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Content

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Status of Aquaculture in Nepal

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Abstract
Aquaculture is an important food sector and is growing rapidly in Nepal. Various types of aquaculture practices are being adopted in Nepal which has all together produced 43400 mt fish in fiscal year 2013/14). Pond aquaculture is the major contributor which alone generated 86.2% (37427 mt) of the total aquaculture production. Capture fisheries also an important sector and production is 21500 mt. Thus total fish production in 2013/14 sums to 64900 mt. Currently, there are 462,070 people engaged in capture fisheries among them 60% are female. Carp seeds are produced in sufficient quantity and distributed in three forms: hatchlings, fry and fingerlings. Both public and private sectors are responsible for seed supply. There are 14 government and 67 private hatcheries, 222 Nursery and 20 fish seed traders working in Nepal. Import of fish and fisheries products is in increasing trend. Fresh fish import in 2004/05 was 2547.38 mt which increased to 12869.5 mt in 2013/14 with 505.2% increment. Export of fresh fish from Nepal was not reported in 2013/14. The best export situation was recorded in 2009/10 which was 850 mt.

Keywords: Aquaculture, capture fisheries, employment, migration, export, import

1. Introduction

Aquaculture is an important food production sector in the world and similarly in Nepal. Freshwater finfish are the only records of production reported. Total fish production in Nepal reached to 57,520 mt in the year of 2012/13 (Mishra and Kunwar, 2014). Aquaculture and capture fisheries are the two sources of fish production. Contribution of aquaculture was 36,020 mt where as of capture fisheries was 21500 mt during 2012/13 (Mishra and Kunwar, 2014). Aquaculture practices that contributed fish productions are: pond fish culture; fish culture in ghols; rice-fish culture; cage-fish culture; pen-fish (enclose-fish) culture; race-way culture (trout culture). Capture fisheries are the fish catch from rivers, lakes, marginal swamps (ghols) and low-land paddy fields. Majority of cultured species are exotic and physiographic condition of Nepal supports for warm as well as cold water species. Nepalese aquaculture is in growing stage and the amount of fish production is too low compared to the world aquaculture production; however the progress achieved in recent years is highly encouraging. Fish is considered healthy source of animal protein however, its consumption in Nepal is rather low compared to poultry, buff or mutton. Its consumption in Tarai belt is higher than in other regions of Nepal. Increasing health awareness among people has led to rise in fish consumption and has promoted to increase in aquaculture industry. Fisheries and aquaculture is a reliable source of income.

Thousands of people are directly or indirectly engaged in this sector that has contributed in reduction of youth migration to some extent.

This paper will discuss present status of aquaculture and fisheries, its contribution in economic development and employment generation that provides sufficient information to all national and international readers about aquaculture and its development trend in Nepal. This paper will also be useful to planners and policy makers in identifying intervention areas and developing appropriate fisheries and aquaculture policies, plans and programs in future.

2. Natural Water Resources

Nepal is rich in natural water resources. Nearly 5.5% area of Nepal is occupied by various types of water bodies which are rich in aquatic flora and fauna. Rivers, lakes, reservoirs, ghols and irrigated paddy fields are the major source of fresh water in Nepal. Among them rivers and irrigated paddy fields are the most dominant water resources within the country.

The total available area is 820,600 ha with potential of 92000 ha to be added in future. There are 217 species of fish reported so far from these water bodies and few of them are endemic to Nepal. Similarly, 15 exotic fish species is available in the country of which 8 are popularly cultured.

Table 1. Available water resources

Resource Details	Estimated Area (ha)	Coverage Percent	Potential for Fisheries (ha)	Remarks
1. Natural Waters	401500	48.9	-	-
a. Rivers	395000	48.1	-	-
b. Lakes	5000	0.6	3500	-
c. Reservoirs	1500	0.2	78000	Estimated to be developed in the future.
2. Ponds	8600	1.1	14000	
3. Marginal Swamps	12500	1.5	12500	Water logged area.
4. Irrigated paddy Fields	398000	48.4	100000	The area considered here is with regular and adequate supply of water
Total	820600	100		

(Source: Directorate of Fisheries Development, 2014)

3. Present status of Aquaculture and Fisheries

Various types of aquaculture practices are being adopted in Nepal which all together produced 43400 mt fish in fiscal year 2013/14 (DOFD, 2014). Pond aquaculture is the major contributor to aquaculture production contributing 86.2% (37427 mt).

In pond aquaculture, Chinese carps and Indian major carps are the dominant species with average productivity of 4.35 mt/ha. These species are generally stocked under polyculture system. However, monoculture of Common carp, Tilapia and Pangasius has also been reported.

Table 2. Status of aquaculture and fisheries in 2013/14.

Particulars	**Pond (no.)**	**Total Area (ha)**	**Fish Production (mt.)**	**Yield (kg/ha)**
A. Fish Production from Aquaculture Practices			43,400	
A1 Pond fish culture	34,400	8,600	37,427	4,352
Mountain	105	7	16.6	2376
Hill	2585	274	711.6	2597
Terai	31710	8319	36699	4411
A2 Other area (ghols)		2,900	5220	1,800
A3 Paddy cum fish culture (ha)		100	45	450
A4 Cage fish culture (m^3)		60,000	360	
A5 Enclosure fish culture (ha)		100	140	1,400
A6 Trout fish culture in raceway (m^2)		10,000	192	
A7 Fish production in public sector (Mt.)			24	
B. Fish production from capture fisheries			21,500	
B1 Rivers		395,000	7,110	18
B2 Lakes		5,000	850	170
B3 Reservoirs		1,500	385	257
B4 Marginal swamps/ghols		11,100	5,990	540
B5 Irrigated low land paddy fields		398,000	7,165	18
Total Fish Production (mt.)			64,900	

Source: (DOFD 2014)

In Nepal, pond aquaculture has been categorized into extensive, semi-intensive and intensive farming. Intensive farming of Cirrhinus mrigala under single stocking and multiple harvesting to produce smaller size fish, called Chhadi, is also a successful farming system in Nepal. Now it is popular in eastern Terai and gaining popularity in other regions too. Farmers have reported productivity of Chhadi system up to 12-15 mt/ha. Such fish are demanded in hotels and restaurants mainly along highways.

Table 3. Regional pond fish production

Region	Pond (no.)	Production (mt)	Area (ha)	Productivity (kg)
Eastern	9,926	10986	2,596.00	4232
Central	12,418	16840	3,666.50	4593
Western	6,479	5922	1,453.50	4074
Mid-western	3,598	2766	654.50	4226
Far-western	1,979	913	229.50	3978

Second contributor in fish production is Ghol. There are 2900 ha Ghols used in aquaculture with 5220 mt production in 2013/14. Fish culture in cage and enclosure together produced 500 mt fish. In Nepal, cage technology was used for the first time in 1962 in Lake Phewa to raise brood fish of Common carp (DOFD 1998). Current data shows that in Nepal, cages occupy 60,000 m3 with average productivity of 6 kg/m3. This is proven as the best method of income generation for land less fishermen communities. In Lake Phewa, about 90 Jalari families have landed their cages which is a reliable source of income for them to sustain their family. However, cage culture is confined to only few lakes of Pokhara Valley and Kulekhani reservoir that needs to be extended in other potential water bodies as well.

Rice cum fish culture is a famous farming technique in many parts of world but this could not get much attention in Nepal. Though it is promoted by various sectors, it is still limited to 100 ha with only 45 mt production.

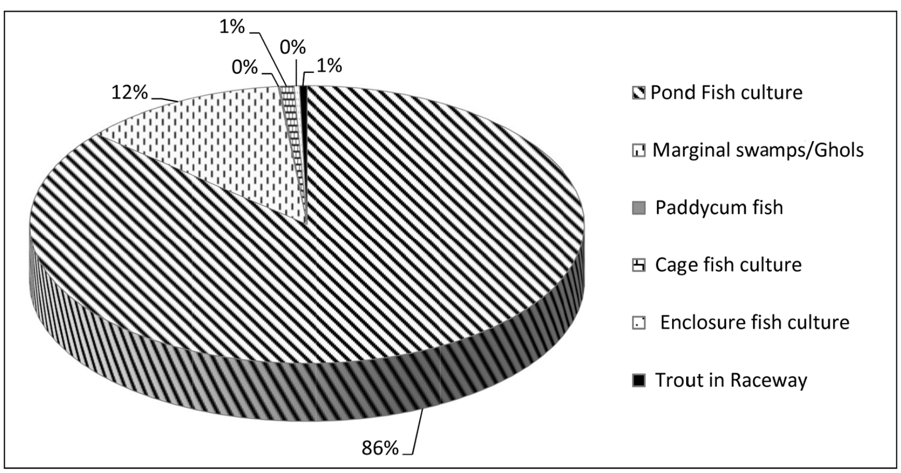


Figure 1: Contribution in aquaculture production

In Nepal, Rainbow trout, a coldwater species, was introduced in 1969 from India (Rai, 2010). However, the first attempt failed to expand it. Second attempt was made by introducing rainbow trout from Japan in 1988 and its commercial farming started in 2002 under one village one product program in Rasuwa and Nuwakot district. Trout farms integrated with restaurants is a common and successful practice in Nepal. By the end of fiscal year 2013/14 trout production reached to 192 mt. At present it has expanded to 18 districts and there is a potential for further expansion. Trout is a unique and the most expensive fish species in Nepalese market because of its taste and high nutritional value. National Inland Fisheries and Aquaculture Development Program is the focal government organization that implements and monitors trout development programs within the country.

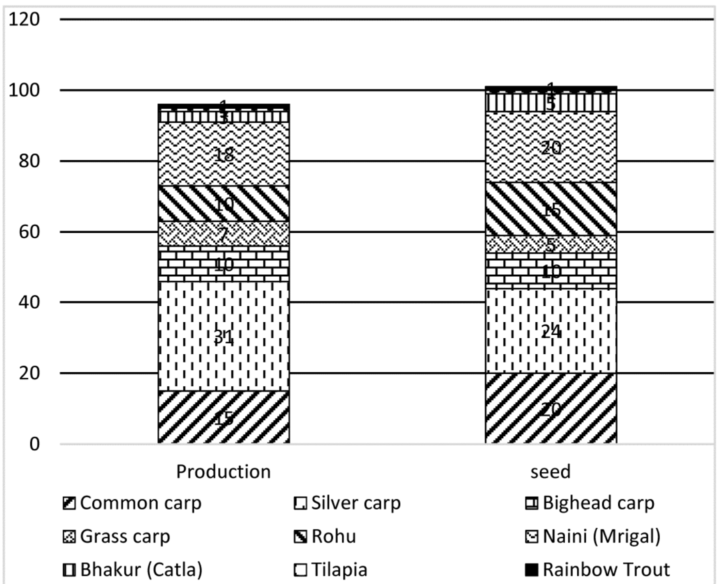


Figure 2: Species contribution (%)

Capture fisheries is very important in Nepal because of its role in fish production as well as employment generation. Capture fisheries production in Nepal is 21500 mt. Irrigated paddy fields, rivers and ghols have significant contribution in fish production whereas reservoirs and lakes have least contribution this is because lakes and reservoirs occupies small water surface areas. Fish production from ghols seems high because of its higher productivity compared to others natural water bodies.

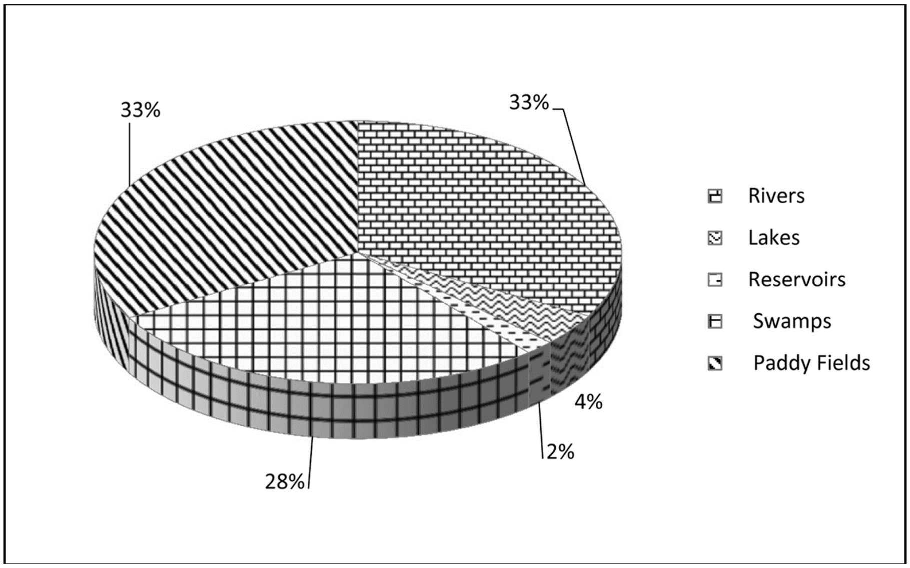


Figure 3: Contribution of various water bodies in capture fisheries

4. Employment Generation by fisheries Subsector

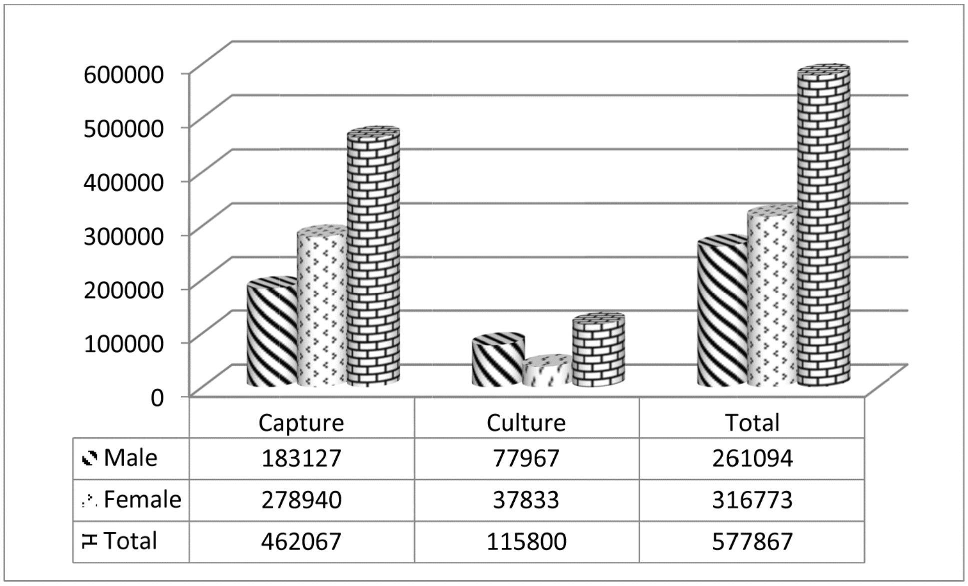
Like in most of the other developing countries, employment is a serious issue in Nepal. There is an increasing trend of youth migration to other countries in search of better employment. Fisheries sub sector can provide better employment within country and minimize youth migration.

4.1 Aquaculture in employment Generation

Aquaculture is a small agriculture practice in Nepal; however it plays a significant role in employment generation. Different ages of people are involved in aquaculture from equipment preparation, fish husbandry to marketing of fish and fisheries items. There are about hundred thousands people working directly or indirectly in this sector among them male covers 67% while female occupies only 33%.

4.2 Capture fisheries in employment Generation

Natural water especially rivers and lakes are the source of economy to many fisheries communities such as Majhi, Jalari, Mallah in Nepal. These communities live close to water source and dependent on its resources from generation to generation. There are 462,070 people engaged in capture fisheries among them 60% are female. Females are not only engaged in capturing fish but also in preparing fishing gears, equipments, fishing and selling fish in the market.



