rather dangerous as they cause very serious infections. Most monogeneous are host-specific in nature. Gill fluke (*Dactylogyrus sp*) infection in common carp fry was first observed in 1965. Indian and Chinese major carps are also susceptible to *Dacylogyrus* and *Grodactylus*. Generally, flukes are not detrimental in adult fish if infestation is very low. Carp larvae and fry up to the weight of about 3g are more prone to the infection and thus can cause heavy losses. All dactylogyroids are oviparous. Their eggs hatch in a few days which then mature in less than a week. These larvae, therefore, must seek a suitable host promptly. Individual hosts do not necessarily acquire a large number of parasites as rapidly as the viviparous gyrodactylids since these are borne directly onto an already infested host. However, in crowded situations, worm prevalence and intensities can build up rapidly (Thoney and Hargis Jr., 1991).

Digenea: Trematode metacercarie constitute the most abundant parasitic infections in fish, particularly in juvenile ones. Most common among digenetic trematodes is the *Diplostomum* sp causing black spot disease in Indian and Chinese carps. This disease is characterized by the presence of numerous small black nodules or cysts all over the body of the fish. Juvenile of *Catla* and *Labeo* are highly susceptible but even heavy infection does not seem to affect fish; however, when melanin accumulates in the metacercarial cyst (black spot), the marketability is greatly reduced (Paperna, 1991; Jha, 2002).

Cestodes: Several genera of cestodes have been found to infect major carps, although they apparently cause little harms. *Bothriocephalus sp*. and *Caryophyllaeus sp* are common tapeworms affecting carps. Cestode infection does not cause epizootic hazards. However, this infection hampers the growth of fry, fingerlings and adult fish, which creates chances for secondary infection and causes mortality (Shrestha, 1982).

Nematodes: Fish are notorious for the variety of nematodes they carry. Nematodes are usually found within the intestine of the host fish. Larval forms as well as adult forms can be found in the liver, visceral cavity, air bladder, muscles and other internal organs. The fish species such as *Mystus*, *Clarias*, *Heteropneustes*, *Tor* and *Aorichthys* are found infected by roundworms like *Procamellanus mahendrai*, *Atracits emilii* and *Hedruris bryllosi* in Nepal (Singh, 1983; Rana et al., 1990).

2.1.5. Hirudinia

Leeches cause considerable damage to the host, especially if the host is young or has already reduced vitality. A number of species of leeches have been reported from wild fish of Nepal. These include *Helobdella stagnalis*, *Hemiclepis marginata*, *Glossiphonia complanata and Erpobdella octoculata* (Yadav and Mishra, 1982; Jha, 1991).

2.1.6. Parasitic crustacea

Two important crustacean parasites are commonly found, parasitizing cultivated major carps and non-cultivated fish. These are fish lice (*Argulus*) and anchor worm (*Lernea*).

Fish lice (*Argulus*): Argulid parasitism is considered one of the most serious threats to farmed fish in warm water systems. The most widespread argulid species in such a system is carp-associated species. Although they are primarily associated with carps, they are opportunistic in their choice of hosts and also parastitize non- cyprinid fish (Jha, 1991). In Nepal, Argulus infection is very common, affecting cultivated and exotic carps in different regions. Several instances of carp mortality have been reported (Mishra, 2005).

Anchor worm (*Lernea*): Anchor worm are also considered harmful to carps. They frequently attack almost all the species of major carps and sometimes cause large-scale damage in nursery and rearing ponds. In carps, usually the female parasite causes mechanical injuries which may eventually lead to secondary fungal or bacterial infections.

2.2. Non-infectious (diseases not caused by pathogens)

Non infectious diseases can be broadly categorized as environmental, nutritional or genetic. Environmental diseases are the most important in commercial aquaculture. Environmental diseases include low dissolved oxygen (DO), high ammonia, high nitrite, variation in temperature and pH, natural or man-made toxins in the aquatic environment. Asphyxiation due to low levels of DO in water is a common occurrence in different fish farms in Nepal. The main factors that influence the amount of DO in a water body are temperature and atmospheric pressure. Generally, water holds less oxygen at higher temperature and low atmospheric pressure. Other factors that affect the amount of DO in water include organic waste loading, excess use of chemical fertilizers, phytoplankton blooms, density of fish and respiration fish and other aquatic animals (Boyd, 1990). It has been reported that high diurnal fluctuation of DO (0.6mg/l in the morning and > 20mg/l in the evening) might have stressed fish and encouraged parasitic infestations (Bista et al., 2001). Similarly, gas bubble disease due to super saturation of water with atmospheric gases cause problem in aquaculture, especially in hatchling and fry. It is a common disease affecting the fry and fingerlings of many fish species.

Another important parameter affecting fish production is ammonia. Non-ionized ammonia is the most toxic to fish. Generally, the rule is higher the pH and temperature, the higher the percentage of total ammonia, i.e., the toxic non-ionized form. Ammonia in aquaculture facility originates from excretion by aquatic organisms, decomposition of organic matters and death of phytoplankton bloom (Boyd, 1990). Nutritional disease due to dietary deficiency is also observed but it can be very difficult to diagnose it. Genetic abnormalities are also common in fish.

3. Prevention of infection

Prevention of fish diseases is accomplished through good water quality management, nutrition and sanitation. Without the foundation of these, it is impossible to prevent outbreaks of opportunistic diseases. A number of strategies for the prevention of diseases in aquaculture have been developed. The most basic strategy - also the most successful if it can be achieved - is to avoid contact between pathogen and fish. This is especially important in the early stages of the fish life when they are most susceptible to pathogens.

An important way of avoiding diseases is the use of specific pathogen free-stock. Another method to control the spread of fish parasites is to safeguard water from the introduction of infected fish. However, introduction of fish from other water bodies from within the country or outside the country becomes essential for the development of aquaculture industry. In such cases, the fish to be introduced must be quarantined against possible parasites. This will minimize the spread of diseases.

Chemotherapy is the major means of controlling many fish diseases. Simple and effective treatments are available for a number of parasitic and fungal diseases. For example, formalin (15-25ppm) is widely used against ecto-parasitic protozoa and dye malachite green (0.05-0.1ppm) is a potent fungicide. The methylene blue @ 3ppm has been recommended effective against protozoans for ponds and aquariums. (Shrestha, 1982). Trichlorfon at 0.25mg/l and formalin at 15-50mg/l as therapeutic control measures were found effective to control *Trichodina sp* in fry and *Agrulus sp* in brood fish (Bista et al., 2001).

A number of antibacterial compounds are available; however, there are no effective chemotherapies for viral diseases. Anti bacterials are widely used in the treatment of bacterial diseases but where they are in regular use, problem of resistance has become widespread, including multiple resistance. The chemical Diptrex @ 0.5-0.8 ppm is being used to control monogenetic trematodes. Similarly, Di-n-butyl tin oxide mixed in fish feed @ 0.28% and fed @ 3% of body weight of fish proved to be quite effective against cestodes (Shrestha, 1982). Generally, lime (CaO @500kg/ha), potassium permanganate ($KMnO_4$ @2-5 ppm), formalin @ 15-25 ppm, common salt (NaCl @ 1-5% for dip), acetic acid and copper sulphate ($CuSO_4$ @0.25-1 ppm) are commonly used for pond treatment. Careful manipulation of aquatic environment and fish health management has significant potential for limiting pathogenic effects from many of ecto parasites.

There is a great scope for the improvement in disease control in aquaculture. It becomes very important to develop effective disease control methods so as to develop aquaculture as an industry. As the world food demand is on increase and the marine fish harvest keeps declining, aquaculture can be one of the best solutions to supply low-cost protein and feed the whole world. New techniques for disease control have been developed in recent years and it is anticipated that there will be further significant advances in the near future.