	Capture	Culture	Total
Male	183127	77967	261094
Female	278940	37833	316773
Total	462067	115800	577867

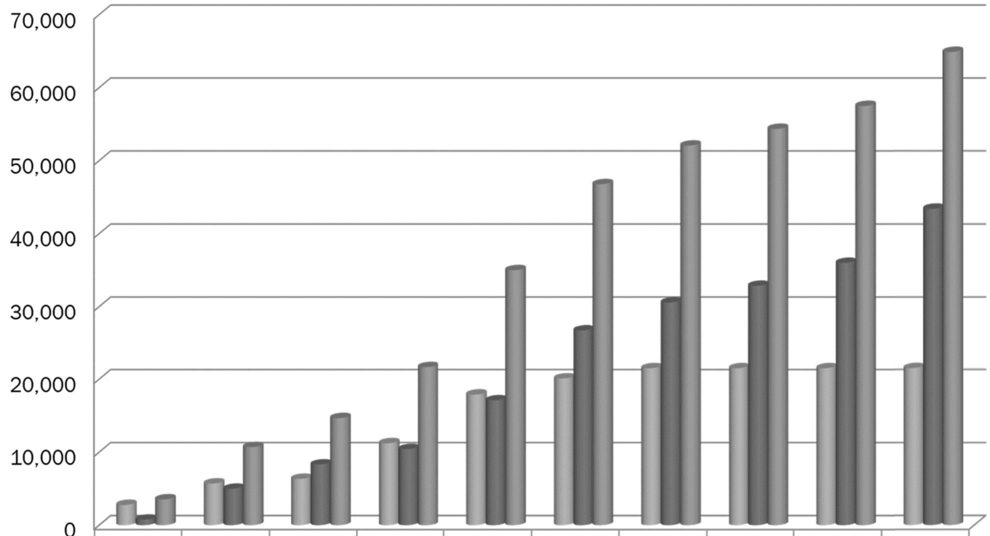
Figure 4: Employment in Fisheries (no.)

5. Development Trend

Aquaculture as a business has short history of 35 years in Nepal. In this period of time all the major indicators have increased significantly. The average growth rate was 6.95% up to 2008/09 which increased on an average to 8.4 % since then. The share of aquaculture in national fish production is constantly on increase.

5.1 Fish Production

According to FAO country profile of Nepal, national production of fish was 500 mt in 1950. This production was entirely contributed by capture fisheries. Aquaculture production was recorded only from 1966 with only 3 mt of fish production. Aquaculture production kept increasing slowly and steadily because of growing aquaculture education and technologies. Capture fisheries shows increasing trend in the beginning but remained constant at 21500 mt since 2007/08. Keeping this capture level at stand still is a big challenge for all aquaculture and fisheries workers. Production status of fiscal year 2013/14 shows that out of 64900 mt fish production, 33.21% comes from capture fisheries whereas 68.79% from aquaculture.



	81/82	86/87	92/93	95/96	2001/02	2006/07	2010/11	2011/12	2012/13	2013/14
capture	2,780	5,711	6,356	11,230	17,900	20,100	21,500	21,500	21,500	21,500
Aqua	760	4989	8317	10429	17,100	26679	30570	32857	36000	43400
Total	3,540	10,700	14,673	21,659	35,000	46,779	52,070	54,357	57,500	64,900

Figure 5: Aquaculture and capture fisheries share in national production (mt.) (Source: FAO time series data)

Per capita fish availability is also in increasing trend. From 1981/82 to 2013/14, it has significantly increased from 330 g to 2385 g due to improved national production.

5.2 Fish seed production

Seed is the most important input in aquaculture. In Nepal fish seed are distributed in three forms: hatchlings, fry and fingerlings. Both public and private sectors are responsible for seed supply. There are 14 government and 67 private hatcheries, 222 Nursery and 20 fish seed traders working in Nepal.

In last decade seed supply by public sector remained more or less constant while private sector has jumped from 5.7 million in 2001/02 to 116 million in 2013/14 this is because government has given priority to private sector in seed supply. To empower private sector, various supportive programs have been launched in the past. In fiscal year 2013/14, government has established five fish seed resource centers under private ownership one in each developmental regions of Nepal.

Table 4. Status of fish seed production in 2013/14

C. Fish Production/Distribution (No. in '000)	148,501
C1 Public Sector	31982
a. Hatchling*	132296
b. Fry	15462
c. Fingerling	8260
C2 Private Sector	116519
a. Fry	116519

* Hatchling of public sector is distributed for fry production in private sector

Source: DOFD 2013/14

Because of increasing demand, seed supply is challenging not only in terms of quantity but also in terms of quality. Government is responsible in quality control by providing financial and technical supports as well as monitoring their activities. In 2012, Food and Agriculture Organization of the United Nations (FAO) supported national fisheries program in quality seed production and regulation through a project entitled "Improving the National Carp Seed production System in Nepal (TCP/NEP/3303)". This project has drafted an act "Nepal Fish Seed Act and Carp Hatchery Accreditation & Seed Certification" (FAO 2012) which is on the process for approval. This act will be a milestone in assuring quality seed supply in the country.

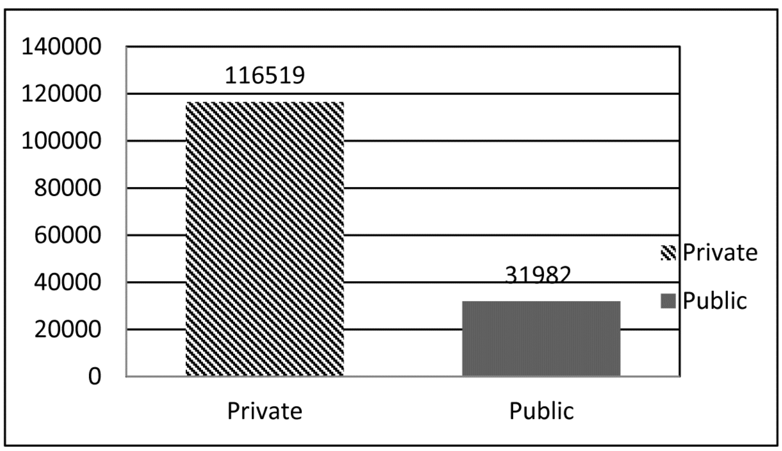


Figure 6: Fish seed production ('000)

5.3 Fish Market

Fish marketing system in Nepal varies from place to place. Farmers themselves either sell their fish from the production site or send it to local markets. In case of huge production, fish is generally marketed through contractors. There are also farmers' organizations that produce fish and sell them through cooperatives. Harpan Phewa Matsya Sahakari working in Kaski district is a successful example practicing such fish marketing system. There are also such cooperatives in Nawalparasi, Rupandehi and Kanchanpur districts (ACEPP, 2010). Recently concept of live fish marketing system has emerged and the number of live fish shop is increasing day by day. Government has also provided financial support in establishing fish marketing stalls and collection centers.

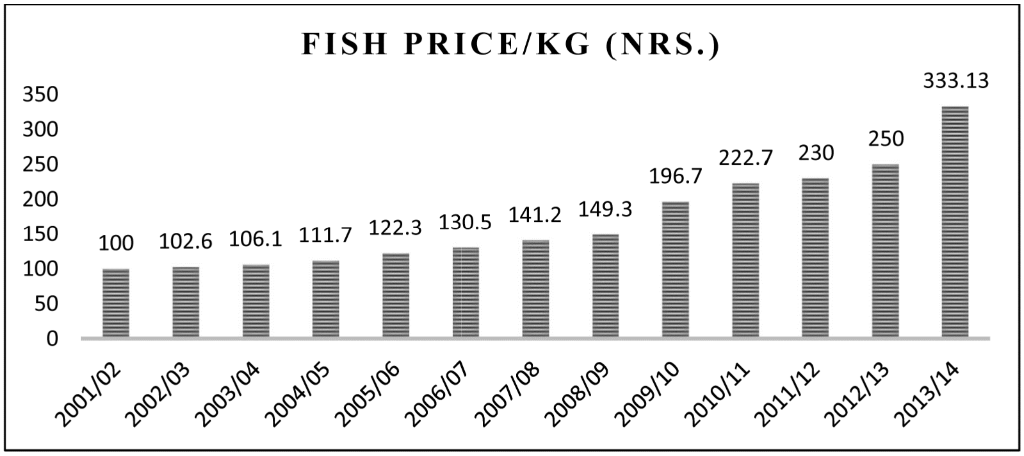


Figure 7: Market Price of fresh fish (NRs.)

In last ten years, price of fish throughout the nation has increased. In 2001/02 price of fresh fish was reported to be Rs. 100 per kg which is now Rs. 260 per kg on average but this price is still lower than price of other animal meats in current Nepali market. Fish price varies from place to place. Fish are more expensive in big cities like Pokhara and Kathmandu. Study report has shown higher fish demand in winter. The least fish consumption was reported to be in Asadh, Shrawan and Bhadra (ACEPP, 2010).

5.3.1 Export/Import Scenario

Import of fish and fisheries products is in increasing trend. Fresh fish import in 2004/05 was 2547.38 mt which increased to 12869.5 mt in 2013/14 with 505.2% increment. Similarly, fish seed Import is also high due to increasing catfish farmers in Nepal. These seeds are imported from Indian through fish seed traders and agents. Import of Bone less fresh fish, dried fish decreased in 2013/14 compared to 2012/13 but import of fish meal increased significantly.

Export of fresh fish from Nepal was not found in 2013/14. The best export situation was recorded in 2009/10 which was 850 mt. No record of fish seed export was shown in recent years however, 233475 fish seeds were reported in 2004/05 export record.

Table 5. Trade of fish and fisheries products

SN	Year	Import					Export	
		Fresh fish (mt)	Boneless Fish (mt)	Fish seed (Number)	Dried fish (mt)	Fish Meal (mt)	Fresh fish (mt)	Fish seed (Number)
1	05/06	2058,11	-	1884200	246.07	1602.95	6.42	113000
2	06/07	2261.23	-	849270	2510.83	30.02	2.86	-
3	07/08	2034.77	-	172590	277.12	351.2	4.15	22300
4	08/09	3469.94	-	14212	313.68	1097.75	134.65	25100
5	09/10	4334.86	253.2	7493	294.89	432.2	850.0	-
6	10/11	5370.2	18.0	3287834	334.11	481.0	0.36	-
7	11/12	7424.94	381.82	8975129	580.81	272.33	0.095	-
8	12/13	9963.06	270.8	14564100	514.64	214.12	0.2	-
9	13/14	12869.5	203.3	11083000	1.1	19419.61	-	-

Source: CAQO, 2014.

6. Conclusion

Aquaculture is important and rapidly growing sector of Nepal. Capture fisheries has been stagnant for since last few years. Two third of total fish production is shared from aquaculture and capture fisheries shares one third. However, capture fisheries has been the important sector for livelihood and employment generation for people residing to open water bodies. Increase in aquaculture area has increased fish seed demand and market system that has eventually promoting aquaculture business and industry in the country.

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Phenotypic divergence of snow trout (*Schizothorax richardsonii*, Gray 1932) from Rivers of Nepal: landmark based truss analysis

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Abstract

Landmark-based morphometrics were examined to evaluate the population status of Asala, *Schizothorax richardsonii*, collected from 6 isolated rivers namely Sabha, Indrawati, Melamchi, Tadi, Phalaku and Khudi). Highly significant morphological differences were observed among the *S. richardsonii* stocks. Multivariate analysis of variance (Wilks' test) indicated a significant difference for mean vectors of mophometric measurements (λ = 0.00104, $F_{110,\ 906}$= 45.363, P<0.0001) among populations. Plotting of principal component factors and discriminant functions (DF) of morphometric measurements revealed high isolation of the 6 stocks; the Indrawati stock was very isolated from the rest 5 stocks at DF1 with 88.6% among group variability, and the Sabha, Phalakhu and Melamchi stocks was located between the Khudi and Tadi stocks at DF2 with 9.5% among group variability, but was closer to the Indrawati stock. The pattern of phenotypic discreteness suggests a direct relationship between the extent of phenotypic divergence and geographic separation.

Keywords: Discriminant function, geographic separation, morphometric, phenotypic divergence, *S. richardsonii*

1. Introduction

Schizothorax richardsonii (Gray, 1832) is a coldwater cyprinid fish, commonly known as 'Asala' in Nepal and also it has been named as 'Snowtrout', formed a substantial natural fishery in the major riverine ecosystem of Nepal. The distribution of this cyprinid species is confined to the Himalayan and Sub-Himalayan rivers and streams along the country. Besides India, this species is distributed in India, Bhutan, Pakistan and Afghanistan (Talwar and Jhingran, 1991). Although *S. richardsonii* is widely distributed along the Himalayan foothills and previous studies have indicated that it is abundantly and commonly found, but recent observations indicate drastic decline in the populations of many areas of its range due to introduction of exotic species, damming and overfishing (Negi and Negi, 2010). In view of the conservational value and the aquaculture potential of asala, there has been a concerted effort to artificially propagate this species (Wagle et al., 2015). Of the aquaculture interest, their inherent biological features such as short growth period and slow growth to maturity are the main constraints hindering their growth and population increase (Mir et al., 2012). Establishment of founding stock with wider genetic variation and better shape size followed by selective breeding program would help to improve the performance of these traits.

Study of morphometric traits is one of the frequently employed and cost-effective methods of phenotypic characterization for fish stock identification. Traditional multivariate morphometrics, accounting for variation in size and shape, have also successfully been discriminated between many fish stocks (Turan, 1999). Multivariate morphometrics have successfully been employed in aquaculture studies, in assessing fish health (Loy et al., 2000), estimation of biomass (Hockaday et al., 2000), conservation driven biogeographical studies (Haas and McPhail, 2001) and population discrimination (Friedland and Reddin, 1994; Pakkasmaa et al., 1998). Such studies have significance on the relative importance of stock origin (genetics) and rearing habitat (environment) in the determination of gross body morphology. Studies of morphological character variation are, therefore, vital in order to elucidate patterns observed in phenotypic and genetic character variation among fish populations (Beheregaray and Levy, 2000).

Before going in for a breeding program, it is important to know the genetic make-up of the stocks as it would help in identifying the traits for which the stocks may be superior or inferior. Establishment of founding stock and its improvement through selective breeding requires superior character in shape and size and high level of genetic variation for traits of interest. Species widely distributed in a heterogeneous environment may be expected to exhibit differentiation in genetic or phenotypic characters or both. Among fishes, the likelihood of such character variation increases if the species has limited powers of dispersal (Planes, 1998). In fish, morphometry has been used as a tool for measuring traits, especially related to body form. Morphometric differences among stocks of a species are recognized as important for evaluating the population structure and as a basis for identifying stocks (Turan, 2004). Geographical isolation may result in notable morphological, meristic and genetic differences among stocks within a species, which may be recognizable as a basis for the conservation and aquaculture management of distinct stocks. In a study of stock differences in the common carp *Cyprinus carpio* L., Corti et al. (1988) found the pattern of morphometric variation to be consistent with differences in the genetic constitution of the stocks.

Usually, the morphometric studies have been restricted to the conventional measurements and their analyses (Hossain et al., 2010). The Truss Network Analysis overcomes the disadvantages of conventional data sets and this method produces a more systematic geometric characterization of fish shape and has demonstrated increasing resolving power for describing inter-specific shape differences (Gopikrishna et al., 2006). Landmarks refer to some arbitrarily selected points on a fish's body, and with the help of these points, the individual fish shape can be analyzed. In other words, a landmark is a point of correspondence on an object that matches between and within populations (Swain and Foote, 1999). Truss network systems constructed with the help of landmark points are powerful tools for stock identification. A sufficient degree of isolation may result in notable morphological, meristic, and shape differentiation among stocks of a species which may be recognizable as a basis for identifying the stocks. The characteristics may be more applicable for studying short-term, environmentally induced disparities, and the findings can be effectively used for improved fisheries management and identification superior stocks for aquaculture (Smith and Jamieson, 1986; Turan, 2004). Hence, the present study examines the stock differences of *S. richrdsonii* obtained from different locations and sources, through truss network analysis using the concept of size and shape.

2. Materials and methods

Specimens of *S. richardsonii* were collected from Sabha River, Indrawati River and Melamchi River of Koshi River Systems and Khudi River, Phalaku River and Tadi river of Narayani Rivers Systems of Nepal (Figure 1). Minimum of thirty specimens from each habitat used for body measurement were collected during September 2013 to February 2015. After capture with gill net, cast net and local traps, specimens were bagged individually, and placed on dry ice for transport to the laboratory where they were stored in a 4°C refrigerator until thawed for measurements and counts. The fish were 8.8-31.5 cm in total length (TL) and 4.9-443 g in weight. Geographic coordinates of sampling sites, the sample size, mean TL, and weight are given in Table 1.

Figure 1: (a) Map of Nepal, with sites where populations of *Schizothorax richardsonii* were sampled: (1) Sabha Khola, (2) Indrawati River, (3) Melamchi River, (4) Tadi River, (5) Phalaku River and (6) Khudi River

Table 1. GPS coordinates, altitude (masl; meters above sea level), number of samples, min-max. length and weight of *Schizothorax richardsonii* across the hill stream of Koshi and Narayani River Systems, Nepal

Parameters	Rivers (sites)					
	(1) Sabha, Sakhuwasabha	(2) Indrawati, Kavre	(3) Melamchi, Sindhupalchowk	(4) Tadi, Nuwakot	(5) Phalaku, Nuwakot	(6) Khudi, Lamjung
Latitude °E	27°21'49"	27°38'27"	27°52'56"	27°55'29"	27°58'35"	28°11'07"
Longitude °N	87°10'47"	85°42'23"	85°32'29"	85°23'06"	85°11'24"	84°27'30"
Altitude (masl)	335	630	985	921	625	638
Number of samples	30	30	30	30	47	40
Min-max TL, cm	11.1-21.0	16.1-31.5	14.3-25.2	8.8-13.0	10.7-24.3	15.0-27.5
Min-max BW, g	9.6-61.6	53.4-443.0	25.0-135.0	4.9-16.4	10.0-125.0	-

On each specimen eleven landmarks delineating 22 distances were measured on the body (Figure 2). Each landmark was obtained by placing a fish on graph paper. At the point of the landmark, a hole was made on the graph paper, using a dissecting needle. Finally, distances on the graph paper were measured using Vernier calipers. After the landmarks were recorded the specimen was removed and the X-Y co-ordinate data were collected. The co-ordinates were then used to calculate the truss network distances between pairs of landmarks using the Pythagorean Theorem.

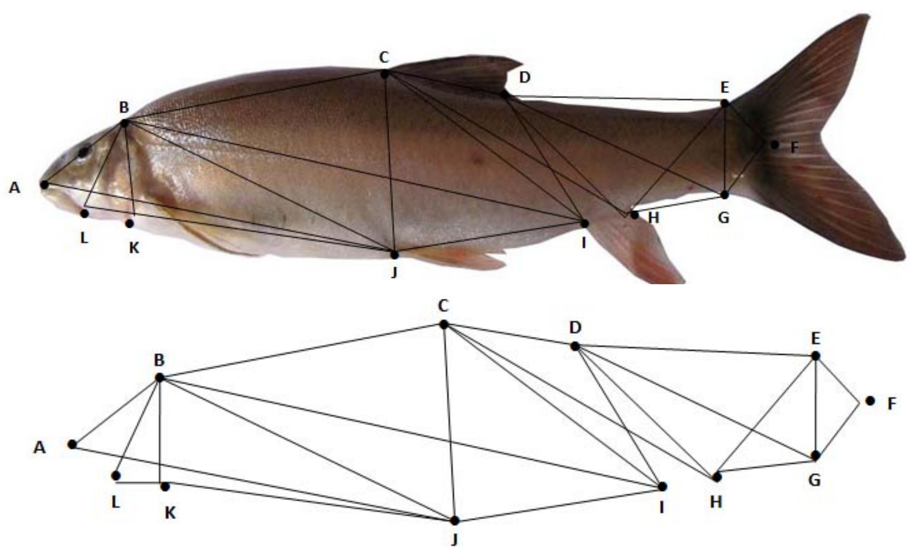


Figure 2: Schematic image of *Schizothorax richardsonii* depicting the 12 landmarks and associated box truss used to infer morphological differences among populations

Univariate analyses (ANOVA) was conducted to examine body size differences between habitats. Since size distributions were highly overlapping between habitats, the data obtained were entered in a database for subsequent factor analysis. Significant correlations were observed between size and morphometric of the samples. Therefore, it was necessary to remove size-dependent variations from all of the characters. The allometric methods are a significant help in achieving the size and shape separation and reasonably meet the statistical assumption (Swain and Foote, 1999). All measurements were standardized following Elliott et al. (1995), to eliminate any variation resulting from allometric growth.

$M_{adj} = M\,(L_s / L_o)^{b}$;

Where, M is the original measurement, M_{adj} is the size-adjusted measurement, L_o is the TL of the fish, and L_s is the overall mean of the TL for all fish from all samples. Parameter b was estimated for each character from the observed data as the slope of the regression of log M on log L_o, using all fish in all groups. This method effectively removes allomectric variation due to differences in fish size (Pakkasmaa et al., 1998). The transformed data were checked for efficiency by testing the significance of the correlation between the transformed variables and total length. Total length was excluded from the final analysis.

Univariate analysis of variance (ANOVA) was performed for landmark based 22 truss measurements to evaluate the significant difference among the six locations. The transformed data were subjected to principal component analysis and discriminant analysis to examine any phenotypic differences between the populations. Principal component analysis (PCA) based on the correlation matrices was done to create uncorrelated principal components from the original variables. The data were further analyzed with discriminant function analysis (DF) exploring the variables most useful for discriminating *S. richardsonii* populations' habitats. This procedure predicts the habitat of origin for each individual by chance. PCA and DF were computed using STATISTICA (StatSoft Inc. ver 5.0) and SPSS (ver 20), respectively.

3. Results

There was no significant correlation between any of the transformed measured morphometric variables and standard length ($P > 0.001$), indicating that the size effect was successfully removed.

Principal components (PC) with Eigen values higher that 1.00 of importance were considered (e.g. Chatfield and Collins, 1983). According to this criterion, two components remained, explaining about 94.16% of the variation of the original size-adjusted morphometric variables. PC1 and PC2 accounted for 84.76% and 9.4% of total variance, respectively, and was positively correlated to some variables and negatively correlated with others, showing that there is variation due to body shape (Table 2). The first PC composed of AB,AJ, BL, BJ, BI, BC, CJ, CI, CH, CD, DI, DH, DG, DE, IJ and JL. The second PC mainly comprised of BK, EH, EG, EF and FG. Thus, the PC 1 and PC 2 of landmark-based truss distances are associated with the swimming ability, feeding and foraging behavior of the fish. The first component (PC 1) was composed mainly of the body depth and head region. The high component loadings in PC 2 were from the characters which mostly contributed to caudal peduncle region. Thus, the PC 1 characters are associated with the swimming ability of the fish while the second component (PC 2) characters associated with feeding and foraging.

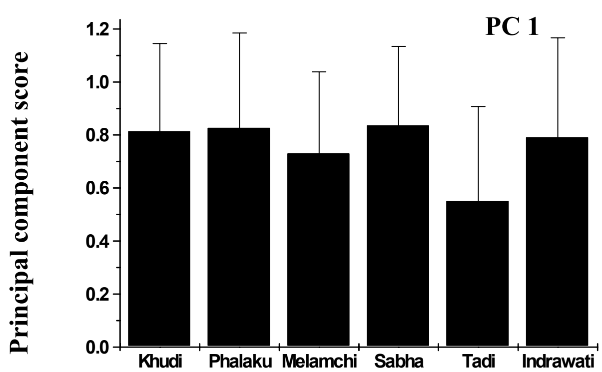
Table 2. Principal component loadings for morphometric characters in *Schizothorax richardsonii* collected from rivers of Nepal. The PCA loadings are listed together with the variables correlations (r) with the component scores. The highest component loadings are indicated in boldface

Component	PC 1	r	PC 2	r
AB	**0.951**	0.048	-0.120	-0.124
AJ	**0.986**	0.050	-0.014	-0.014
BL	**0.948**	0.048	-0.124	-0.128
BK	0.669	0.034	**-0.729**	-0.753
BJ	**0.989**	0.050	0.001	0.001
BI	**0.986**	0.050	0.076	0.079
BC	**0.957**	0.048	0.044	0.045
CJ	**0.965**	0.049	-0.045	-0.047
CI	**0.990**	0.050	0.058	0.060
CH	**0.990**	0.050	0.048	0.050
CD	**0.899**	0.046	0.134	0.138
DI	**0.990**	0.050	0.018	0.018
DH	**0.992**	0.050	0.005	0.005
DG	**0.986**	0.050	0.041	0.042
DE	**0.973**	0.049	-0.009	-0.009
EH	-0.059	-0.061	**0.961**	0.049
EG	-0.037	-0.038	**0.980**	0.050
EF	-0.084	-0.086	**0.942**	0.048
FG	-0.177	-0.183	**0.933**	0.047
GH	0.103	0.107	**0.909**	0.046
IJ	**0.953**	0.048	0.185	0.191
JL	**0.837**	0.042	0.532	0.550
Eigen values	19.749		0.968	
% of variance	84.76		9.40	
Cumulative % of variance	84.76		94.16	

Location specific (random factor) principal component scores clearly separate the population of *S. richardsonii* of Tai River from the population of other rivers (Figure 3). Average of component loadings was higher for Khudi, Pkalkhu, Sabha and Indrawati River population at PC1. Average of component loadings for location specific populations separates *S. richardsonii* populations of Indrawati and Tadi Rivers from the populations of Sabha, Phalaku, Melamchi and Khudi Rivers (Figure 3).

Discriminant function analysis (DF) was used to look for, in more detail, the body shape variables which are most explicitly differentiating among the six populations of *S. richardsonii* originating from rivers. Wilks λ tests of discriminant analysis indicated significant differences in morphometric characters of all populations ($P < 0.001$). The DF was based on the correlation matrix of the size-adjusted variables, thus giving equal weight for variation in all variables. Forward stepwise discriminant analysis of the 22 variables produced two discriminating functions. The first canonical discriminant function of the discriminant analysis explained 88.6% of the total variance while the second one accounted for 9.5% of the total variance. However, the functions emphasize the body-shape variables more than the principal component does (Table 3). Pooled within-group correlations between discriminating variables and DFs revealed that ten body measurements (AB, BL, BJ, BI, BC, CJ, CH, DI, DE, FG, IJ and JL) covering whole organism contributed dominantly to first DF. The loadings on second DF (BK, AJ, CI, EH, EG, EF and GH) dominantly contributed to opercular and caudal peduncle of the fish, implying that these characters are the most important in the description of population characteristics (Table 3). The variables loaded on first and second factors were mostly positive indicating the positive correlation between the variables within a factor. This relationship is expected as the variables loading on first factor belonged to the middle portion of the body and these traits grow proportionately with one another.

The multiple scatter plots of discriminant function (DF) axes DF1 vs. DF2 explained 98.1% of total variance among the samples and showed significant distinction among *S. richardsonii* groups from the Rivers of Nepal (Figure 3). The DF1 comprised of 88.6% of total variance completely separated Indrawati population from other five River populations which were intermingled at this axes. DF2 accounted for 9.5% of the total variance discriminated Khudi, and Sabha and Tadi populations and other three populations intermingled between these two populations. The DFA segregation was also confirmed by PCA, where the graphs of PC1 and PC2 scores for each sample revealed clear demarcation among six populations of *S. richardsonii.*



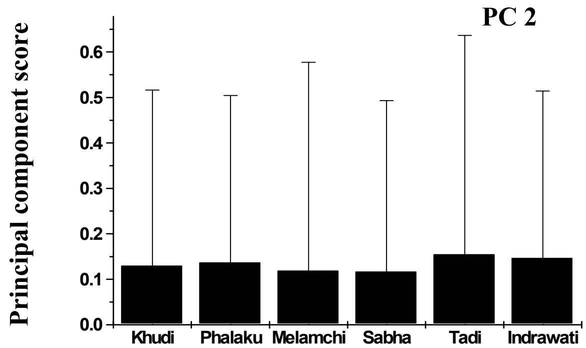


Figure 3: Location specific (random factor) principal component scores (mean with 95% confidence limit) for the six population of *S. richardsonii* studied.

Table 3. Canonical discriminant function (DF), standardized by within variances, and correlations (r) with the size adjusted morphometric variables. Largest coefficients (absolute values) for each variable are indicated by asterisk

	DF 1	r	DF 2	r
AB	0.529*	-0.840	-0.065	0.530
BL	0.553*	0.367	-0.067	-0.092
BK	-0.322	-0.920	0.451*	-0.395
AJ	-0.075	-0.253	0.759*	0.131
BJ	0.740*	-0.292	-0.070	-0.315
BI	0.751*	0.941	-0.059	0.245
BC	0.637*	-0.593	-0.052	0.094
CJ	0.635*	0.128	-0.062	0.134
CI	-0.055	0.006	0.670*	-0.349
CH	0.673*	-0.970	-0.057	-0.342
CD	0.510	0.463	-0.031	0.186
DI	0.664*	0.558	-0.059	-0.124
DH	0.670*	0.421	-0.063	0.387
DG	0.694	0.683	-0.061	0.442
DE	0.676*	-0.791	-0.068	0.680
EH	-0.067	-0.442	0.601*	0.106
EG	-0.059	0.829	0.550*	-0.903
EF	-0.057	-0.462	0.507*	-0.444
FG	0.542*	0.781	-0.071	0.131
GH	-0.040	0.196	0.554*	-0.910

IJ	0.622*	0.107	-0.031	-0.471
JL	0.756*	-0.369	0.019	0.834
Eigen values	9.221		3.409	
Cannonical R	0.996		0.879	
Cummulative variance explained	88.61		98.11	

Wilks' λ = 0.00104, $F_{110, 906}$= 45.363, P<0.0001

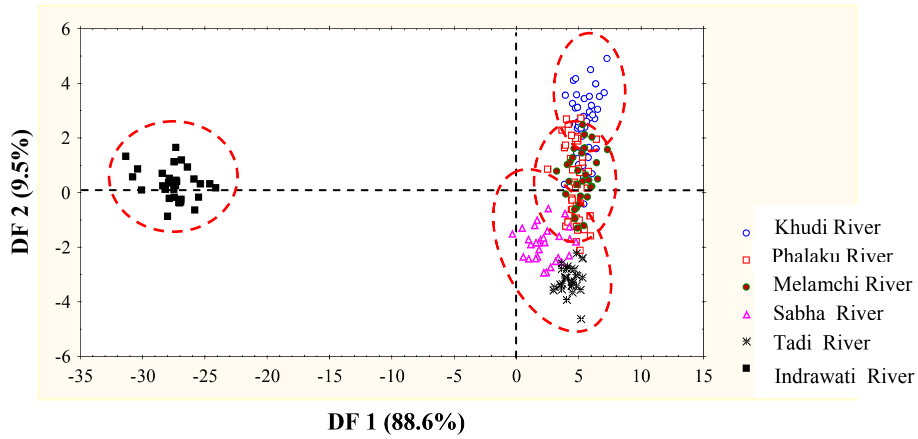


Figure 4: Discriminant function analysis scores (DF) of morphometric characters of *Schizothorax richardsonii*

4. Discussion

With multivariate statistics (PCA and DF) the morphometric characters that best discriminated *S. richardsonii* populations of river origin were identified (Table 2 and 3). The observations of morphometric characters indicated that *S. richardsonii* of Indrawati River demonstrates differences in the complexes of morphological features from the other five Rivers of Nepal. Such indications of stock structure arise from consideration of the first and second factors. This study showed that the variation is evident in the head region, body depth and the caudal region, which were useful for the stock separation. Those characters reflect the swimming, feeding and foraging ability of the fish. The variation in the caudal region of specimens from the six water bodies could be a consequence of phenotypic plasticity in response to uncommon hydrological conditions (Mir et al., 2013).