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Performance of hybrid solar dryer for value addition in fish product

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Abstract

Hybrid solar dryers can be employed for drying food products, using either solar panels or firewood. Thus, they can be utilized at any time of the day and even in rainy season, when sufficient solar radiation may not be available. Such dryers had not yet been evaluated for their performance, practically for drying fish product. In the present study, we evaluated the performance of hybrid solar dryer using firewood to dry fresh rohu (*Labeo rohita*) of approximately 1.0 kg. The fish was cut into small pieces - approximately of the same size (~50 g each) and divided into three treatments: 2.5% salt mixed, 2.5% turmeric mixed, and in control (without salt and turmeric). Five trays were used for drying and each tray consisted of all the three treatments. During the experiment, the internal dryer temperature and weight of the fish samples were monitored. The initial moisture in fish muscle was 76.0%. The final moisture content in all the three treatments remained 6.8% after a drying period of 72 hours. The fish samples placed in the bottom tray dried faster than those in the middle and top trays - probably due to more heat exchange from the combustion chamber in the bottom portion of the dryer. However, the final moisture content in the samples placed in the various trays of the hybrid solar dryer did not vary at the end of drying process. The quality of dried fish was good as there was no contamination of dust and insect.

Keywords: Hybrid solar dryer; Drying rate; Quality

1. Introduction

Fish are highly perishable raw material, whose flavor and texture change rapidly during storage after death. In order to inhibit unfavorable enzymatic and microbiological changes, they should immediately be gutted, washed and chilled. If fish is not sold fresh, preservation methods should be applied to extend shelf life by freezing, smoking, canning and sun-drying. Sun-drying is an old traditional method practiced in many parts of the world (Sachithananthan et al., 1986; N'jai, 1986). A major problem with this type of preservation method could be the loss of dried products due to rats, cats, dogs, birds and infestation with insects, which reduce income of fishermen. Besides, it needs sunlight, which may not be available in the nights and for longer period in rainy days.

Another common option of fish preservation is smoking, using fire wood, where traditionally fish are dried above the fireplace. This method has also limitations as firewood is becoming scarce everyday. To resolve this, a hybrid solar dryer was designed by Engineering Division of Nepal Agricultural Research Council (NARC) to undertake drying of perishable commodities even in the case when there is poor solar radiation (in night time) or in the rainy days. The dryer uses fuel wood or agricultural residues such as corncob as a fuel along with the solar radiation. The present paper aims at elucidating the performance of the hybrid solar dryer for fish drying in terms of drying rate and quality of the dried product.

2. Materials and methods

2.1. Hybrid solar drier

The dryer consists of fire chamber with a great and gate for controlling the air inlet. There are 7 fuel gas pipes passing through the drying chamber to exchange heat. It also consists of the air inlet and exhaust chimney with valve connected to the chamber as in the case of normal solar dryer. It consists of 5 trays with steel nets to keep the products for drying (Fig. 1a and 1b).

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Fig. 1a

Fig. 1b

Fig. 1a and 1b. Hybrid solar dryer.

2.2. Fish drying experiment

Freshwater fish locally known as rohu (*Labeo rohita*) were obtained from Lagankhel market. Fish samples were transported to the Engineering Division of Nepal Agricultural Research Council (NARC) at Khumaltar where hybrid solar dryer was installed. Scales of fish were removed with a knife, and they were degutted, deheaded and washed properly with tap water. Fishes were cut into several pieces. Heads were excluded from drying.

There were three treatments - each with three replicates. 2.5 % salt and 2.5 % turmeric were mixed with fish in treatments 1 and 2, respectively. In treatment 3, fish was dried without any salt and turmeric.

The experiment was started on 20 Ashad 2065 and terminated on 23 Ashad 2065, when moisture content in the muscle reached approximately 6.8% by international standard. At the start of the experiment, local firewood was burnt for 24 hours in an interval of 3.5 days. The firewood was burnt around 10 AM and remained active till 5 PM. It is expected that if the dry pieces are maintained at this moisture content, there would no fungal infestation. The initial moisture content of rohu was determined by oven dry method. The fish were dried in all five trays of the hybrid solar dryer. Each tray consisted of all three treatments. Each treatment pieces of fish was weighed in an interval of 30 minutes over the whole drying period. For the weighing of samples, a balance with an accuracy of 0.01 g was used. The air temperatures inside and outside various dryers were measured using mercury thermometers of 1ºC precision. Drying experiment was carried out only during the day time.

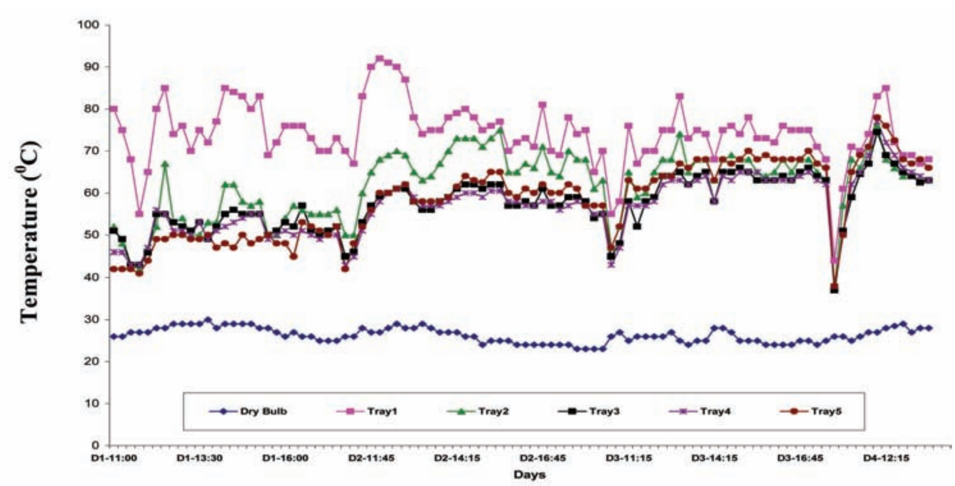

Fig. 2. The ambient temperature and dryer temperature developed in different trays of hybrid solar dryer

3. Results and discussion

The ambient temperatures and dryer temperature developed within the different dryers are shown in Fig. 2. The initial moisture content of rohu was about 76%. The final moisture content in all the three treatments at the end of 24 hours of drying was 6.81%. Fish samples placed in the bottom tray dried faster compared to the middle and top tray due to more heat exchange from the combustion chamber in the bottom portion of the dryer. The final moisture content of the fish placed in different trays of the dryer did not vary at the end of drying. The drying curves of fish rohu drying by using hybird solar dryer have been given in Fig. 3.

4. Conclusion

The hybrid solar drying outperforms sun-drying or firewood drying in terms of the quality of the dried fish due to lower level of contamination from the dust and insects. Having large capacity (20 kg) with large surface area per unit land space, the multi-tray hybrid solar dryer has a high potential for commercialization. Yet, the other quality attributes need to be studied in more detail.

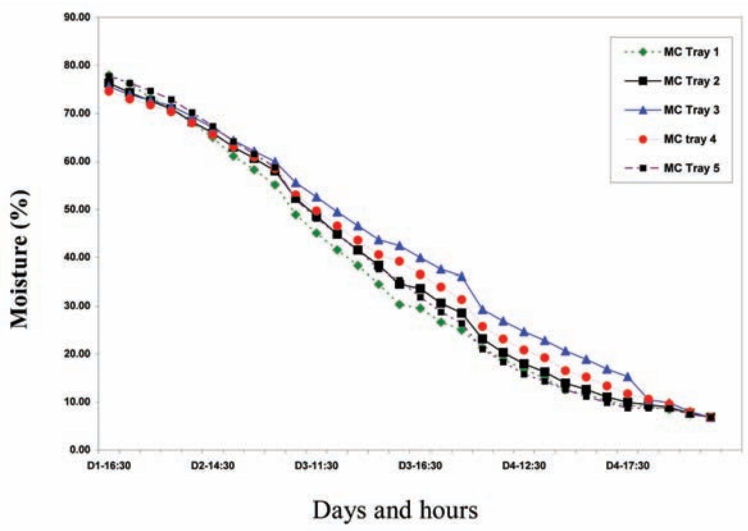

Fig. 3. Moisture content in dried fish in different trays in hybrid solar dryer.