The differences in the morphometry of *S. richardsonii* between these rivers could also be because of their geographic and topographic differences. The sampling sites on Indrawati and Khudi Rivers are more wider (100-200 m) and deeper (3-5m) with relatively low human influences towards upstream whereas, the site on Sabha and Tadi Rivers are narrow (<50m) and shallow (<2m) with extensive human interruptions towards upstream. The sites on Phalaku and Melamchi Rivers are characterized by narrow and high slope gradients producing turbulent water conditions. Within this scenario, these pressures can result in more resistance on fish body during the swimming. Most fish in rivers and streams are presumably habitat specialists that could evolve various morphological and behavioral adaptations to exploit specific habitat types (Gorman and Karr, 1978; Wood and Bain, 1995).

In the present study, highly significant morphometric variations were found among the six river populations of *S. richardsonii.* The phenotypic discreteness suggests a direct relationship between the extent of phenotypic divergence and geographic separation, which indicates that geographic separation is a limiting factor to migration among stocks. Similar results for native fish species *Liza abu* (Heckel 1843) populations from the Orontes, Euphrates, and Tigris Rivers in Turkey and *Labeo calbasu* populations from the Jamuna and Halda Rivers in Banglaesh were reported by Turan et al. (2004) and Hossain et al. (2010), respectively.

Morphometric differences in intra-specific stocks are expected in geographically separated and the populations originated from different ancestors (Hossain et al., 2010). Therefore, it is not unlikely that obvious environmental variations exist in these 6 habitats (the Sabha, Indrawati, Melamchi, Phalakhu, Tadi and Khudi Rivers). Fish are very sensitive to environmental changes and quickly adapt themselves by changing necessary morphometrics. It is well-known that morphological characters can show high plasticity in response to differences in environmental conditions, such as food abundance and temperature (Swain et al., 1991; Wimberger, 1992). In general, fish demonstrate greater variances in morphometric traits both within and between populations than any other vertebrates, and are more susceptible to environmentally induced morphological variations (Wimberger, 1992). In a small mountainous country like Nepal, there are large ecological and environmental changes from place to place. The Indrawati and Khudi Rivers possess a unique environment that differs from rest of the rivers under this study. In spite of the large environmental variations, the conventional morphological study of *S. richardsonii* from these rivers has weakly demonstrated the morphological differences among the populations (Wagle et al., 2015). Population discreteness with small morphological differences in fish might be impossible to detect with study of gross morphomeristic characters (Hossain et al., 2010). Therefore, truss network measurements were employed in this experiment. Truss network systems are a powerful tool for identifying stocks of fish species (Turan et al., 2004). An unbiased network of morphometric measurements over a 2 dimensional outline of a fish removes the need to find the types of characters and optimal number of characters for stock separation, and provides information over the entire fish form (Turan et al., 2004). The truss network system can effectively be used to distinguish among the stocks of *S. richardsonii* originating from different habitats. In this case, more-significant differences were expected because of the 2 completely different habitats i.e., one is wider and deeper habitat (Indrawati River) and the other group is narrow and turbulent water. In the long term the truss system can provide a better and more direct comparison of the morphological evolution of stocks while using the same set of measurements.

Relationships among the 6 stocks differed according to whether the 1st or 2nd DF was considered (Figure 4). Considering 1st DF, the Indrawati stock displayed distinct characteristics with 88.6% group variability. Based on the 2nd DF, the Indrawati, Phlaku and Melamchi stocks, however, broadly overlapped, while the Khudi, Sabha and Tadi stocks clearly differed. The 1st DF accounted for 9.5% of the among group variability and it is obvious that the 2nd DF explains much less of the variance than does the 1st DF. The 2nd DF is; therefore, much less informative in explaining differences among the stocks.

Truss system based morphometric characters suggest high phenotypic differentiation among the *S. richardsonii* stocks from the rivers Sabha, Indrawati, Melamchi, Tadi, Phalaku and Khudi. Differences between stocks coincide with geographic proximity. The strong association of different morphological variants with geographic proximity provides a biological basis for the evolution of morphometric and meristic differentiation, since differences in water temperature or food availability, for example, may lead to variation in growth rates, size at maturity and spawning activity (Turan et al., 2004). Phenotypic variation among natural populations sometimes reflects genetic adaptation to local selective pressures (Schluter, 2000). At other times, it reflects plastic responses to local environmental conditions (Berven et al., 1979; James, 1983). Most of the time, populations could diverge via alternative, genetically based morphologies, or through environmentally induced phenotypes (Langerhans et al., 2003). Disentangling the relative contributions of genetic and environmental effects is particularly important for understanding the factors that promote or constrain evolutionary diversification. Whether the observed morphological patterns were produced in this study through genetic differences or phenotypic plasticity is unknown. Crabtree (1986) found substantial morphological variation associated with genetic variation in *Atherinops affinis*. Similarly, greatest differences in genetic, morphometric and meristic data are known between wild and cultured tilapia (*Oreochromis* spp.) with high and low levels of genetic variation, respectively (Barriga-Sosa et al., 2004). Indeed, low genetic diversity is commonly reported for natural population of fishes, perhaps largely because of high gene flow in the continuous water environment (Grant and Bowen, 1998). The analyses of the present study revealed variation among *S. richardsonii* populations in morphometric characters. In species which have a wide range of zoogeographical distribution, most of the characters are strongly influenced by the environment and for the species showing restricted distribution the morphometric characters are genetically controlled (Vladykov, 1934). In a study, Negi and Negi (2010) reported that 90% variation in morphometric characters of *S. richardsonii* populations from Uttar Kashi, India are genetically controlled and environmentally controlled characters are a few (10%). Even though genetic differentiation so far has not been demonstrated in present *S. richardsonii* populations, it should be emphasised that the application of more powerful genetic techniques (Shaw et al., 1999) or the use of a number of polymorphic loci (Hauser et al., 2001) would be very beneficial to support the detected phenotypic variation.

5. Acknowledgement

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Fish catch seasonal variation in Phewa Lake, Nepal

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Abstract

This study examined the seasonal trends of fish catch with some environmental variables in Lake Phewa situated in mid hills of Nepal. To meet the purpose we collected fish catch data on daily basis from fishermen involved in gill net fishing for 11 months from October 2004-August 2005. The water quality parameters such as water temperature (°C), rainfall (mm), chlorophyll a (mg.L^{-1}), and dissolved oxygen (DO, mg.L^{-1}) were collected once in a month. The fish catch yield showed up to 20 time higher biomass in December than in August. The low catch yield from April-August was probably associated with windy rain in evening and nights during pre-monsoon and monsoon. Our analysis showed that bighead carp (*Aristichthys nobilis*) and silver carp (*Hypophthalmichthys molitrix*) were the most contributing fish in terms of biomass yield. The total fish catch yield did not fit with examined environmental variables. Contrarily, grass carp (*Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*), magur (*Clarias* spp), rewa (*Chagunius chagunio*), bhitta (*Puntius* spp) showed significant relations (P<0.05) with Chlorophyll *a*. Sahar (*Tor* spp), Katle (*Acrossocheilus hexagonolepis*) showed significant relation (P<0.05) with Chlorophyll *a*, water temperature and Dissolved Oxygen.

Keywords: Gill net fishery, Phewa Lake, water temperature, Cholorophyll *a*, rainfall

1. Introduction

Lake water environmental parameters have been seen as an important parts of the fish catch prediction (Quiros, 1990; Matthews, 1998; Gray et al., 2015). However, such prediction fails in many lakes, suggesting larger data set required to establish relations between lake water parameters and fish yield (Ranta and LindstrÖm, 1992; 1998). Besides, scientific importance, lakes provide ecological services to societies through open water fisheries and other various uses. Capture fishery as an occupation of mostly marginalized small scale fishers represented nearly by 20 ethnic groups comprising nearly 10.8% of the total population of the country (IUCN, 2004; Gurung, 2007).

Lake Phewa is a small lake in central Nepal with mountainous environment (Ferro, 1978; Gurung, et al., 2006). This lake has been stocked with exotic carp to enhance fishery around 1975 with aim to support the livelihood of deprived fishers living around the shore lines (Ferro, 1978; Swar and Gurung, 1988; Gurung et al., 2005). The open water fisheries in Lake Phewa is mainly comprised of Chinese carp, indigenous major carp, minor carp, some catfish and few other group of fishes. These fishes exhibit specific patterns and life history traits such as reproduction, feeding, short migration, adaptation to certain biotic and abiotic rhythm according to winter, summer, monsoon, water temperature, nutrients concentration, Chlorophyll *a*, abundance of phytoplankton and zooplankton, in general (Quiros. 1990; Matthews. 1998; Rai, 2000; Bera et al., 2014). There are few studies on seasonal trend of gill net fish yield in lakes (Vašek et al., 2009; Bobori and Salvarina, 2010), although long term yield studies are persisting well (Jul-Larsen et al., 2003; Gray et al., 2015). Seasonal gill net fish yield studies could be useful to plan fishing, developing market and postharvest, restocking strategies for better management. Since, the gill net fish yields in relation to lake environmental parameters were not clearly known in Lake Phewa. Therefore, in present study the seasonal gill net fish yield in relation to important water quality variables has been evaluated.

2. Materials and Methods

2.1 Study site

Lake Phewa is situated in south-west of Pokhara Valley (28°7’ N to 28°12’ N and 84° 3’ E to 84° 10’ E) in Central Himalaya Nepal (Fig. 1). It is a small monomictic lake, occupying approximately an area of 4.43 km^2 at 782 masl in mountainous area, receiving highest amount of rain in the country, exceeding sometimes more than 5000 mm per annum (Gurung et al., 2006). The Lake Phewa, a subtropical one, fluctuates from oligo to eutrophic in its nutrient concentration (Rai, 2000). The maximum depth of the lake is 23.5 m. with an average of 8.6 m.

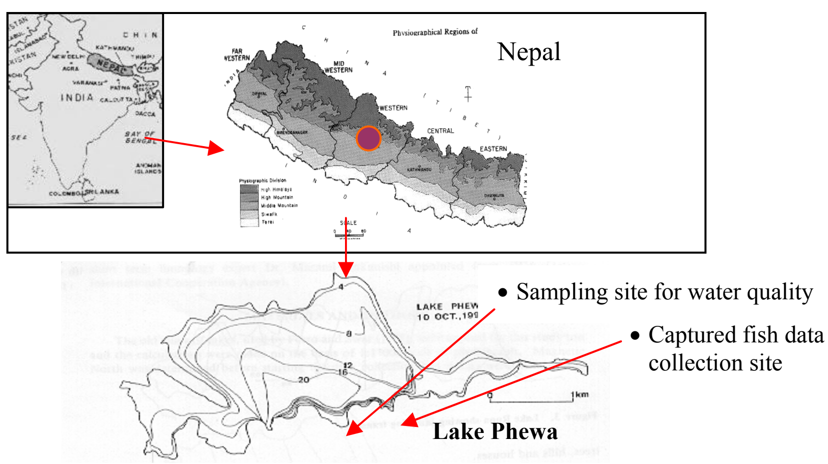


Figure 1: Water quality and captured fish data collection site of in the study area

The present study was carried out in Lake Phewa from October 2004 to August 2005 for 11 months. In the lake fishing with modern gears such as gill net started around 1960 with the initiation of United Nations Food and Agriculture Project (Ferro, 1978). Before that caste net and hooks were the mainly gears used for fishing in the lake (Gurung et al., 2005).

2.2 Fishing gear

The gill nets were all operated by local fishers living around Phewa Lake daily except few days in holidays for their livelihood by a total of about 100 households. The gill nets were made up of polyamide monofilament type with a length varied from 20 to 40 m and width of 5 to 7.5 m. The seasonal trend of mesh size use varies in winter and summer (monsoon) months. The smaller mesh nets (25mm-30mm) are usually operated in rainy season towards the shore line or littoral areas targeting to capture smaller fishes represented mostly by indigenous fishes having individual body weight from few grams to 1 kg at maximum, except large size Sahar, Katle, Rohu, Bhakur etc.

The large meshed gill nets (100, 250 and often 300 mm) set up offshore in deeper parts are rolled up in windy rain, in such case these net becomes useless. The large meshed gill nets are often targeted to catch big sized fishes often ranging from 3 to 50 Kg individual body weight, such as bighead carp, silver carp mostly and rarely Rohu, Mrigal, Bhakur, Sahar, Katle and others. In calm winter months with no strong wind, the fishers operates large meshed gill nets offshore in deeper area targeting to catch bighead, silver and other native major carp. Approximately 150-250 gill nets were used daily for fishing in the Lake Phewa.

The gill nets were set at around 1600-1800 hrs in the evening depending on season, early in the winter and late in summer with the support of small positive buoyancy or floats at the surface and negative buoyancy or sinkers at the bottom. The gill nets were examined for fish entangled early in the morning at around 0400-0500 hrs (some time 0500-0600 hrs in winter) by fishers owing the net. The entangled fish were collected in the boat and brought to the bank for weighing and marketing purpose. To collect the gill net fish catch daily landings were closely monitored and documented for weight and species in single market outlet from 0600-0800 hrs in the morning. The body weights were measured using commercial pan balance having the capacity up to 100 kg.

2.3 Water quality

The water quality parameters collected from the lake were water temperature, dissolved oxygen, Chlorophyll *a* on monthly basis. The water temperature was measured using simple thermometer. The sample for DO and Chlorophyll *a* were collected from 0, 2.5, 5, 7.5, 10, 15 and 20 m depths using 3-0 L capacity van-Dorn sampler from the deepest part of the lake located at nearly 750 m away from the eastern bank of the lake. Dissolved

Oxygen (DO) was measured using Winkler's method, while the Chlorophyll *a* concentration was measured using the method as described in Gurung et al. (2006). The rainfall data were collected from nearby meteorological stations situated approximately 1.0 away from the lake. The statistical analysis was carried out using simple regression linear model. Mean and Coefficient of Variation (CV%) of fish yield and major aquatic variables were calculated.

3. Results

The fishes which were captured by the use of gill nets could be categories mainly as those of Chinese carp, native carp and catfishes (Table 1). There were mainly 15 genus of fish recorded in gill net captured fisheries in the lake. Lake Phewa, a small lake in central mid hills occupies a catchment areas receiving highest amount of rainfall in Nepal (Fig. 2 A). The rainfall with strong wind, storm followed by mostly associated with lightening in evening start around the end of March as pre-monsoon shower followed by monsoon mostly from middle of June to end of September. Usually the weather and lake surface remains calm during the month of October to February. The lake water temperature ranges from 17 - 29°C, lowest in January and highest recorded in June during the study period. The lake stratifies clearly once in a year, thermocline begin to develop after the end of March, while mixing initiated in November and holomixing occurring in January, when most water environment parameters become same almost in whole water column from bottom to surface (Fig. 2 B). The chlorophyll *a* concentration ranged from 5 - 14 mgL^{-1}, lowest in October and highest in June (Fig. 2 C). The chlorophyll *a* picked in June but sharply declined in July and August October onward, the chlorophyll-*a* slowly increased except in January. The concentration of DO ranged from 3.3 to 8.7 mg L^{-1}, lowest recorded in the month of May and highest in February in water column of the lake. The DO increases in lake-column after June except some decline in the month of August and peaked in February (Fig. 2 D).

Table 1: Enlisted fishes in Lake Phewa (2004-05) captured by stagnant gill nets

Scientific names	Vernacular name	English name
Hypophthalmichthys molitrix	Silver carp	Silver carp
Aristichthys nobilis	Bighead carp	Bighead carp
Ctenopharyngodon idella	Grass carp	Grass carp
Cyprinus carpio	Common carp	Common carp
Labeo rohita	Rohu	Rohu
Cirrhinus mrigala	Naini	Mrigal
Catla catla	Bhakur	Catla
Tor putitora	Sahar	Mahseer
Chagunius chagunio	Rewa	Minor carp
Neolissochilus hexagonolepis	Katle	Katle

Mastacembelus armatus	Bam	Spiny eel
Puntius spp	Bhitte	Barb
Xenentodon cancila	Dhunge bam	Freshwater gar
Barilius spp	Fageta	Barilia
Clarias spp	Magur	Catfish

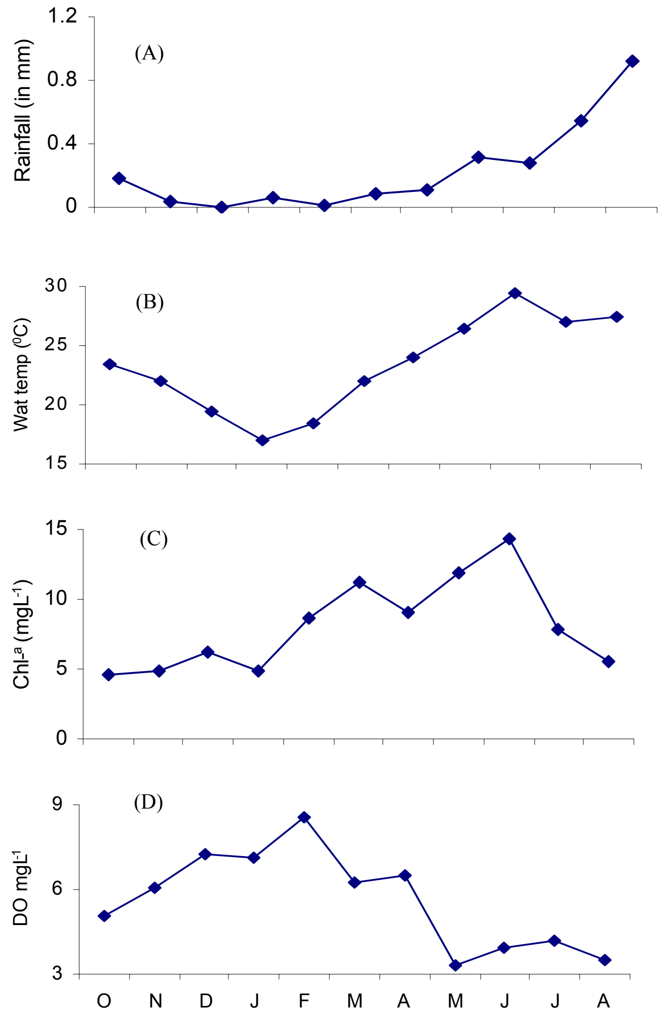
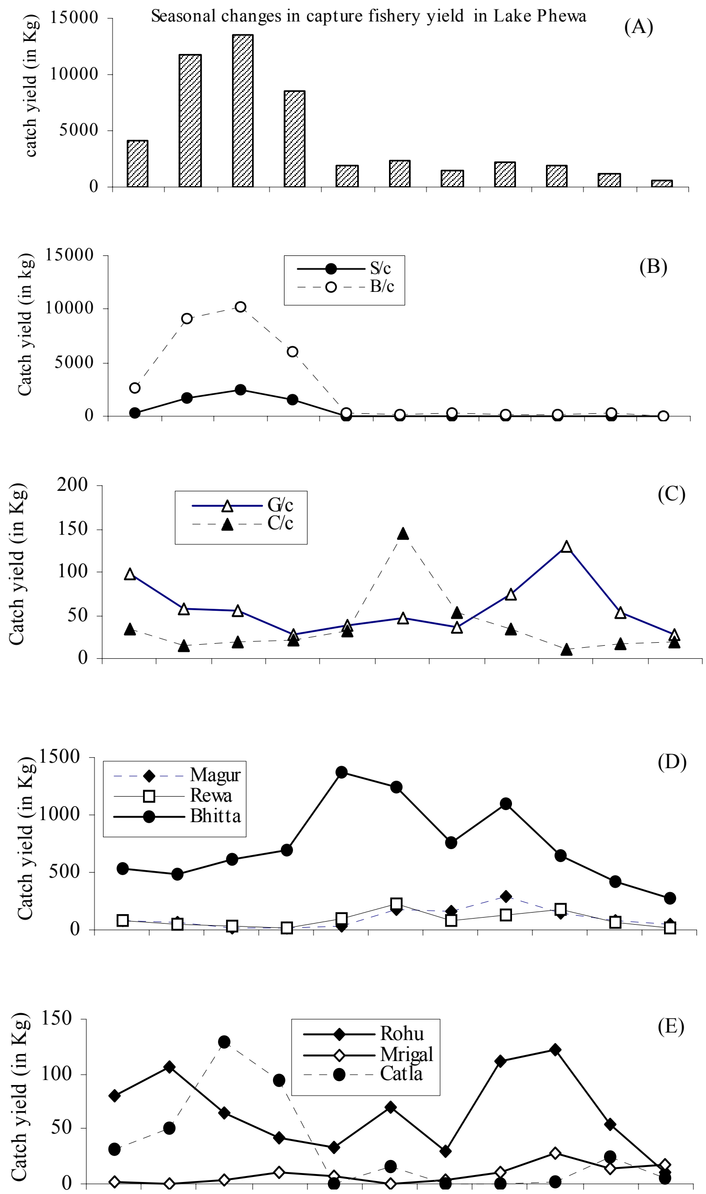


Figure 2: Seasonal variation of rainfall (A) in surrounding area, water temperature (B), Chlorophyll *a* (C), and Dissolved Oxygen (D) in Lake Phewa during study period

The fish yield by gill net showed ranging from 650-13568 Kg per month, lowest in August and highest in December (Fig. 3 A). The fish yield started to rise up from October, steadily increasing in the month of November and reaching highest yield in December. The fish catch then gradually declined in January. The months from October to December seemed most promising for higher gill net fish yield. The fish catch declined sharply in months from February to August.



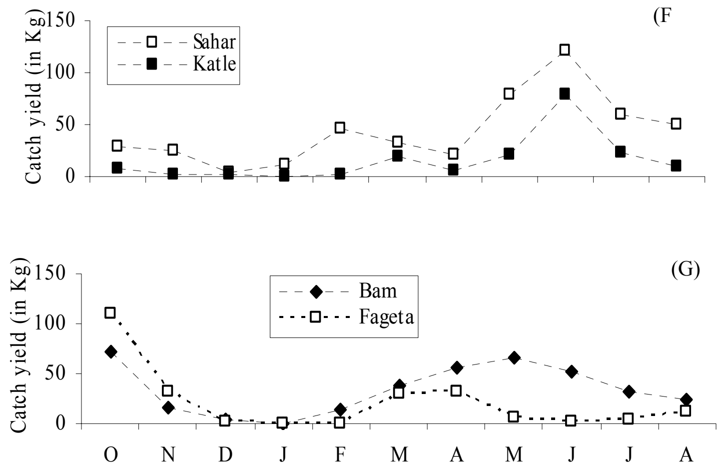


Figure 3. Seasonal changes in total capture fish yield (A), Silver carp (S/c) and Bighead carp (B/c) (B), Grass carp (G/c) and Common carp (C/c) (C), Magur, Rewa and Bhitta (D), Rohu, Mrigal and Catla (E), Sahar and Katle (F), Bam and Fageta (G).

The major contributor in gill net fish yield was Bighead carp followed by Silver carp (Fig. 3 B). The gill net yield of bighead and silver carp showed almost similar trend, but the magnitude of bighead carp yield was almost 5 folds more comparing to Silver carp from October to January in winter months. In rest of the months also the catch yield of Bighead carp was always higher than Silver carp. The low catch fish yield occurred in the months from January to August. Only small fractions of fish yield in gill net fishery contributed by grass carp and common carp (Fig. 3 C). The total gill net capture fish yield of grass carp was from 27 to 135 Kg per month, lowest in January and highest in June; while common carp yield varied from 10-144 Kg per month, lowest in June and highest in March.

Among important native fish species minor fishes were the major contributors (Fig. 3 D). *Puntius* spp collectively known as Bhitta showed the yield from 276 to 1365 kg per month, lowest in August and highest in February. The other species which contributed the fishery were Rewa, Rohu, Mrigal and Catla (Fig. 3 E, F). The catch yield of Rewa, Rohu, Mrigal and Catla only reached up to 140 kg per month at most. Among other major native fishes Sahar and Katle also contributed negligibly (Fig 3 F). The Sahar showed a range of yield from 3 to 135 kg per month, lowest in December and highest in June. Similarly, Katle showed a range of yield from none to 79 kg per month, minimum in January and maximum in June (Fig. 3 F). Spiny eel, (*Mastacembelus armatus*) (Bam) showed the yield ranging from 0.5 to 72.5 kg per month, lowest in January and highest in October (Fig. 3 G). *Barilius barna* (Fageta) also showed a range of yield from none to 110 kg per month, none in February and highest in October (Fig. 3 G).

Mean (X) and Coefficient of Variation (CV%) of gill net fish yield showed higher fish yield variation in bighead carp and least with Mrigal (Table 2).

Table 2. Mean (X) and Coefficient of variation (CV%) of fish yield and some major environmental variables in Lake Phewa (2004-05)

Variables	**X**	**CV (%)**
Hypophthalmichthys molitrix (Silver carp) (kg)	562	1.57
Aristicthys nobilis (Big head carp) (kg)	2675	1.45
Ctenopharyngodon idella (Grass carp) (kg)	58	0.54
Cyprinus carpio (Common carp) (kg)	36.31	1.04
Labeo rohita (Rohu) (kg)	65.61	0.55
Cirrhinus mrigala (Mrigal) (kg)	8.68	1.01
Catla catla (Bhakur) (kg)	31.81	1.35
Dissolved Oxygen ($mg.L^{-1}$)	5.61	1.22
Chlorophyll *a* ($mg.m^{-3}$)	8.10	0.40
Rainfall (mm)	0.23	1.22
Water temperature (^{o}C)	23.36	0.17

The values of environmental variables were within the range as reported earlier in several studies. The relationship between gill net capture fish yield and environmental parameters (Table 3) had no significant relations ($P<0.05$). Similarly, bighead carp and silver carp did not show any significant relationship ($P<0.05$) with the measured parameters. Grass carp and Common carp showed significant relation with Chlorophyll *a* concentration, while Magur, Rewa and Bhitta also showed significant relationship ($P<0.05$) with Chlorophyll *a*. The Sahar and Katle captured yield also showed significance relationship ($P<0.05$) with temperature, Chlorophyll *a* and DO.

Table 3. The regression model (linear model = a + b*x) showing relationship with gill net capture fish yield and environmental parameters (P<0.05).

	Variables	F-ratio	P-Value	R^2	Statistical Significance
Total Capture Yield	Rainfall	3.71	0.0861	0.292	NS
	Temperature	4.85	0.055	0.3503	NS
	Chlorophyll *a*	3.36	0.0999	0.2719	NS
	DO	2.29	0.1645	0.2028	NS
Silver carp + Bighead carp	Rainfall	2.7	0.1345	0.231	NS
	Temperature	4.34	0.0668	0.3255	NS
	Chlorophyll *a*	4.5	0.063	0.3332	NS
	DO	1.99	0.1916	0.1813	NS
Grass carp +Common carp	Rainfall	0.57	0.4691	0.0596	NS
	Temperature	0.56	0.4716	0.059	NS
	Chlorophyll *a*	5.36	0.0459*	0.373	Fit
	DO	0.23	0.6442	0.0247	NS
Magur+Rewa+Bhitta	Rainfall	2.13	0.1785	0.1913	NS
	Temperature	0.22	0.6536	0.0233	NS
	Chlorophyll *a*	7.58	0.0224*	0.4571	Fit
	DO	0.56	0.4735	0.0585	NS
Rohu+Mrigal+Catla	Rainfall	0.81	0.3928	0.0821	NS
	Temperature	0.18	0.6819	0.0195	NS
	Chlorophyll *a*	0.12	0.7319	0.0136	NS
	DO	0.02	0.8849	0.0024	NS
	Transparency	0.03	0.876	0.0037	NS
Sahar+Katle	Rainfall	1.36	0.274	0.131	NS
	Temperature	13.13	0.0055*	0.5932	Fit
	Chlorophyll *a*	11.99	0.0071*	0.5711	Fit
	DO	6	0.0368*	0.4001	Fit

4. Discussion

The distribution of fish communities could be highly heterogeneous and fluctuating over space and time in lakes (Quiros, 1990; Ranta and Lindstrom, 1992; Matthews, 1998). In present study, the seasonal gill net total capture fish yield in Lake Phewa did not show significant relationship (P<0.05), however, showed significant relationship (P<0.05) with fish species mostly native, categorized as Sahar, Katle, Magur, Rewa, Bhitta except introduced Grass and Common carp (Table 3). The reasons of such contradictory results could be several; essentially the gill net captured fish might represent only a fraction of total fish biomass in the lake. Previous studies revealed that the capture fish yield hardly shows positive relationship with water quality variables (Ranta and LindstrÖm, 1992; 1998). Apparently, it seems there should be positive relationship between the gill net yield an lake water environmental parameters, in fact a long term data set might required establishing such positive relationship empirically, a shorter time series data may not be adequate. The trend of total fish yield may also depend on effort of catch, fishing devices, mesh sizes, weather conditions, species composition etc (Matthews, 1998; Bobori and Salvarina, 2010; Mboya, 2013; Bera et al., 2014).

The gill net yield of the total fish was many folds higher in winter months from October to January comparing to rest of the months. The high yield associated in these months were due to dry and calm weather conditions, when gill nets were not disturbed but remain intact in absence of windy storm in lake (Fig. 2 A, 3 A, 3 B). These showed that October to January was the best season to operate large mesh gill net off shore in the lake for catching most dominantly caught bighead and silver carp in terms of biomass. Other months, from February to August was not suitable to use the gill nets offshore, especially those with large mesh size, because in period from February to August, fishes other than bighead and silver carp were caught in substantially low amount. Exceptionally, some fish species categorized as Grass carp, Common carp and native Rewa, Bhitta, Magur, Sahar and Katle showed significant relationship ($P<0.05$) with Chlorophyll *a* (Fig. 2 C, Table 3, Fig. 3 E, F). In support of such relationship, it was showed that gill net fish catch and fisher folk activities are highly influenced by weather, rain, and climate variability in African lakes (Mboya, 2013). Implying that gill net fish yield need to be viewed in relation to climate change scenario to support small scale marginalized fishers.

Generally, native fish species with exception of grass and common carp caught at shoreline or littoral zone using small mesh gill nets showed significant relationship ($P<0.05$) with Chlorophyll *a*. This relationship might due to the smaller mesh size of gill net probably which had been not accounted in detail in present study. There was no significant relation ($P<0.05$) of the highest contributed bighead and silver carp with lake water environmental parameters. The bighead and silver carp were mostly caught from offshore using larger mesh gill nets from October to January in winter months.

Contrarily, fishes other than bighead and silver were mostly caught at littoral zone using smaller mesh gill nets during sun shining, warm, stormy and raining months from February to August. Since the Chlorophyll *a* concentrations usually increases in these months, therefore a significant relationship might existed with fishes other than bighead and silver carp, in general (Table 3). The gill net yield of Sahar and Katle showed significant relationship ($P<0.05$) with water temperature and DO (Table 3). This was because Sahar and Katle were mostly caught during late pre- to almost mid monsoon phase (May-July) with prevailing high water temperature naturally (Fig. 2 C, 3 F).

Recently, it has been shown that smaller mesh size gill nets succeeded to catch relatively higher amount of fish comparing to bigger mesh net (Hay et al., 2002; Muthmainnah et al., 2014). In present study the fishers used large mesh size gill nets from October to January, because this period is relatively calm and useful to set gill net focusing on larger exotic fish such as bighead and silver in Lake Phewa. While, in other months since storm and windy rain upset the gill nets set in off shore in deeper parts, therefore the fishers avoid using large mesh net. Instead, set smaller mesh gill net at inshore focusing to catch smaller native fish species for their livelihood. The significant relation ($P<0.05$) of predominantly native fishes with water environment parameters might reflect higher efficiency of smaller mesh gill nets.