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Indigenous minor carps: An important contribution to livelihood of fisher folks in Nepal

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Abstract

Indigenous minor carps are those cyprinids that do not generally grow larger than a foot even in the adult stage. Such small fish contribute substantially to the livelihood of fishing communities in Nepal, especially in the season when big fish are not captured adequately. Capture fisheries in Phewa and Begans lakes of Pokhara valley have shown that approximately 90% of the catches are composed of indigenous minor carps, which implies that these fish contribute substantially to the total fish production in the country and to the livelihood of fishing communities. Except for a few , they are deprived of any conservation efforts and are in crisis for their existence. It is recommended that conservation of minor carps is highly desirable in the present context of unconventional fishing pressure caused by the use of explosives, poison and electric current inaquatic habitats. Measures should be taken to conserve gene pools of indigenous minor carps in the country through networking among various areas such as extension, education, research and development.

Keywords: Small cyprinids; Unconventional fishing pressure; Fishing communities

1. Introduction

In contrary to major carps, which grow fairly large, minor carps are generally small cyprinids. They often do not exceed a foot in body length in their adult stage. Traditionally, these species rated low-valued compared to major carps. However, recent trend suggests that people prefer small native species not only as a food fish but also as a fish of high aesthetic value. Sometimes these species fetches several fold higher prices than major carps.

Culturally, fish is regarded as an auspicious item in Nepal. A fish dish is always considered a delicacy and valued food in Nepalese society. Minor carps serve the needs of most of the households in rural areas. Their contribution to the capture fisheries, and hence to the livelihood of fisher folks is immense (Sharma and Shrestha, 2001; Swar 2002; Thilsted, 2009). The contribution of small cyprinids to the poor communities - in terms of nutrition and from the perspective of livelihood - might be higher than that of large species.

Thousands of rivers in Nepal are originated from the Himalayas. As an impact, people in the past were highly dependent on fisheries, evolving into several ethnic castes depending only on fishing and allied activities (Gurung et al., 2005). The country has great potential for the development of aquaculture sector on several grounds: (i) about 83% of its population lives in villages; (ii) fish is one of the most favored animal protein foods; and (iii) several ethnic communities are traditionally engaged in fishing. To support fish production, vast unexploited natural resources, such as 395,000 ha of rivers, 5,000 ha of lakes, 1,500 ha of reservoirs, 6,500 ha of ponds, 398000 ha of irrigated paddy fields and 12,500 ha of marginal lands and swamplands, are available in Nepal (Gurung et al., 2003). It has been estimated that about 136,220 families are engaged in aquaculture activities and that about 503,664 people are actively involved in this profession (DoFD, 2005). Yet, fisheries and aquaculture contribute only 2.32% of the agricultural gross domestic product (AGDP) and 0.9% of the national GDP (DoFD, 2005). Despite its auspicious character and significant increment in total production, the per capita consumption of fish in Nepal is about 1,611 g/year (in 2003/04). Aquaculture in the country revolves around the cultivation of native, and to a greater extent, of exotic carps. Promotion of some promising species of minor carps in aquaculture practices would be an avenue by which national fisheries could be increased and minor carps could be simultaneously conserved.

However, efforts on the conservation of fisheries resources are limited. There are no national level institutions working exclusively in this area, and depletion of some indigenous species has been noticed (Swar, 2002). In the present work, database for main minor carps is prepared based on a review of available literature.

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2. Economically important minor carps

Out of the total minor carps reported in Nepal (Table 2), several have high economic value. Species such as *Schizothorax spp, Chagunius chagunio, Labeo dero, Labeo angra, Barilius spp* and *Semiplotus semiplotus* are famous for their specific value, e.g., food, sport for recreation, decorative and academic (Rajbanshi, 2002). Minor carps are well accepted in the society since there is no restriction on their species and size for consumption. Fish under *Schizothorax* spp and *Barilius* spp groups are considered an exceptionally good quality food fish and a highly esteemed delicacy. Many minor carps are also well known for their high sport value. Minor fish in the hilly region with their typical morphology and coloration are of high interest and preferred to be used in aquariums. Moreover, changes in morphological structures due to the adaptation against fast flowing torrent water, as seen in various groups of hill stream fish and some of the fish with unstable systematic, are of great academic interest. Although minor fish are of great value, very little effort has been made in studying their biology, behavior, propagation and domestication from the perspectives of both conservation and economic utilization.

3. Contribution of minor fish species to livelihood

Although a complete database on the role of minor fish species in national fishery production in Nepal is not available, minor fish species contribute significantly to the total yield. The total national fish production is 46,779 mt and capture fisheries share about 43% (DoFD, 2007). Since capture fisheries are practiced in natural waters, the production solely comprises of indigenous fish, which varies from 17.4 kg/ha in irrigated rice fields to 449.3 kg/ha in marginal swamps. Even though information on species-wise contribution of aquatic resources is meager, indigenous fish catch comprises of over 90%, with minor carps from lakes in Pokhara valley accounting for total catch (Bista et al., 2005). Capture fisheries of minor indigenous species play a critical role in the livelihood of rural people by enabling them to:

- diversify their livelihood activities and better insure against the risk of failures of other activities, e.g., agricultural production;
- optimize the use of labor resources among various activities, depending on the season;
- gain access to income-generating activities with very little capital investment and no lands; and
- maintain/improve nutrition as fresh/processed fish represent a significant source of protein (Wagle et al., 2008a).

Capture fisheries of indigenous variety, more specifically minor carps from different types of water bodies make up about 53% of the total annual income of some communities (Wagle et al., 2008a). The contribution of minor carps to the total catch from lakes in Pokhara and to the enhancement of the livelihood of the Jalari or Pode community living around them can be taken as a representative example of aquatic resources and their relationship with communities dependent on them. Minor carps contributed a large percentage to the total catch (25.5-64.9%), and more vigorously, to the indigenous fish catch (41.3-96.7%) from Phewa and Begnas lakes during the last two decades, despite the fact that stocking enhancement with ranching of major carps were made in these lakes (Table 1).

Peak catch of minor carps in these lakes occur during May-October in summer until the onset of winter, when catch of major carps remain low (Fig. 1). During this period, reproduction of minor carps takes place at a relatively high rate but at a constant water temperature, followed by an increased precipitation (Fig. 2). The use of gill nets with small mesh size in offshore fishing of major carps at increased water level and temperature is not effective in Phewa and Begnas lakes. Hence, the Jalari fishers tend to use gill nets with small mesh opening (<35 mm) to target minor carps in summer and rainy seasons (Wagle et al., 2008b). However, most of the wetlands in Nepal are not yet subject to fish stocking enhancement. Fishing community from various ethnicities living around most of the aquatic resources depends on the catches of minor fish throughout the year for securing their subsistence livelihood.

Table 1
Contribution of minor carps to total fish catch from Phewa and Begnas lakes in Pokhara (1985-2007)

Description	Catch statistics					
	1985	1990	2000	2002	2004	2007
Phewa lake (523 ha)						
Total catch yield (kg)	15,092	18,602	18,260	10,691	11,491	33,082
Total catch yield of indigenous fish (kg)	3,256	8,454	4,602	4,726	1,362	14,916
Catch yield of minor carps (kg)	3,155	8,124	4,366	4,552	980	12,825
Contribution of minor carps to indigenous fish yield, %	96.7	96.1	94.9	96.3	72.0	86.0
Begnas lake (320 ha)						
Total catch yield (kg)	12,200	22,854	21,787	18,652	15,074	15,891
Total catch yield of indigenous fish (kg)	11,800	20,122	6,630	12,013	18,214	5,285
Catch yield of minor carps (kg)	11,200	18,762	5,986	11,135	15,003	2,184
Contribution of minor carps to indigenous fish yield (%)	95.0	93.3	90.3	92.7	82.4	41.3

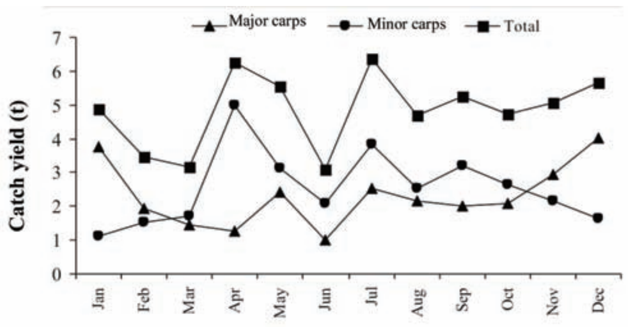

Fig. 1. Catch yield of minor carps and major carps and the total from Phewa and Begnas lakes of Pokhara (2007).