Gill net fishing is the main occupation of about 100 deprived small holder fisher's families living around Lake Phewa. Considering the seasonal fish catch data, it seems that besides the months from October to January the fish catch is not adequate for food and nutrition security. Therefore, from management perspective option to increase adequate gill net fish catch and improving productivity (Misund et al., 2002; Kolding and Zwieten. 2006), the Lake Phewa should be prioritized in forthcoming studies. One of the objectives of lake-fishery management is to find appropriate methods capable of predicting fish yield in lakes with known characteristics (Ranta and LindstrÖm, 1992; Rawson, 1951; Ryder, 1982). The present study showed that gill net fish yield substantially declined in monsoon months, suggesting that options should be developed to overcome such constraints for consistent catch throughout the year to support the livelihood of fishers depending on fishing. Since, the gill net catch yield may represent the fish abundance and biomass of particular lake, thus to establish clear cut relationship of gill net fish yield with water environment parameters more detail and long term data on gill net types, fishing efforts and fish landings would be essential.

5. Acknowledgement

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Effect of aromatase inhibitor on gonadal development and growth of female Nile tilapia (*Oreochromis niloticus)*

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Abstract

An experiment was conducted to examine the effect of aromatase inhibitor (Exemestane) on growth and gonadal development in sub-adult female Nile tilapia (*Oreochromis niloticus*). All-female Nile tilapia of 100 days after hatching (dah) were stocked at the rate of 30 fish, in 50-L glass aquariums and fed with control and aromatase inhibitor treated feed (1 mg/g diet) for 120 days. The experiment was laid out in a completely randomized design with three replicates in each treatment. Results showed a significant increase in body weight and decrease in gonadosomatic index in aromatase inhibitor treated fish than control. The gonadal development was completely suppressed in aromatase inhibitor treated fish during treatment. Fish treated with aromatase inhibitor significantly suppressed plasma estradiol-17β level and increased level of 11-ketotestosterone. These results indicate that treatment of sub-adult Nile tilapia with aromatase inhibitor enhance fish growth, apparently by a complete suppression of gonadal development.

Keywords: Aromatase inhibitor, Exemestane, Nile tilapia, Gonadosomatic index

1. Introduction

Tilapias are currently the second most farmed group of finfish with an annual world production of 2.7 million tons (FAO, 2014). However, early maturation, crowding and stunting still are the major problems in tilapia aquaculture. Thus, most of the prior researches focused on the production of monosex or sterile tilapia to solve the problem of precocious maturity and uncontrolled reproduction (Brämick et al., 1995). In tilapia, it has been proved that the administration of exogenous estrogens or androgens during sex differentiation to genetically male or female individuals, respectively, transforms the sexual phenotype to the opposite gender (Nakamura et al., 1998; Strüssmann and Nakamura, 2002), which is desirable in commercial culture. However, this exogenous sex steroid treatment must be performed throughout the so-called critical period, which includes both the physiological and morphological phases of sex differentiation to induce sex reversal in an effective manner (Nakamura and Iwahashi, 1982).

Aromatase inhibitors (AIs) are chemicals that block P450arom activity, leading to reductions in the production of estrogen (Steele et al., 1987). AIs have been used in the treatment of breast and ovarian cancer in postmenopausal women (Howell et al., 2005) and in studies of sex change in a wide range of teleost fish, e.g., genetically female tilapia (Kwon et al., 2000; Afonso et al., 2001; Kobayashi et al., 2003; Ruksana et al., 2010), Japanese flounder (Kitano et al., 2000), and zebra fish (Uchida et al., 2004). The ability of AI to induce sex reversal towards male in fish makes this chemical a valuable tool for reproduction control, and analyzing the role of estrogen in the processes of sex differentiation and sex change.

Use of AIs for the production of all-male populations is widespread in tilapia aquaculture (MacIntosh and Little, 1995), but the use of this chemical for the sexually differentiated fish is not developed for practical usage. It is very difficult to get large numbers of sexually undifferentiated juveniles in practice because of failure to optimize the proper breeding and other necessary parameters. The aim of this study was to test the effect of aromatase inhibitor, Exemestane, on growth and gonadal development in sexually differentiated Nile tilapia.

2. Materials and Methods

All-female Nile tilapia of 100 days after hatching (dah) were stocked at the rate of 30 fish, in 50-L glass aquariums, each with a separate temperature regulation, aeration and recirculation system. Fish were fed twice daily on a commercial pellet feed. Aromatase inhibitor (Exemestane) at the rate of 1 mg/g diet were prepared and mixed with the commercial feed. This dose was based on the results of our previous study, which showed that administration of Exemestane at the rate of 1 mg/g diet during the critical period of sex differentiation induce complete masculinization in Nile tilapia (Ruksana et al., 2010). Exemestane (aromasin, 25 mg tablets, Pfizer Japan Inc., Tokyo, Japan) was dissolved in 100% ethanol and added to the feed, which was then dried overnight at room temperature to completely evaporate the ethanol. For experimental treatments, fish were fed with Exemestane containing feed from 100 dah for 120 days, whereas control groups were fed with normal feed. This experiment was conducted in a completely randomized design (CRD). Fish growth and survival were calculated periodically throughout the experimental period. Gonadal status of fish was observed monthly by killing at least 5 fishes from each group. Serum estradiol-17β (E_2) and 11-ketotestosterone (11-KT) were determined by enzyme-linked immunosorbent assay (ELISA) as described by Asahina et al. (1995). Water temperature and fish mortality were observed daily throughout the experimental period. Water temperature was ranged 25-30^{o}C during the experimental period. Data were analyzed statistically by analysis of variance (ANOVA) using SPSS (version 16.0) statistical software package (SPSS Inc., Chicago). All means are given with ±1 standard error (S.E.).

3. Results

The initial and final body weight, total length, daily weight gain, survival rate, and GSI for control and AI-treated group of Nile tilapia in the present study are given in Table 1. There was no significant difference in survival between control and AI-treated fish. The mean harvest weight and daily growth of AI-treated fish (0.8 g/fish/day) was significantly higher than control group (0.6 g/fish/day), whereas the gonadosomatic index of AI-treated fish (0.1 %) was significantly lower than the control group of fish (3.5 %) (Figure 1 and 2).

After 120 days of treatment, the plasma levels of E_2 in AI-treated fish (2,130 pg/mL) were significantly lower than in the control fish (14,364 pg/mL) (Figure 3). Similarly, the levels of 11-KT was significantly higher in AI-treated fish (3,809 pg/mL) than in the initial (323 pg/mL) and control fish (405 pg/mL) (Figure 4).

Table 1. Mean initial and harvest total length, total weight, survival and gonadosomatic index (GSI) of control and AI-treated Nile tilapia, *Oreochromis niloticus* after 120 days treatment period. Values with different superscript letters in the same raw are significantly different (P<0.05).

Parameters	**Treatments**	
	Control	**AI-treated**
Initial		
Total length (cm)	4.1±0.2 ^{a}	4.1±0.2 ^{a}
Total weight (g)	6.3±0.1^{a}	6.3±0.1^{a}
At harvest		
Total length (cm)	16.8±0.4 ^{a}	17.8±0.7 ^{a}
Total weight (g)	77.2±2.1 ^{a}	98.1±3.2 ^{b}
Daily weight gain (g/fish/day)	0.6±0.03 ^{a}	0.8±0.04 ^{b}
GSI (%)	3.5±0.5^{b}	0.1±0.0 ^{a}
Survival (%)	100±0.0 ^{a}	100±0.0 ^{a}

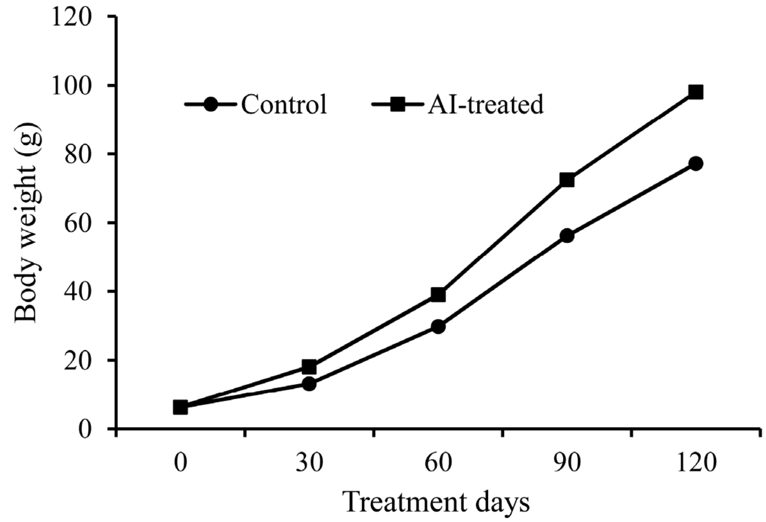

Figure 1: Monthly growth of control and AI-treated group of Nile tilapia during experimental period of 120 days.

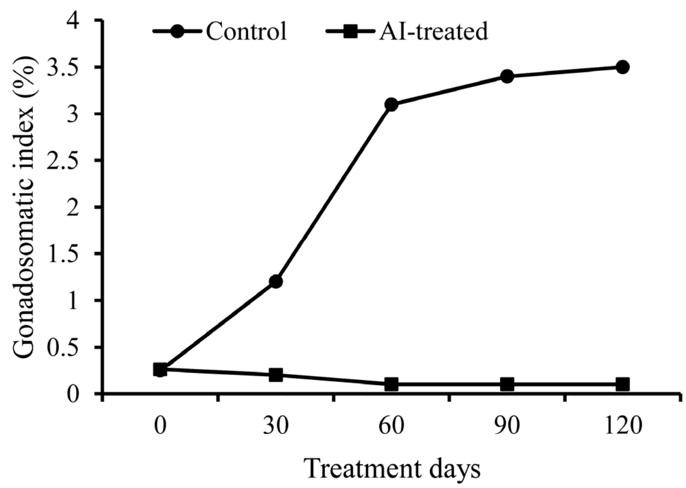

Figure 2: Effects of aromatase inhibitor on gonadosomatic index of Nile tilapia during experimental period of 120 days.

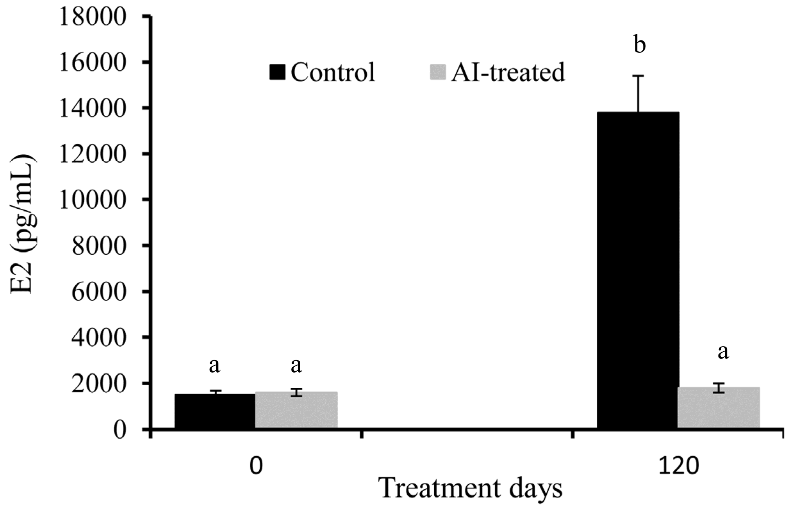

Figure 3: Effects of aromatase inhibitor on in vivo production of serum estradiol-17β (E_2) in Nile tilapia. Different superscript letters indicate statistically significant different ($P<0.05$).

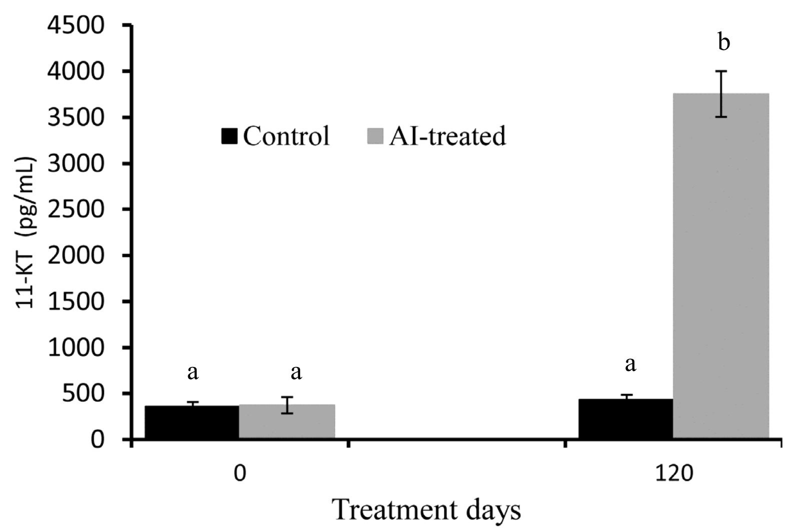

Figure 4: Effects of aromatase inhibitor on in vivo production of serum 11-ketotestosterone (11-KT) in Nile tilapia. Different superscript letters indicate statistically significant different ($P<0.05$).

4. Discussion

In the present study, the mean harvest weight and daily growth of AI-treated fish were significantly higher than the control group, whereas the gonadosomatic index of AI-treated fish was significantly lower than the control group. The higher growth of AI-treated fish might be due to the re-direction of metabolizable energy from gonadal development to somatic growth as described by Basavaraja et al. (1997) and Benfey (1999). This fact indicated that the gonadal development and maturation in normal fish needs more energy and the suppression of gonadal development provides the benefit to transfer energy to body growth. Razak et al. (1999) found that the sterile triploids of *Oreochromis* species produced by heat shocks would not be of benefit to aquaculture because of their slow growth rate. In this context, the present study might be an alternative approach for reproduction control and getting faster growth in Nile tilapia.

At the end of treatment, the plasma levels of E_2 in AI-treated fish were significantly lower than in the control fish, whereas the levels of 11-KT was significantly higher in AI-treated fish than in the control fish. These results indicated that the suppression of the gonadal development in AI-treated fish was associated with suppression of E_2 production. A similar result of significantly lower levels of E_2 was observed by Ruksana et al. (2010) in AI-treated Nile tilapia. Although the plasma E_2 concentrations in the present study were very low, the AI-treated fish grew faster than normal females, suggesting that the lower level of E_2 does not affect the growth in Nile tilapia. It is known that estrogens have contradictory effects on growth in other fishes, such as in European eel *(Anguilla anguilla)*, E_2 has anabolic effects (Degani, 1986). Similarly, growth stimulating effects of testosterone and typical androgens such as 11-KT or 17α-methyltestosterone, have been described in tilapia (Rothbard et al., 1988; Davis et al., 2010).

The results of the present study demonstrated that the AI treatment is an easy and effective method to suppress the gonadal development and control reproduction in Nile tilapia. The faster growth of these AI-treated fish indicated that it might be an excellent candidate for aquaculture to increase production. In this experiment, we compared the growth of AI-treated fish with all-female Nile tilapia. It seems that the growth of AI-treated fish will be more advantageous when it compared with mixed-sex Nile tilapia culture, where the stunting effect is common due to the increasing number of fry in culture ponds. Further studies are recommended to examine the composition of AI-treated Nile tilapia (including its residual effect), to examine the economic viability of this approach, and to compare the growth of AI-treated female with male Nile tilapia.

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Successful semi-artificial breeding of pond reared Mahseer, *Tor tor* and its initial growth performance

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Abstract
Mahseer, *Tor tor*, is a large endangered riverine and sport fish with high food value. Wild fingerlings of *T. tor* were collected from Kali Gandaki River and reared in a control system for more than 12 years at Kali Gandaki Fish Hatchery, Beltari, Syangja. A female fish (5.1 kg, 77 cm TL) stripped eggs (250 g, 46 eggs/g) successfully for the first time in Nepal on 29 September 2014, and fertilized with stripped milt. The mean weight of newly ovulated eggs was 21 mg, which was bigger than *T. putitora* (12 mg; stripped at the same time). The eggs were hatched at 84-108 h after fertilization at 22-24ºC water temperature. The fertilization and hatching rates were 95% and 90%, respectively; and produced 9,800 larvae. The mean weight of juveniles of 25 mg with the age of 14 dAH (days after hatching) grown to 330 mg, 30 mm (165 dAH); which were larger than the juveniles of 17 mg (14 dAH) grown to 180 mm, 26 mm (165 dAH) of *T. putitora* (hatched on the same day). This study shows the possibilities of mass seed production of *T. tor* and could be a potential candidate for the development of an open water fisheries as well as aquaculture.