Capture fisheries are widely scattered throughout the mid-hill valleys, high hills and mountains of the country and are not well organized. Capture of minor carps and other fish for the purposes of subsistence and sports is practiced at varying levels of intensity in different rivers and lakes. Communities living along rivers and lakes use their traditional fishing gears mainly for subsistence production, generating only marginal economic benefits. A large number of them rely on fishing for their livelihood. Nepal has some 103 ethnic groups (CBS, 2003), and 20 of them - 12.62% of the national population - are traditionally dependent on the wetlands (IUCN Nepal, 2004). For instance, Majhis on the banks of Koshi river and Podes in lakes of Pokhara depend on fisheries as a primary source of income. However, Tharus and Wadis [indigenous people of Terai (southern plains)] perform fishing as a “favorite pass time and supplementary means of subsistence” (Shrestha, 1995). Communities that depend on various water bodies are some of the poorest and most marginalized in Nepal. As revealed in catch statistics, their livelihood is substantially supported by the capture of minor fish species from various wetlands in their vicinity. Despite their contribution, attempts on the conservation minor species are unsubstantial.

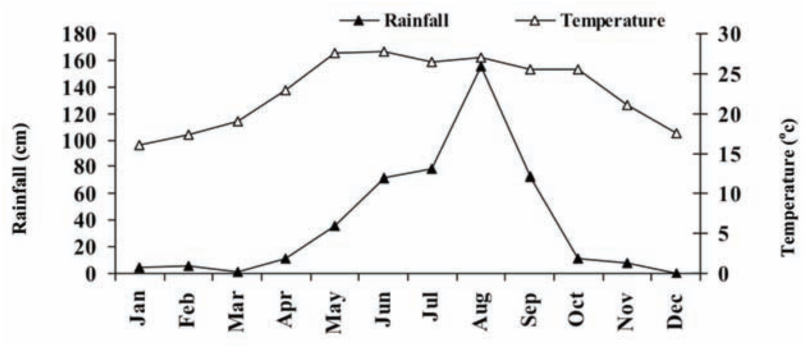

Fig. 3. Water temperature and rainfall pattern in Pokhara (2007).

4. Status of indigenous minor fish conservation

Altogether 91 species have been compiled as minor fish in Nepal (Table 2). These numbers well coincide with previous reports on fish species in the country (Rajbanshi, 1981; Shrestha, 1981; Rajbanshi, 2002; Gurung et al., 2003). Among the species listed, *Schizothorax spp, Barilius spp, Chagunius spp, Crossocheilus spp, Labeo spp* and *Puntius* are commonly occurring minor carps and they represent a significant proportion of yield from capture fisheries. For the conservation of fisheries resources in the country, Government of Nepal has formulated several different Acts and Codes of Conduct for fishing and promulgated a set of guidelines, rules and regulations. One of the oldest is Jalchar Sanrachhn Ain-2017 (Aquatic Life Protection Act-1961), which was amended later in 2055 to make fish ladders or hatcheries an obligation of dam construction over rivers and lakes. The amendment has drawn significant attention of the organizations associated with dam construction. Recently, a fish hatchery - Kali Gandaki Fish Hatchery - has been established within the premises of Kali Gandaki Hydro Power Project. The main goal of the hatchery is to carry out research and promote native fish inhabiting Kali Gandaki river.

Most of the conservation measures and strategies focus on the environmental improvement of different habitats of fish, enforcement of acts and laws against illegal fishing, and mass awareness campaign. Various measures have been advocated for the rehabilitation and conservation of fish such as improvement of deteriorating spawning grounds, and provision of fish ladders and sanctuaries (Nautiyal and Lal, 1984; Kulkarni, 1991; Swar, 2002). However, environmental conditions have not improved to the extent that natural stock of fish biodiversity could be rehabilitated without any artificial intervention.

In order to protect and conserve minor fish, it is necessary to culture and propagate their seed on a large scale and transplant them in streams and lakes. Research and development efforts have been initiated on propagation techniques and fry production of some minor species to restock them into natural water bodies and introduce as a candidate for aquaculture practices. The seeds produced are being released in natural water (Kali Gandaki river) to mitigate the effects of damming on the diversity of this species. Similarly, studies on reproductive biology, diversity and socio- economic connection of several other important minor carps are being carried out by the hatchery, fisheries institutions under Nepal Agricultural Research Council (NARC) and Department of Agriculture (DoA) of Government of Nepal. Hopefully, these endeavors will be helpful in conservation of native minor carps as well.

5. Conclusions and recommendations

Richness of biodiversity is a result of mosaic of interactions between the components of terrestrial and aquatic habitats. The alteration of habitats and pressure of over fishing are a threat to the conservation of minor fish in Nepal. Increasing pressure caused by the use of unconventional methods of fishing such as electro-fishing and poisoning in aquatic habitats, is one of the factors that put these fish in danger. Moreover, invasion of persistent fish species in recent years (Gurung, 2005) has increased the vulnerability of existing minor carps. Launching awareness programs for all stakeholders and expanding aquaculture further in the country could be one of the solutions to conserve this minor species. There is a lack of a national-level fisheries development organization, which could coordinate education, extension and research activities. In such a situation, efforts made on the conservation of fish biodiversity are scattered. Hence, it is recommended that a central-level organization, using skilled and experienced human capital with the most up-to-date education and training, be established in the country, which could contribute to the sustainability of the conservation of fisheries resources in the near future.

Table 2

Distribution of minor carps in rivers, streams, lakes and ponds in Nepal

SN	Species	Local name	English name	Status	Major habitats	Terai	Mid hills	High hills
1	*Carassius carassius* (Linnaeus)	Kandae, Ratomachha	Crucian Carp	NC	Ponds	-	+	-
2	*Chagunius chagunio*	Rewa (Hamilton-Buchanan)	Chaguni	NC	Lakes and Rivers	+	+	-
3	*Cirrhinus reba* (Hamilton-Buchanan)	Reba	Reba carp	C	Rivers and Streams	+	-	-
4	*Labeo angra* (Hamilton-Buchanan)	Thed, Rahu	Angra labeo	NC	Rivers and Streams	+	+	-
5	*Labeo bata* (Hamilton-Buchanan)	Bata	Bata labeo	C	Rivers and Flood plains	+	+	-
6	*Labeo boga* (Hamilton-Buchanan)	Rahu	Boga labeo	NC	Rivers and Streams	+	+	-
7	*Labeo calbasu* (Hamilton-Buchanan)	Calbasu	Kalbasu, Black rohu	NC	Rivers	+	-	-
8	*Labeo caeruleus* Day	Rahu	Sind labeo	NC	Rivers and Streams	+	-	-
9	*Labeo dero* (Hamilton-Buchanan)	Gardi	Kalabans	NC	Rivers and Streams	+	+	-
10	*Labeo dyocheilus* (McClelland)	Gardi	Brahmaputra labeo	NC	Rivers and Streams	+	-	-
11	*Labeo fimbriatus* (Bloch)	Fringed-lip	Ped peninsular carp	R	Rivers	+	-	-
12	*Labeo gonius* (Hamilton-Buchanan)	Kursa	Kuria labeo	C	Rivers	+	+	-
13	*Labeo pangusia* (Hamilton-Buchanan)	Termassa, Kalnacha	Pangusia labeo	C	Rivers and Flood plains	+	-	-
14	*Labeo sindensis* (Hamilton-Buchanan)	Sind	Labeo	NC	Rivers	+		
15	*Oreichthys cosuatis* (Hamilton-Buchanan)	Patharchatti	Cosuatis barb	UN	Rivers			
16	*Osteobrama cotio cotio* (Hamilton-Buchanan)	Gurda	Cotio	C	Rivers, Ponds and Marshy lakes	+	-	-
17	*Puntius apogon* (Cuvier and Valenciennes)	Patharchatti		C	Shallow rivers and Ponds	+	-	-
18	*Puntius chola* (Hamilton-Buchanan)	Sidre	Swamp barb, Chola barb	C	Shallow rivers and Ponds	+	-	-
19	*Puntius clavatus* (McClelland)		Stedman barb	UN	Ponds, Rivers and Lakes	+	-	-
20	*Puntius conchonius* (Hamilton-Buchanan)	Pothia, Sidre	Rosy barb, Red barb	C	Shallow rivers and Ponds	+	-	-

Table 2 (Continued)

Distribution of minor carps in rivers, streams, lakes and ponds in Nepal

SN	Species	Local name	English name	Status	Major habitats	Terai	Mid hills	High hills
21	*Puntius gelius* (Hamilton-Buchanan)		Golden barb, Golden dwarf barb	UN	Rivers			
22	*Puntius guganio* (Hamilton-Buchanan)		Glass-barb	UN	Low flood plains			
23	*Puntius phutunio* (Hamilton-Buchanan)		Dwarf barb, Pigmy barb	NC	Rivers	+		
24	*Puntius sarana subnasutus* (Valenciennes)	Bhitti, Kande	Peninsular olive-barb	UN	Rivers, Ponds and Lakes	+	+	-
25	*Puntius sophore* (Hamilton-Buchanan)	Poti	Spotfin swamp barb	C	Rivers, Ponds, Flood plains	+	+	-
26	*Puntius ticto* (Hamilton-Buchanan)	Sidrae, Poti	Ticto barb, Two-spot barb	C	Rivers, Flood plains	+	+	-
27	*Naziritor chelynoides* (McClelland)	Karange			Rivers and Reservoirs		+	
28	*Neolissochilus hexastichus* (McClelland)				Rivers			
29	*Cyprinion semiplotum* (McClelland)	Chepti	Assamese Kingfish	UN	River and Streams	+	+	-
30	*Amblypharyngodon mola* (Hamilton-Buchanan)	Mada	Mola carplet, Plae carplet	C	Lakes and Streams	+	+	-
31	*Aspidoparia jaya* (Hamilton-Buchanan)	Mara	Jaya	C	Lakes and Streams	+	+	-
32	*Aspidoparia morar* (Hamilton-Buchanan)	Hado, Harda	Aspidoparia	C	Ponds and Lakes	+	-	-
33	*Barilius barna* (Hamilton-Buchanan)	Fageta	Barna baril	C	River, Streams and Lakes	+	+	-
34	*Barilius barila* (Hamilton-Buchanan)	Chachale, Phageta	Barred baril	C	Rivers, Streams and Lakes	+	+	
35	*Barilius barnoides Vinciguerra*	Fageta	Burmese baril	C	Rivers, Streams and Lakes	+	+	
36	*Barilius bendelisis* (Hamilton-Buchanan)	Fageta	Hamilton's barila	C	Rivers, Streams and Lakes	+	+	-

Table 2 (Continued)

Distribution of minor carps in rivers, streams, lakes and ponds in Nepal

SN	Species	Local name	English name	Status	Major habitats	Terai	Mid hills	High hills
37	*Raiamas bola* (Hamilton-Buchanan)	Goha, Bola		PRO	Rivers	-	+	-
38	*Barilius gatensis* (Valenciennes)		River-carp baril		Rivers, Streams and Lakes	+	+	
39	*Barilius guttatus* Day 1878	Jalkapoor		C	Rivers and Lakes	+	+	-
40	*Barilius radiolatus* (Gunther)		Gunthar's baril		Rivers, Streams and Lakes			
41	*Barilius shacra* (Hamilton-Buchanan)	Fageta	Shacra baril	C	Rivers and streams	-	+	-
42	*Barilius tileo* (Hamilton-Buchanan)		Tileo baril	UN	Rivers	+	-	-
43	*Barilius vagra* (Hamilton-Buchanan)	Tilwa, Fageta	Vagra baril	UN	Rivers, Streams and Lakes	+	+	-
44	*Brachydanio rerio* (Hamilton-Buchanan)	Zebra	Zebra danio, Zebrafish	UN	Rivers, Streams and Lakes	+	+	-
45	*Danio aequipinnatus* (McClelland)	Chelwa, Bhitte	Giant danio	PRO	Rivers	-	+	-
46	*Danio dangila* (Hamilton-Buchanan)	Nepti, Bhitte	Dangila danio	C	Rivers and Streams	+	+	-
47	*Danio devario* (Hamilton-Buchanan)	Chitari	Devario danio	C	Rivers, Streams and Lakes, Ponds	+	+	-
48	*Esomus danricus* (Hamilton-Buchanan)	Dhedawa	Flying barb	C	Rivers, Streams and Lakes, Ponds	+	+	-
49	*Rasbora daniconius* (Hamilton-Buchanan)	Dhedhawa	Blackline rasbora	C	Rivers, Drainage and Ponds	+	+	-
50	*Rasbora rasbora* (Hamilton-Buchanan)	Darai	Gangetic scissortail rasbora		Rivers and Ponds	+	+	-
51	*Bengala elanga* (Hamilton-Buchanan)		Bengala barb	PRO	Rivers, Ponds and Shallow lakes	+	-	-
52	*Chela cachius* (Hamilton-Buchanan)		Silver hatchet chela	C	Rivers, Ponds and Shallow lakes	+	+	-
53	*Chela laubuca* (Hamilton-Buchanan)	Deduwa	Indian glass barb	C	River, Ponds and Shallow lakes	+	+	-

Table 2 (Continued)

Distribution of minor carps in rivers, streams, lakes and ponds in Nepal

SN	Species	Local name	English name	Status	Major habitats	Terai	Mid hills	High hills
54	*Salmostoma bacaila* (Hamilton-Buchanan)s	Chela, Gadela	Large razorbelly minnow	C	River, Ponds and Lakes	+	-	-
55	*Salmostoma acinaces* (Valenciennes)		Silver razorbelly minnow	R	Rivers	+	+	-
56	*Salmostoma phulo* (Hamilton-Buchanan)		Finescale razorbelly minnow	C	Rivers			
57	*Securicula gora* (Hamilton-Buchanan)	Chelwa	Gora-chela	R	Rivers	+	+	-
58	*Crossocheilus latius* (Hamilton-Buchanan)	Lohari	Gangetic latia	C	Rivers and Lakes	+	+	-
59	*Garra annandalei Hora*	Budhuna	Annandale garra	UN	Rivers and Streams	+	+	-
60	*Garra gotyla* (Gray)	Budhuna	Gotyla	C	Rivers and Streams	+	+	-
61	*Garra lamta* (Hamilton-Buchanan)	Budhuna	Lamta garra	C	Hills streams	-	+	-
62	*Garra mullya* (Sykes)	Budhuna	Mullya garra	C	Hills streams	-	+	-
63	*Garra nasuta* (McClelland)		Khasi garra		Rivers and Streams	+	+	-
64	*Garra rupecula* (McClelland)		Mishmi garra	C	Rivers and Streams	+	+	-
65	*Schizothorax* (Oreinus) *sinuatus* (Heckel) 1838	Asla			Rivers and Streams	-	+	-
66	*Schizothorax richardsoniii* (Gray)	Soal, Asla	Alwan snowtrout	C	Rivers and Streams	-	+	-
67	*Schizothoraichthys esocinus* (Heckel)	Thundae			Rivers and Streams	-	+	-
68	*Schizothoraichthys macrophthalmus* (Terashima) 1984	Asala	Nepalese snowtrout	R	Lake Rara	-	-	+
69	*Schizothoraichthys nepalensis* (Terashima) 1984	Asala		R	Lake Rara	-	-	+
70	*Schizothoraichthys raraensis* (Terashima) 1984		Rara snowtrout	R	Lake Rara	-	-	+
71	*Schizothoraichthys progastus* (McClelland)	Chuche Asala	Dinnawah snowtrout	C	Hill streams	-	+	-

Table 2 (Continued)