Key words: *Tor tor*, stripping, ovulated eggs, growth

1. Introduction
Tor tor (Hamilton, 1822) is a large freshwater, benthopelagic and potamodromous cyprinid fish (Riede, 2004), which is reported to reach 150 cm in total length (Misra, 1959) and gain a maximum 68 kg in body weight (Thomas, 1897); and considered a long-living species (Desai, 2003). *T. tor* is referred to as "Tor Mahseer" and "Deep-bodied Mahseer"; and locally known as "Malunge Sahar" and "Falame Sahar" (Shrestha, 2008). *T. tor* is a native fish of Trans-Himalayan region and is distributed throughout mountain rivers, lakes and reservoirs of most of the South Asian countries including Nepal (Shrestha, 1981; Rajbanshi, 1982); India, Bangladesh, Pakistan (Talwar and Jhingran, 1991); Bhutan (Rajbanshi and Csavas, 1982) and Myanmar (Menon, 1992). In Nepal, this fish is distributed in all major river systems and inhabits fast flowing rivers, rivulets, pools and lakes. Among the mahseers, *T. tor* is the most important food and game fish after Golden Mahseer, *T. putitora* (Hamilton, 1822). On the basis of temperature tolerance, *T. tor* is eurythermal fish, which can widely survive in cold-water and warm-water condition (Desai, 2003). *T. tor* is a subtropical fish, which can tolerate water temperature between 15ºC to 30ºC (Shrestha, 1999).

Populations of this fish in open water bodies (rivers/lakes) are decreasing due to various forms of human impacts such as high fishing pressure, loss of habitats resulting from river damming for hydroelectricity and other developmental works, natural disasters, pollution, reclamation of wetlands and harvesting of fish during the critical migration period (Islam, 2005). Shrestha (1995) had reported this fish as the only one endangered species and recommended as the most important species with critical status in Nepal and listed in National Red Data Book of Nepal (Anonymous, 1995) for its legal protection. Shrestha (1999) had reported this fish as in danger of extinction (ED) based on Nepal Country Report on Biological Diversity, IUCN Nepal. This fish is also listed as vulnerable and threatened in Bangladesh (Ameen et al., 2000), threatened fish of the World (Islam, 2005), endangered in Nepal (Shrestha, 2008), only one endangered species in Nepal (Shrestha, 2012) and near threatened (NT) in IUCN Red List Status (IUCN, 2014). In order to save this fish from being extinct, it is necessary to culture and propagate them on a large scale and for restocking into the natural water bodies for enhancing fishery and introduction of the species as a candidate for aquaculture practices. Open water ranching and stock enhancement with artificially reared fish is under experimental trial in Nepal and India (Petr and Swar, 2002). Artificial propagation has been successfully done in Bangladesh and India and domestication is under trial (Desai, 2003). Many aquaculture trials have shown that this species is a promising candidate for coldwater aquaculture (Islam, 2005). In Nepal, wild fingerlings of this fish collected from Kali Gandaki River are rearing and under domestication at Kali Gandaki Fish Hatchery, Beltari, Syangja, since 2002 to develop breeding and culture technology of this fish. This paper describes the semi-artificial breeding of pond reared *T. tor* and its initial growth.

2. Materials and Methods

Experiment on semi-artificial breeding of pond reared *T. tor* was conducted at the Kali Gandaki Fish Hatchery, Beltari, Syangja (Joint Project of Nepal Agricultural Research Council and Nepal Electricity Authority) on 29th September 2014. Similarly, experiment on initial growth of *T. tor* was conducted for 5 months.

Wild fingerlings of *T. tor* were collected from Kali Gandaki River and reared in a control system for more than 12 years. Brood fish of *T. tor* were stocked with *T. putitora* at the rate of about 3 Mt/ha in a 0.03 ha size concrete pond with earthen bottom with regular supply of fresh water. Brood fish were fed pellet feed containing 30% crude protein to satiation daily.

The female fish that released eggs on gentle pressure on the abdomen near vent were transported to the hatchery and stripped gently for the eggs in a clean, dry plastic bowl and weighed. One g of unfertilized eggs was weighed using a top pan balance and their number was counted with the naked eye. The stripped eggs were fertilized with milt pressed out from the healthy males using bird feather for dry fertilization. After mixing the eggs and milt for about 1 min, water was added and gently stirred to ensure fertilization. The fertilized eggs were washed with water several times.

The fertilized eggs were incubated for hatching in Atkin's incubator trays by allowing one layer of eggs on single mesh screen trays in flow through system. The fertilized eggs were covered with black plastic screen. Water flow in the incubation trays was maintained at a discharge rate of 4-5 L/min. Dead eggs were removed using forceps to protect from fungal infection. Dead eggs were easily infected with fungus, which could spread rapidly to the adjacent healthy eggs. After 3-4 days, hatching occurred and was completed within 12 hours. In the experiment, ovulation, number of eggs released, fertilization rate, hatching and hatching rates were observed. The size of ovulated eggs, fertilized eggs and larvae were measured. Newly hatched larvae possessed large yolk sacs and settled near corners of the incubation trays. After attaining free-swimming stage the larvae were transferred into a tank of 2.5 x 0.40 x 0.30 m dimension. Supplementary boiled chicken egg yolk was fed to the larvae till yolk sac absorption and further growth until 14 days after hatching (dAH). The weight of newly ovulated eggs and hatched larva were measured using top pan balance.

The larvae (14 dAH) of *T. tor* and *T. putitora* (which were stripped on the same day and hatched on the same time) were measured on top pan balance with water (100 tails at a time). The larvae were stocked in two concrete tanks (37.5 sq. m. each) filled with clean and fresh water. Water depth was maintained at 0.8 m deep. Ponds were stocked with 14 dAH old *T. tor* (25 mg individual weight) in one pond and another pond was stocked with same size of *T. tor* and 14 dAH old *T. putitora* (17 mg individual weight). Final harvesting of all fish was done on 17th March 2015 after complete draining of each pond. During harvest, all fish was counted and weighed to assess survival rate and growth performance. Fish were sampled monthly for growth determination. At least 20% fish were netted and weighed to determine growth. Water temperature, dissolved oxygen (DO) and pH were measured.

3. Results

A female *T. tor* (5.1 kg, 77 cm TL) stripped eggs (250 g, 46 eggs/g) successfully for the first time in Nepal on 29th September 2014, and fertilized with milt using dry fertilization method. The mean weight of newly ovulated eggs was 21 mg, which was bigger than those of *T. putitora* (12 mg; stripped at the same time). The eggs were hatched from 84 h to 108 h after fertilization at 22-24ºC water temperature. The fertilization and hatching rates were 95% and 90%, respectively. *T. tor* produced 9,800 hatchlings (0 dAH) and 8,880 larvae (14 dAH), respectively, (Table 1).

Table 1. Breeding and larvae production of *Tor spp*.

Parameter	***Tor tor***	***Tor putitora***
Body weight of female (kg)	5.1	1.5
Total length of female (cm)	77	56
Water temperature (ºC)	22-24	22-24
Total weight of eggs (g)	250	100
No. of eggs/g	46	78
Size of egg (mg)	21	12
Total no. of egg released	11,500	7,800
Fertilization rate (%)	95	90
Hatching rate (%)	90	85
Total no. of hatchlings (0 dAH)	9,800	6,000
Total no. of larvae (14 dAH)	8,880	5,500
Survival rate (%)	91	92
Size of 14 dAH old larvae (mg)	25	17

The mean weight of juveniles with the age of 14 dAH (days after hatching), 45 dAH, 75 dAH, 105 dAH, 135 dAH and 165 dAH were 25 mg, 109 mg, 194 mg (26 mm TL), 221 mg (28 mm TL), 263 mg (28 mm TL) and 330 mg (30 mm TL) respectively; which were larger than the juveniles of 14 dAH (17 mg), 45 dAH (68mg), 75 dAH (136 mg, 24 mm TL), 105 dAH (172 mg, 26 mm), 135 dAH (175 mg, 26 mm) and 165 dAH (180 mm, 26 mm) of *T. putitora* (hatched on the same day) (Table 2; Fig 1 & 2). During the experimental period, water temperature, dissolved oxygen and pH were ranged from 11.0-25.0ºC, 7.92-9.42 and 8.5-9.5, respectively.

Table 2. Stocking, growth check up and harvesting record of *Tor spp*.

Pond No.			R-5				R-4			
Pond size (sq. m)			37.5				37.5			
Stocking density (nos./sq. m)			213			23			147	
Species			*Tor tor*			*Tor tor*			*Tor putitora*	
Date	Day after hatching (dAH)	Nos.	Total wt. (g)	Av. wt. (mg)	Nos.	Total wt. (g)	Av. Wt. (mg)	Nos.	Total wt. (g)	Av. Wt. (mg)
17 Oct 14	14	8000	200.0	25	880	22.0	25	5500	95.0	17
17 Nov 14	45	100	10.9	109	100	16.5	165	100	6.8	68
17 Dec 14	75	100	19.4	194	100	27.8	278	100	13.6	136
16 Jan 15	105	100	22.1	221	100	34.8	348	100	17.2	172
15 Feb 15	135	100	26.3	263	100	35.7	357	100	17.5	175
17 Mar 15	165	100	33.0	330	100	36.0	360	100	18.0	180
	Total	7200	2376.0	330	800	288.0	360	4900	882.0	180
	Survival rate	90.0			90.9			89.9		

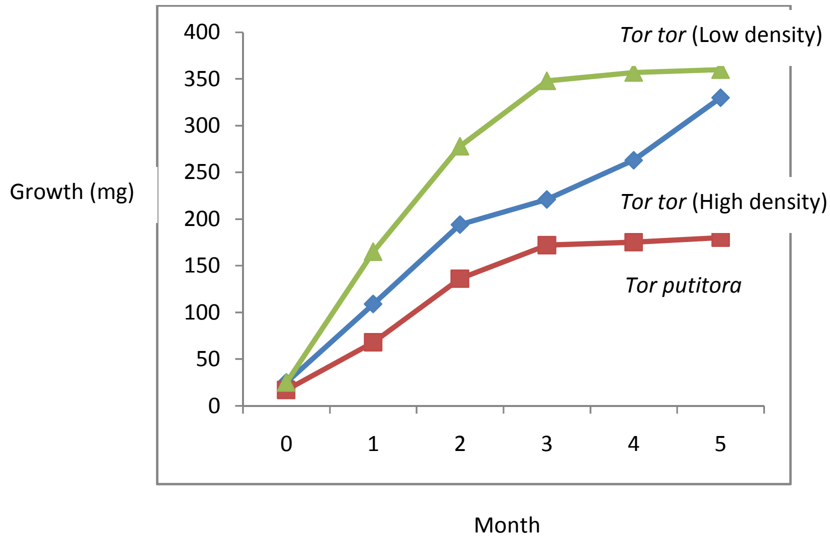

Figure 1: Growth of *Tor tor* and *Tor putitora*

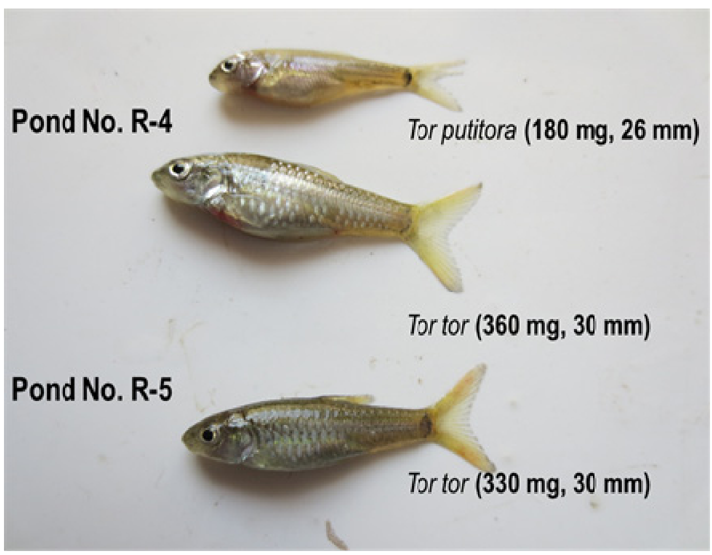

Figure 2: 165 dAH Juveniles of *Tor tor* and *Tor putitora*

4. Discussion

In this study pond reared *T. tor* after domestication for more than 12 years succeed to spawn when attained size of 5.1 kg in BW and 77 cm in TL. Karamchandani et al. (1967) reported that *T. tor* from plains is reported to attain its first maturity in the size range of 273-290 mm. Desai (1973) reported that 5% of fish are mature at 280 mm, 50% at 360 mm, 90% at 440 mm and all the fish are mature when over 500 mm in TL in Narmada River. Female fish attained first maturity (50% mature ovaries) in the size range of 340-380 mm in TL and more than 500 g in BW in the third year. Chaturvedi (1976) reported that the smallest mature female was encountered at 322 mm in TL in Lake Udaipur in Rajasthan. According to him, all females below 320 mm size were found immature and most of the females above 390 mm were found mature. Hence it may be stated that the average size at first maturity lies between 320-390 mm. In Lake Bhimtal this species attained maturity in the size range of 280-350 mm in TL (Pathani and Das, 1983) and the smallest ripe female was 289 mm TL (age group 3+) (Pathani, 1983).

The result showed that well domesticated wild fingerlings of *T. tor* grown to maturity in captivity can be used for semi-artificial breeding without hormone treatment. Karamchandani et al. (1967) observed that breeding season of *T. tor* from Narmada River commenced in August-September and continue up to December with the peak breeding from July to September. Desai (1973) suggested that *T. tor* from the Narmada River spawn more than once in each spawning season. Chaturvedi (1976) concluded that wild *T. tor* has a short spawning period, which spawns only once a year in natural condition after monsoon season during July to September with its peak in August. In Nepal, wild *T. tor* spawns from March to September (Swar, 1979) over gravel and stones as spawning substrate (Shrestha, 1999). It is to be confirmed whether the same fish spawn twice a year or not as *T. putitora*. *T. putitora* spawned in two consecutive breeding periods: from February to April and from September to November (Baidya et al., 2007). The spawning time and frequency might be different in natural and cultured conditions. The spawning time also differs a little bit from country to country depending upon climatic conditions. In present study, *T. tor* spawns during last week of September.

5. Conclusion

The success of breeding promises that there are possibilities of mass seed production of *T. tor* and this fish could be a potential candidate for the development of an open water fishery as well as aquaculture; and to restore this endangered species in open waters.

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Efficacy of common carp (*Cyprinus carpio*) testis on sex reversal of Nile tilapia (*Oreochromis niloticus*) fry

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Abstract

Feeding common carp (*Cyprinus carpio*) testis (CCT) to Nile tilapia during the critical period of sex differentiation caused skewness towards male based on dose dependent manner. Six types of feed containing varied proportion CCT viz.: 0% (Control), 50%, 65%, 80%, 95% and 100% were fed to 9 DAH (days after hatching) tilapia fry for 25, 30 and 35 days. Treatment with CCT and control feed was carried out in 18 glass aquaria of 60cm x 30cm x 45cm while rearing was carried out in 50cm x 50cm x 100cm nylon happas suspended cemented tank up to 160 DAH. There was no significant effect of treatment duration on sex reversal. Highest proportion of male (95.8±7.2%) was obtained with 100% CCT feed fed for 30-35 days compared to lowest (62.5±12.5%) obtained with 50% CCT feed fed for 25-30 days excluding the normal sex ratio with 0% CCT feed. Thus, it was concluded that common carp testis can efficiently masculinize Nile tilapia fry when fed for at least 30 days after hatching.Further refinement of testis could be more effective in sex reversal of Nile tilapia which could replace the use of synthetic androgen (17α-methyltestosterone).