Distribution of minor carps in rivers, streams, lakes and ponds in Nepal

SN	Species	Local name	English name	Status	Major habitats	Terai	Mid hills	High hills
72	*Psilorhynchoides (Psilorhynchus) homaloptera*	Patharchati	Homaloptera	PRO	Rivers and Streams		+	
73	*Psilorhynchoides (Psilorhynchus) pseudecheneis* (Menon and Datta)	Titaemacha	Nepalese minnow	R	Rivers	-	+	-
74	*Psilorhynchus balitora* (Hamilton-Buchanan)	Titari	Balitora minnow	PRO	Rivers	-	+	-
75	*Psilorhynchus sucatio* (Hamilton-Buchanan)	Patherchati	Sucatio minnow	CDR	Rivers and Swamps	+	-	-
76	*Balitora brucei* Gray	Tite	Gray's stone loach	R	Rivers	-	+	-
77	*Nemacheilus corica* (Hamilton- Buchanan)	Gaddelo	-	PRO	Rivers and Streams		+	
78	*Acanthocobitis* (Nemacheilus) *botia* (Hamilton-Buchanan)	Natawa	-	PRO	Rivers and Streams		+	
79	*Nemacheilus* (Schistura) *rupecola* (McClelland)	Gadela	-		Rivers and Streams		+	
80	*Schistura beavani* Gunther	Patgadela	-	PRO	Rivers and Streams			
81	*Schistura devdevi* Hora		-		Rivers and Streams			
82	*Schistura multifasciatus* Day		-	PRO	Rivers and Streams			
83	*Schistura scaturigina* (McClelland)		-		Rivers and Streams			
84	*Schistura savona* Hamilton-Buchanan)		-		Rivers and Streams			
85	*Botia almorhae* Gray	Baghi	Almorha loach	PRO	Rivers and Streams		+	
86	*Botia lohachata* Chaudhuri 1912	Bhaghae	Y-loach	UN	Rivers and Streams		+	
87	*Botia 213ario* (Hamilton-Buchanan)		Necktie loach	PRO	Rivers and Streams		+	
88	*Botia dayi* Hora	Bhaghae	Hora loach, Botya loach		Rivers and Streams		+	
89	*Botia histrionica* Blyth		Burmese loach	R	Rivers and Streams		+	

Table 2 (Continued)

Distribution of minor carps in rivers, streams, lakes and ponds in Nepal

SN	Species	Local name	English name	Status	Major habitats	Terai	Mid hills	High hills
90	*Lepidocephalus guntea* (Hamilton-Buchanan)	Lata, Nakta	Guntea loach	CDR	Rivers and Streams			
91	*Somileptes gongota* (Hamilton-Buchanan)	Baga Lata	Gongota loach	C	Rivers and Streams		+	

* C= Common, NC= Not common, R= Rear, CDR= Conservation dependent and rare, Un= Uncommon or lower risk/least common, PRO= Data deficient pristine rare ornamental

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Situation analysis of Mahseer conservation in Nepal and prospects of developing angling tourism

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Abstract

Sahar or Mahseer and other fish populations in Nepalese waters are dwindling at an alarming rate. No form of fish conservation program is in place in the country. Neither is there any clarity as regards to which government entity has the responsibility to conserve fish in our rivers and lakes despite the existence of Aquatic Animal Protection Act-1961. No one cares about preserving something they never see. Even the agencies working in the non-government sector have put aquatic animals - unlike tigers and rhinos - in the back seat. The 21st century has made battery packs, dynamite and pesticides more easily accessible than before and local people have replaced their hooks and nets with these more effective devices. The demand for Sahar makes investing in the means to procure the fish more worthwhile. Sahar are still considered a prize delicacy so much so that large Grass carp are being sold in Khichapokhari market in Kathmandu as Sahar to those who do not have knowledge. With the rise in population along rivers and rapid urbanization, uncontrolled excavation of sand and gravel has resulted in a widespread destruction of spawning grounds. Even where Mahseer are able to spawn, the rampant use of pesticides and other chemical fertilizers - locally referred to as Aushadhi - is decimating every form of life in our streams. Besides, hydropower projects are also disrupting the routes of migratory fish and despite the acknowledgement of the problem and identification of remedial measures, no one is monitoring their actions.

A healthy fish population across the Himalayan rivers has to be maintained. Active conservation measures on the part of people whose lifestyle is dependent on these riverine systems is essential. Better angling opportunities in these rivers should be created and through this h a vibrant tourism industry needs to be developed. It is suggested to advocate the enforcement of the Aquatic Animal Protection Act-1961 with the government and other conservation agencies and build awareness in communities that inhabit core habitat areas. However, awareness of the problem alone is of no consequence to those communities whose lives will be affected by the solution itself. Therefore, they should be ensured economically viable and comfortable livelihood options in the long-run. Excavation of sand/gravel/rock should be restricted to areas that affects the population of endangered aquatic species. Promotion of angling as a form of tourism, which will provide the locals with alternate employment opportunities and also incentives to conserve fish in our rivers and lakes are very much required.

Keywords: Sahar; Endangered aquatic species; Irrational fishing; Game fish

1. Introduction

Nepal became a signatory to the Convention on Biological Diversity (1992) on 21 February 1994, which obliges the government to: (i) conserve and ensure sustainable use of biological diversity, and equitable sharing of benefits; (ii) prepare and implement national strategies, plans or programs for the conservation and sustainable use of biodiversity; and (iii) ensure in-situ and ex- situ conservation, and promotion of biotechnology and genetic research. In accordance with the principles of the Convention, Nepal Biodiversity Strategy was prepared in 2002, which provides strategic thrust and direction to be taken over the next 20 years to ensure biodiversity conservation in the nation (MoFSC, 2002).

However, a significant gap remains between international environmental instruments and their implementation at the national level (Belbase, 1997). This is most apparent in Nepal's lack of efforts to conserve aquatic biodiversity, despite the promulgation of Aquatic Animal Protection Act in 1961, which prohibits the use of explosives, electricity and poisons to kill fish, and the revision in the same in 1999, which imposes regulations on fishing gear, season and size (Swar, 2002). Yet, these activities continue unabated as no agency has been designated to administer and enforce the Act, resulting in a rapid depletion of natural fish population throughout the Nepalese waters.

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Besides the intrinsic value of biological diversity, open water capture fisheries also provide income and protein supplements to some of the most deprived communities living along rivers and lakes. A review of selected studies reveals that 204,000 people depend on capture fisheries in 6 rivers and 2 lakes alone (Swar, 2002). Considering the vast network of other rivers, streams and lakes throughout the country, the actual number of people dependent on capture fisheries is thus much higher than this figure and many of the communities have the lowest ranking in terms of economic indicators (Dahal et al., 2002).

Fish by virtue are not a charismatic animal like tigers and rhinos, which can be enjoyed by simply viewing them. To derive their aesthetic value, one must learn to catch them on rod and reel - a sport which once learnt becomes addictive. Developing angling opportunities in Nepalese waters can thus create a powerful stimulus for aquatic animal conservation efforts, and at the same time, provide viable employment opportunities for some of the most deprived communities. Such dual benefits, which are in line with the principles of the Convention on Biological Diversity, are being reaped in some rivers in India such as the Cauvery and Ramganga, where strict protection of certain stretches of the rivers has ensured the revival of record-sized fish and created employment opportunities for the local fishermen as angling guides.

This paper reviews the status of the Mahseer (*Tor* spp) in waters of Nepal; analyzes problems associated with their rapidly declining number; and provides suggestions on restoring their natural population. This one species is considered on the basis of its ecological characteristics, economic value, and its attributes as a game fish with immense potential for viable tourism development.

2. Review of Mahseer and other game fish

There is variation in the total number of fish species reported from Nepal, and some degree of confusion prevails in fish genera, species and synonyms. The latest taxonomic review of fish of Nepal published by Shrestha (2001) reports a total of 182 fish species belonging to 92 genera under 31 families and 11 orders. Two species of Mahseer - *Tor tor* (Hamilton) and *Tor putitora* (Hamilton) - have been recorded from rivers and lakes of Nepal out of 10 species of valid Mahseer reported from around the world (Desai, 2003): (i) *Tor putitora* (Hamilton), (ii) *Tor tor* (Hamilton), (iii) *Tor mosal* (Sykes), (iv) *Tor khudree* (Sykes), (v) *Tor mussullah* (Sykes), (vi) *Tor progeneius* (McClelland), (vii) *Tor douronensis* (Valenciennes), (viii) *Tor sinensis* (Wu), (ix) *Tor tambroides* (Bleeker), and (x) *Tor zhobensis* (Mirza).

Another species found in Nepal - *Neolissocheilus hexagonolopis* (Katle) - is also closely associated with Mahseer and is a game fish like them. However, this species, unlike Mahseer, is not migratory, and therefore does not provide angling opportunities in hill streams and rivers year long. Goonch (*Bagarius bagarius*) is the largest fish species found in Nepal, growing to over 200 kg (Gundger, 1945; Shrestha, 2001). However, they are not a fighting fish like Mahseer and do not fall high on anglers' list. *Schizothorax* and *Schizothoraichthys* (Asla) can be caught on rod and reel in winter when the season for Mahseer is off, and provide viable angling opportunities. Besides these fish, freshwater eel (*Anguilla bengalensis*), Rohu (*Labeo rohita*) and introduced carps (Common carp*, Cyprinus carpio;* and Grass carp*, Ctenopharyngodon idella*), which are now found in Phewa and Begnas lakes in Pokhara as well as in some big rivers in Terai (southern plains), can also be caught on rod and reel. Similarly, although Rainbow trout (*Oncorhynchus mykiss*) and Brown trout (*Salmo trutta*) have not yet been introduced in natural waters of Nepal, their selective and controlled release in some high altitude streams and lakes can provide unmatched angling opportunities to the world.

3. Status of Mahseer

Very few long-term studies have been conducted on the distribution and status of Mahseer in Nepalese waters. Most of the available literature simply deal with the identification of species and their relative abundance at sporadic periods of time. However, important conclusions can be drawn from a valuable study conducted by Shrestha (1997) and comparing his data and information with more recent studies, available literature, and extensive communication with local fishermen and anglers over the last few decades.

From these inferences, it appears that not only are Mahseer population rapidly declining throughout waters of Nepal and also India but large Mahseer specimens also seem to be dwindling all over the region. Early records of Mahseer from India can be found in the Journal of the Bombay Natural History Society (Gudger, 1945):

“Sanderson states that another and slender specimen measured 5 ft. 6 inches but weighed only 80 lbs (36.4 kg.).This fish was large but not a record fish. However, two high records have been made by C.E. Murray Aynesley. In 1906, he captured the largest mahseer of which some account has been found. Its length was 60 inches; girth 37 inches; mouth 8.5 inches across; tail spread (vertical) 19 inches; and weight 104 lbs (47.3 kg.)...In 1909, he recorded another mahseer which was only very slightly less heavy. It was 64 inches long; 39 inches was its girth; mouth and tail as in the other fish; and weighed 103 lbs (46.8 kg.)”

Recent records have not been well documented but fish of this size have become a rarity. Communication with local fishermen in West Seti, Karnali, Bheri, Narayani, Trishuli, Sun Koshi and Tama Koshi in 2008 revealed that fish of around 20-30 kg each were still being caught, though very rarely. More importantly, all fishermen reported diminishing catches every successive year.

More scientific analyses conducted recently reveal that the population of Mahseer has declined rapidly in the last decade and their both the species have become very rare in rivers of Nepal warranting their protection (Shrestha, 1997; Shrestha 2001; Dhital and Jha, 2002; Jha et al., 2006; Jha et al., 2007). Shrestha (2001) lists nine fish species, including *Tor putitora* as vulnerable and *Tor tor* as endangered and recommends their legal protection. More recently, Jha et al. (2006) conclude that the threat category of as many as 36 out of 47 species recorded in their study need to be revised. Clearly, there is an urgent need to take steps to protect aquatic biodiversity.

In December 2008, the authors of this paper conducted a rapid fish survey in Likhu Khola - a tributary of Tadi river, which was the principle investigation site of the detailed study on Mahseer conducted by Shrestha (1997). Random sampling using wading method with the aid of backpack electro-fishing was conducted in two stretches for 15 minutes each at about 3 km upstream from the confluence of Likhu and Tadi and in another stretch for 20 minutes at the confluence. The results are presented in Table 1.

The 50 minutes of electro-fishing yielded a diversity of 14 species and a total catch of 342 fish. Mahseer (*Tor putitora*) accounted for 1.8% of the total catch with an abundance of 1.20 catch per unit effort - a very poor result indeed. No deep-bodied Mahseer (*Tor tor*) were found. According to Shrestha (1997), juvenile Mahseer remain close to the area where they hatch for up to one year before migrating downstream to large rivers. Given that the typical spawning period is from September to October, and Mahseer reach the stage of jumping fry in 30 days, the survey should have yielded a much higher frequency of Mahseer fingerlings in these waters. Shrestha (1997) mentions that an unspoilt habitat can support up to 300 fry per 100 m^2 but can hold only less than 50 per 100 m^2 where the habitat is disturbed. At the time of sampling, the turbidity of Likhu Khola was high due to some road construction work going on in the upstream. However, Tadi river was very clear, but still yielded a very few Mahseer, indicating that the problem is far more serious. Interviews with the locals confirmed the frequent use of poison (pesticides) in these rivers, and in fact, the team found an empty packet of pesticide by the river bank where the sampling was carried out.

In autumn 1988, Shrestha (1997) tagged 300 adult Mahseer to study their return migration trend and found that only 15 -16% came back to the spawning grounds in the subsequent year. This indicates an extremely high mortality rate on the journey to large rivers and back to the spawning grounds. As no conservation measures have been taken in Narayani river system since the study, it can be inferred that adult breeding Mahseer are becoming extremely rare, and a very few are making their come back to the spawning grounds year after year. Shrestha (1997) mentions that Mahseer follow their homing instincts and return to the same creek where they were hatched to spawn. This means that every spawning ground has its own specific group of Mahseer, and each of these must be taken as a distinct unit. Decimation of the entire brood stock from a particular spawning channel means that the stream or river will never see Mahseer again. This may possibly be reversed by releasing artificially hatched fry into such locations. More investigation is needed to confirm this hypothesis though.

Table 1
Results of fish survey in the Likhu Khola (December 2008)

Common name	Scientific name	Count	% of Total Count	Abundance
Asla	*Shizothorax richardsonii*	1	0.3	0.20
Buduna	*Gara gotyla*	8	2.3	1.60
Buduna	*Gara annandalei*	2	0.6	0.40
Chuike	*Lepidocephalus guntea*	1	0.3	0.20
Dhade	*Acanthocobitis botia*	93	27.2	18.60
Hile	*Channa gachua*	5	1.5	1.00
Kabre	*Glyptothorax telchitta*	43	12.6	8.60
Katle	*Neolissocheilus hexagonolopis*	3	0.9	0.60
Pate	*Schistura beavali*	76	22.2	15.20
Pate	*Schistura rupicola*	45	13.2	9.00
Phaketa	*Barilius barila*	54	15.8	10.80
Sahar	*Tor putitora*	6	1.8	1.20
Sidre	*Puntius conchonius*	4	1.2	0.80
Singhe	*Heteropneustes fossilis*	1	0.3	0.20
Total Count		342	100.0	68.40

Note: Abundance = Catch per unit effort; No. per 10 minutes of electro-fishing.

4. Causes of decline of Mahseer and other game fish

All researchers who conducted status surveys of natural fish stocks in Nepal have warned of the rapid decline in fish numbers (Dhital and Jha, 2002; Gubhaju, 2002; Ranjit, 2002; others) and a number of them (Shrestha, 1997; Shrestha, 2001; Jha et al., 2006; others) have recommended the inclusion of at least 10 species in the list of protected fauna of the country. Shrestha (1997), after his pioneering work on Mahseer, strongly has recommended the establishment of protected waterways. However, the government has remained mute to all cries for protecting aquatic biodiversity, and none of the major conservation agencies working in Nepal have any definitive programs on the protection of aquatic biodiversity. Whatever efforts are underway in the name of the wetlands they are restricted to natural lakes and ponds. Virtually no focus on protecting aquatic fauna in our rivers can be found anywhere. Rivers of Nepal remain, for the most part, open access resources. Where local bodies have taken some steps, they have been contracted out to certain parties for fishing, but without any concerns for their conservation. There exist no restrictions on the fishing devices and fish size, and no seasonal considerations are made when contracts for fishing rights are given. In Bharatpur municipality, sections of Narayani river are reported to have been contracted out for NRs 16,501-61,000 per annum, and Gaidakot Village Development Committee has contracted out fishing rights in Narayani for NRs 7,100-13,000 per annum (Dhital and Jha, 2002).

The main problem seems to be in the lack of awareness in this field. Darwall et al. (2008), in their review of the IUCN Red List, recognize that freshwater species are "extremely threatened, possibly more so than species in the marine and terrestrial systems." The fact that not a single species, out of the 182 species identified in Nepal, is listed in any threat category in the IUCN Red List or the CITES list is proof of the lack of attention that this vulnerable ecosystem is getting even in the international arena. Furthermore, Swar (2002) observes that fisheries, being under the jurisdiction of the Ministry of Agriculture and Cooperatives and appended to agriculture development programs, has not received due priority. This is especially true with regards to open water natural fisheries management. Consequently, as of today, there is no designated agency to administer or enforce the provisions of the Aquatic Animal Protection Act-1961 (Belbase, 1997) and rampant poaching (employing fine mesh nets to harvest fingerlings of important species and their food) and the use of electro-fishing devices, explosives, and alarmingly more frequently, and toxic pesticides continue unabated throughout Nepal. Thus, the first and the most important cause of the destruction of aquatic biodiversity is the lack of awareness and enforcement of the legal provisions.

The following have been identified by various researchers (Shrestha, 1997; Shrestha, 2001; Dhital and Jha, 2002; Gubhaju, 2002; Ranjit 2002; Jha et al., 2006; others) as the causes of the decline in fish population in natural waters in the country:

- Destructive fishing methods using pesticides, electricity, explosives and fine mesh nets indiscriminately kill fish of all sizes. Because of their limited range, these devices are mostly used in small streams, which unfortunately are where many of the species hatch and live in their early years (Shrestha, 1997). Hence, in the last decade or so, new fish stocks have been decimated, reducing the chances for fish population to replenish itself. Commonly used pesticides/insecticides are Aldrin, Thiodine, Benzene Hexachloride (BHC), Malathion and Dichloro-Diphenyl-Trichloroethane (DDT) (Swar, 2002). Indiscriminate use of chemical fertilizers and pesticides in order to increase food production has been reported since the mid-eighties (Sharma, 1990).
- Round the year fishing disregarding migratory and spawning needs is another important reason for the decline in fish numbers. Shrestha (1997) found only 15-16% of adult Mahseer surviving the annual migration to return to their spawning grounds. Furthermore, fish are being wantonly killed during the spawning season when they enter small streams and creeks.
- Urbanization along river valleys is producing raw wastes, which are dumped into rivers without treatment. Increase in the use of chemical fertilizers and pesticides in agriculture is also a non-point source pollution but more in-depth enquiry is needed to ascertain its effects on aquatic biodiversity.
- Extraction of sand and gravel from every possible site for building and road construction is severely altering the physiography of rivers and streams. Shrestha (1997) points out that for Mahseer to spawn, they need at least 70% gravel in the size range of 30–65 mm in diameter and less than 10% fine particles (i.e., less than 2 mm diameter); and that the minimum depth of gravel should be 50 cm. If one drives along Trishuli or Sun Koshi rivers, he/she can see trucks excavating gravel and stones from virtually every possible site.
- Dam construction and other hydraulic engineering activities inadvertently block migratory routes of fish and alter stream and river ecosystems. However, some positive efforts can be seen in hydropower project sites. For example, while conducting the project's environmental impact assessment, Kali Gandaki A has adopted a system to restore fish population, besides carrying out in-depth studies on fish composition in the river. The system catches migratory fish below the dam and releases them upstream. Similarly, Khimti hydropower project has its own monitoring system in place and ensures that the minimum 10% flow is maintained. A tour of the area by the present authors in 2003 confirmed a healthy fish size and numbers in Khimti Khola. These are positive steps which need to be given more momentum in the future.

5. Prospects of revival of Mahseer and other fish

The government, through its three Fisheries Research Centers in Godawaari, Trishuli and Pokhara, has been successfully breeding Mahseer, Katle and Asla for some time now. It is also promising to see that 3-5-year old pond-raised Golden Mahseer (*Tor putitora*) have been spawned without the use of hormones since they were placed on a 30-40% crude protein supplement (Gurung et al., 2002). However, the major focus of these research stations has been on producing fast-growing exotic species such as carp, and high-value species like Rainbow trout. Enhancement efforts are being carried out in lakes in Pokhara and Indrasarover reservoir in Makawanpur (Swar, 2002), and fry of Rainbow trout are being distributed in small scale to private farmers. However, Directorate of Fisheries Development is yet to stock rivers to boost depleted fish population, and as mentioned above, Department of National Parks and Wildlife Conservation, which is otherwise leading the effort on species conservation, does not have any programs on fisheries. Nor do any of the major conservation agencies working in Nepal have such programs.

Nevertheless, technical knowledge to produce fingerlings of Mahseer and other game fish in hatcheries is already available. What seems to be a constraint is funding for a large-scale production to stock natural waterways. There are promising prospects though. Hydropower projects in Nepal are required to conduct environmental impact assessments and adopt mitigation measures. Some projects like the Kali Gandaki A have, as a mitigative plan, the operation of a hatchery to produce and restock the river above the dam. This could be taken to a whole new scale by establishing a national trust fund to be funded by all hydropower projects, and using the proceeds to operate a hatchery to mass produce fingerlings of Mahseer and other game fish and restocking natural waterways. An example of such a scheme is Lonavla Hatchery being operated by Tata Electric Company in India which has been producing Mahseer fry and distributing them to state government fisheries departments and angling associations since 1970 (Ogale, 2002). The initial programs concentrated on the production of *Tor khudree* (Decaan Mahseer) and *Tor mussullah* (Mussulah Mahseer) but since 1995, the Lonavla Hatchery has been successfully producing fingerlings of *Tor putitora* (Golden Mahseer), which is of concern to Nepal. Until 2000, the hatchery had distributed-for free-more than 1.2 million fingerlings of Mahseer, including to the Lao PDR. Collaborating with them would be a viable option for Nepalese fisheries projects.

6. Conclusion and recommendations

Promotion of small-scale aquaculture in Nepal will increase resilience of rural livelihood. In addition, restoration of fish population in natural waterways will have a dramatic impact on poverty reduction owing to a vast network of waterways across the nation, which can make waters accessible by the most remote communities. While aquaculture is currently being restricted by the lack of access to waters, financial conditions of the poor and topography of the country, development of open water fisheries-with a focus on angling opportunities-could have far-reaching impacts on poverty reduction, especially among the most deprived communities.

Thus, considering the grave situation with regards to natural population of fish in Nepalese waters, the following recommendations are made:

- Raise awareness on the need to conserve aquatic biodiversity, including waterfowls, extending beyond the current definition of the wetlands, which is restricted to lakes, swamps, reservoirs and ponds. This means officially acknowledging that rivers and fish, which live in them, are also a vital ecosystem warranting the utmost attention. Awareness campaign needs to focus on government agencies involved in biodiversity conservation as well as other agencies working in Nepal.
- Lobby for a clearly designated agency to administer the Aquatic Animal Protection Act-1961.
- Raise awareness among local people on the harmful effects of consuming fish killed by poisoning. This is an attempt to address the problem from demand side.
- Develop partnerships with local fishermen and explore possibilities of community-based conservation of aquatic resources. This is a major factor for the sustainability of any effort, and this is where sport fishery comes in. Developing viable angling opportunities will create the much needed employment for local fishermen, enabling them to work as fishing guides and fish rangers. These guides/rangers must be given legal authority to enforce rules and regulations.
- Develop partnerships with hydropower projects to establish a national trust fund for producing indigenous fish and re-stocking natural waterways.
- Build partnerships with universities and research agencies to develop human resource in the field of open water fisheries management.

- Standardize fish survey processes and analysis methods to enable comparison of data collected by different researchers. A long term-fish monitoring program is vital. One of the academic institutions needs to take the lead in this as they have a constant source of students who can give continuity to the research.
- Promote angling in Nepal. This entails developing recreational sites both close to cities, which have the advantage of generating the awareness among the masses, and in remote areas, which can be promoted as adventure destinations. The most vital aspect of this endeavor is the maintenance of viable population of fish in these sites. It is proposed that the pond in the central zoo and other ponds in city (e.g. Nag Daha) be promoted for this purpose. It is also suggested that certain natural waterways, such as the stretch of Bagmati river above its dam in Sundarijal, be explored for the prospects of releasing trout species for developing angling opportunities. Last but not least, re-stock our rivers!

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