Keywords: Nile tilapia, sex reversal, common carp testis (CCT)

1. Introduction

Nile tilapia (*Oreochromis niloticus*) is recognized as suitable species in tropical and subtropical climate worldwide due to its wider range of tolerance to environmental factors (Pillay and Kutty, 2005). But uncontrolled reproduction in ponds has emerged as a problem of this species in aquaculture due to which it is also considered as invasive species. Among several techniques to control the population in tilapia farming, monosex culture using androgens and aromatase inhibitors is most promising. Sex reversal (conversion to male) using 17α- methyl testosterone is one of the most widely used and most successful techniques to produce all male population in tilapia (Beardmore et al., 2001; El-Sayed et al., 2012). The principle behind hormonal use for sex reversal technique is that at the stage when the tilapia larvae are said to be sexually undifferentiated (from hatching upto 2 weeks stage) the extent of male hormone (androgen) and female hormone (estrogen) is equal in fish, thus increasing the level of one hormone will direct the fish to monosex depending on hormone used. However, little is known about the actual impact of the hormonal residuals on human health and environment (Desprez et al., 2003; Megumphan et al., 2006). Also the availability of 17α- MT and expensiveness in developing countries must be considered while planning to apply for commercial production. This controversy has led to the search of new alternatives for sex reversal in tilapia. Such alternatives may include using phytochemicals and other natural androgen sources that exhibit endocrine disruptive activity (Phelps et al., 1996; Dabrowski et al., 2007; Meyer et al., 2008). Some previous experiments indicated that testis of mammals (Haylor and Pascual, 1991; Phelps et al., 1996; Meyer et al., 2008; Odin and Bolivar, 2011) and fish (Khanal et al., 2014) can be used to produce all male tilapia population. Present study was focused to explore the possibility of common carp (*Cyprinus carpio*) testis (CCT) in sex reversal of Nile tilapia which is a major species used in carp polyculture with higher gonado-somatic index (Singh et al., 2010; Shaikh Abdullah and Lohar, 2011) and early sexual maturation than other carps.

2. Materials and methods

The experiment was carried out at the Department of Aquaculture and Fisheries, Agriculture and Forestry University, Chitwan. The whole experiment was divided into brood rearing, egg incubation, treatment phase (sex reversal phase) and post treatment phase (rearing phase).

Egg from four female brood fish (442.5±94.0 g) was collected on 30th April, 2015 from brood fish reared in nylon hapa suspended in an earthen pond. Thus collected eggs were incubated in a locally made incubation unit. After 9 days of hatching (dah) yolk sac of all fry were absorbed which were then transferred to 18 glass aquaria (60 cm x 30 cm x 45 cm). After treatment, rearing was carried out in hapas suspended in three cemented tanks situated near the laboratory. Analyses of gonads were done in the laboratory of Department of Aquaculture and Fisheries, AFU.

2.1 Experimental design and setup

Treatment phase included feeding six types of feed with different proportion (0%, 50%, 65%, 80%, 95% and 100%) of CCT to Nile tilapia fry for three different durations (25, 30 and 35 days). With the completion of each treatment period, lot of fry were pooled from each aquarium and stocked in respective happas (50 cm x 50 cm x 100 cm) suspended in cemented tank (5 mx 5 m x 1.5 m). In this way, three tanks each with 18 hapa were used for rearing. After rearing for 160 dah in hapa gonads of all fish were analyzed for sex differentiation. During treatment phase, about 90% of water in each aquaria were exchanged in two days while during rearing phase, about 50% of water in tank was exchanged weekly.

2.2 Feed preparation and feeding

Fresh Common carp testes (maturing and spermiating stage) were collected from fish market of Narayanghat and Chanauli and sun dried for 1-3 days till they are completely dried. Dried testes were crushed into pieces and grinded in grinding machine to make fine particle. It was then sieved and only fine particles were used to make feed for treatment. Similarly, dried fish meal was also grinded and fine particles were sieved. Required amount of fish meal and CCT powder was then mixed well (Table 1) and stored in airtight glass bottles in refrigerator for feeding during treatment phase. Results of proximate analysis showed that fish meal contained 46.3% CP while CCT powder contained 67.8% CP. Feed was supplied to each aquarium according to treatment given twice daily (10-11 am and 3-4 pm) from allotted feed for day. Initially feeding was done at rate of 20% of total biomass for first week which was then reduced by 2.5% each week till it reached 5% of total biomass after which it was kept constant.

For post treatment phase feed was made using fish meal (30%), mustard oil cake (40%), soyabean oil cake (20%) and rice bran (10%). All ingredients were grinded and fine particles were sieved to make pellet. Pellet feed was sun dried and again grinded to make fine particles which were fed during rearing phase at rate of 5% of body weight.

2.3 Sex differentiation

Gonad analysis was performed as followed by Khanal et al. (2014) and suggested by Guerrero and Shelton (1974). Fish were dissected starting from the anus to below the base of the pectoral fin and all visceral material was removed carefully so that gonads are intact. Gonads were then cut and placed on a slide and their peritoneal lining was removed and a drop of dye (Acetocaramine) was used for staining. Now, it was pressed gently using a coverslip and observed under microscope. The type of gonad was noted down according to the structure seen under microscope (Photo 1 and 2). However, in many cases of females, ovaries were found with eggs (Photo 3) and testes is swollen (Photo 4) that can be seen easily with naked eyes. In those cases it was not necessary to observe under microscope.

Photo 1: Female gonad under 100X

Photo 2: Male gonad under 100X

Photo 3: Ovaries with eggs

Photo 4: Swollen testes

2.4 Statistical analysis

Effect of different types of feed and treatment duration on male population proportion were analyzed using one-way ANOVA. While combined effect of feed type and treatment days on male population proportion was analyzed using two- way ANOVA. For significant difference in result, mean comparison were performed by DMRT. Analysis for percentage data were done after square root transformation of original data.

3. Results

3.1 Sex reversal

Male population in groups fed with 100% CCT for 30 and 35 days were found significantly higher ($p<0.05$) than group fed with other types of feeds (except 95% CCT feed) different duration (Table 1). Similarly, proportion of male population in groups fed with 0% CCT feed for different duration was significantly lower ($p<0.05$) than groups fed with 65%, 80%, 95% and 100% CCT feed for different durations except 80% feed for 25 days.

Table 1. Male proportion with combined effect of feed type X treatment duration (Mean±SD)

Feed type (CCT%)	Treatment duration (days)			Mean
	25	30	35	
I (0%)	50.0 ± 0.0^{h}	54.2 ± 7.2^{gh}	54.2 ± 7.2^{gh}	52.8 ± 5.5^{C}
	(50.0-50.0)	(50.0-62.5)	(50.0-62.5)	(50.0-62.5)
II (50%)	62.5 ± 12.5^{fg}	62.5 ± 12.5^{fg}	75.4 ± 6.9^{cde}	66.8 ± 11.5^{B}
	(50.0-75.0)	(50.0-75.0)	(71.4-83.3)	(50.0-83.3)
III (65%)	68.8 ± 6.2^{ef}	75.0 ± 12.5^{cde}	72.6 ± 14.4^{def}	72.1 ± 10.4^{B}
	(62.5-75.0)	(62.5-87.5)	(57.1-85.7)	(57.1-85.7)
IV (80%)	62.5 ± 12.5^{fg}	69.6 ± 18.8^{ef}	79.2 ± 7.2^{bcde}	70.4 ± 13.9^{B}
	(50.0-75.0)	(50.0-87.5)	(75.0-87.5)	(50.0-87.5)

V (95%)	83.3±7.2^{abcd}	91.7±7.2^{ab}	90.5±8.2^{ab}	88.5±7.6^{A}
	(75.0-87.5)	(87.5-100.0)	(87.5-100.0)	(75.0-100.0)
VI (100%)	87.5±0.0^{abc}	95.8±7.2^{a}	95.8±7.2^{a}	93.1±6.6^{A}
	(87.5-87.5)	(87.5-100.0)	(87.5-100.0)	(87.5-100.0)
Mean (Excluding I)	72.9±13.3^{A}	78.9±16.9^{A}	82.7±12.1^{A}	

Mean values with similar superscripts are not significantly different at $p<0.05$

Results of present study showed that feeding of CCT to Nile tilapia during the critical period of sex differentiation caused skewness towards male based on dose dependent manner (Figure 1). Average male population in group fed with 0% CCT feed for different period was significantly lower ($p<0.05$) than groups fed with 50%, 65% and 80% CCT feeds which in turn was significantly lower than groups fed with 95% and 100% CCT feed for different periods.

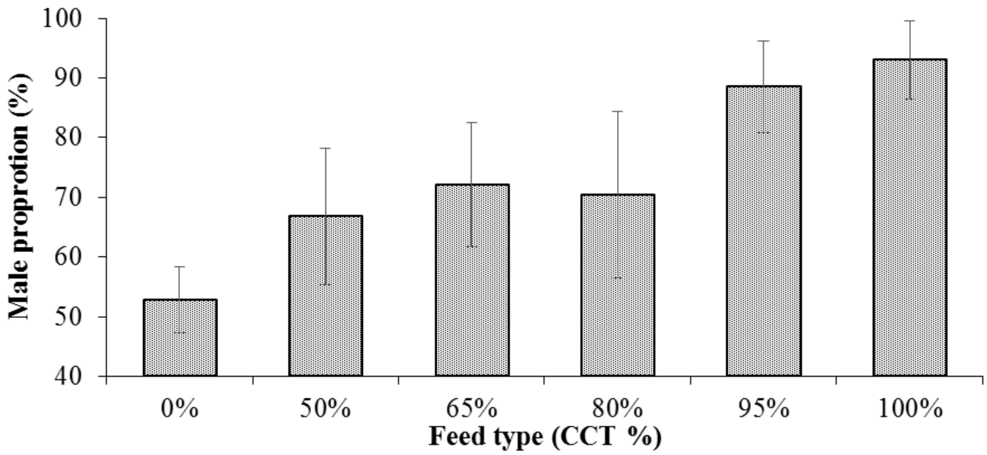

Figure 1: Effect of different doses of CCT on proportion of male population

There was no significant effect ($p>0.05$) of feeding duration on average proportion of male population fed with CCT diets. However, general increase in proportion of male population with increased treatment duration was found (Figure 2).

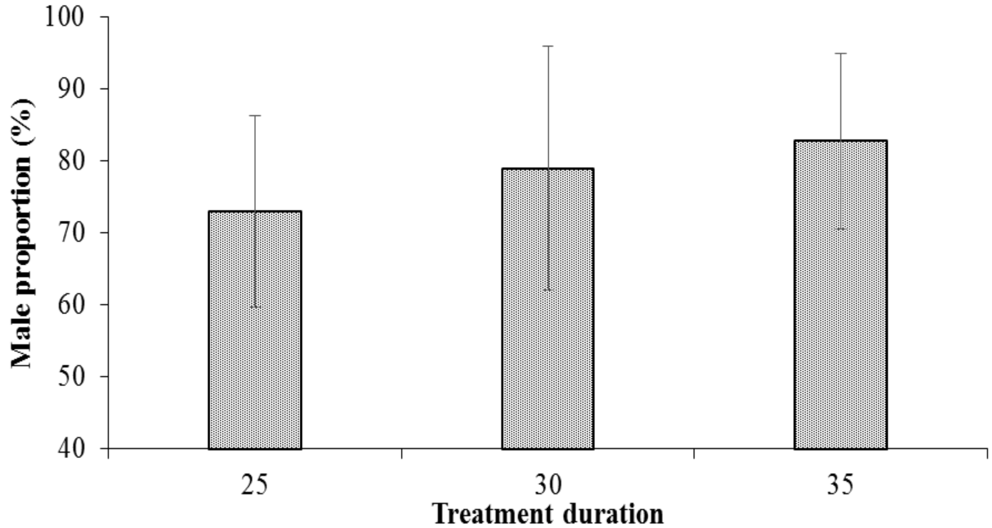

Figure 2: Effect of treatment duration with different feeds (excluding control feed) on proportion of male population

3.2 Growth and survival of fry/ fingerlings

Survival of fish at the end of treatment phase was significantly higher in 0% CCT feed (90.0±4.4%) than with CCT feed (61.4±10.7%). However, daily weight gain at the end of experiment was significantly lower in 0% CCT feed (6.3±0.3 mg/fish/d) than with CCT feed (11.9±0.7 mg/fish/d). Similarly, the specific growth rate at the end of experiment was significantly lower in 0% CCT feed (8.6±0.1 %/day) than with CCT feed (10.3±0.2 %/day).

3.3 Water quality parameters

Water temperature during treatment phase ranged between 23.6–35.5°Cwhileduring rearing phase it ranged between 24.2-30.2°C. Similarly, the DO ranged between 7.3–9.4 mg/L during treatment phase and 4.2-8.5 mg/L during rearing phase. The pH ranged between 7.9-8.9 during treatment phase and 7.9-9.2 during rearing phase.

4. Discussion

In present study, feeding Common carp testis to sexually undifferentiated Nile tilapia for different duration in different doses resulted 62.5±12.5 to 95.8±7.2% male population in contrast to about 50:50 male and female ratio in natural population. The sex reversal potentiality of testis from different other organisms have been already studied. However, result of CCT feeding obtained during present study was remarkably higher than the result obtained with bull testis (64.8- 87%) (Phelps et al., 1996 & Odin and Bolivar, 2011), ram testis (85.19%) (Haylor and Pascual, 1991) and hog testis (83%) (Odin and Bolivar, 2011) and almost similar to the result with rohu testis (82.5±2.7–91.4±1.2%) (Khanal et al., 2014). This might be due to compatibility of sex hormone in fish rather than other mammalian testis.

Result of the present study showed that with increase in the amount of CCT in feed there is increase in male population for all feeding duration with some exceptions such as lower male population with feed IV (80% CCT) with duration of 25 and 30 days than feed III (65% CCT) for similar duration. The exceptions may have been due to smaller sample size since there is no significant difference in exceptional cases. Phelps et al. (1996) also reported significantly higher male population (64.8%) with 50% bull testis diet than control (50% male) and 25% bull testis diet (52.4% male) suggesting that higher amount of testis in feed increases the maleness. Higher percentage of male population with higher amount of 17α- MT consumed was also reported by several authors (Mainardes- Pinto et al., 2000; Megumphan et al., 2006; Marjani et al., 2009; Ferdous & Ali, 2011).

Difference in feeding duration did not showed significant effect on the average proportion of male population however, proportion of male population with longer treatment duration was comparatively higher than compared to shorter treatment duration. Longer treatment duration by hormone has also been reported to increase male population in Nile tilapia (Khanal et al., 2014).

The combined effect of CCT dose and treatment duration showed that there is increase in male population with increase in dose and treatment duration. Highest male population (95.83±7.22%) was found in 100% CCT dose fed for 30 and 35 days while lowest male population (62.50±12.50%) was found with 50% CCT fed for 25 days excluding the control (0% CCT feed). This might have been due to increase in total amount of androgen consumption which has been previously reported with 17α- MT (Mainardes-Pinto et al., 2000; Mengumphan et al., 2006; Marjani et al., 2009; Khanal et al., 2014), 11β-OHA4 (Desprez et al., 2003) and fadrazole (Afonso et al., 2010).

5. Conclusion

Feeding of common carp testis in inducing sex reversal in Nile tilapia fry might be an option to be developed. Further refinement of testis preparation technique for feeding could be more effective in sex reversal in Nile tilapia which could replace the use of synthetic androgen (17α- methyltestosterone).

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Survival rate of hatchling, fry and fingerling of carps in private fish hatcheries in Nepal

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Abstract

Aquaculture is rapidly expanding in Nepal and access to adequate high quality seed is the basis for sustainable development. Fish hatcheries normally encounter high mortalities at hatchlings and fry stages. Improving efficiency of hatcheries is one of the best options. However, there was no reliable information on the reasons of high mortalities in the hatcheries. Therefore, a survey of 40 private fish hatcheries was conducted from different regions of Nepal to assess status and identify the problems of high hatchling mortality and issues of health. The survey revealed that average survivals of hatchlings, fry and advanced fry ranged from 22-28%, 50-53% and 60-65% respectively. Almost all hatcheries indicated problems of asphyxiation, predatory aquatic insects, frogs, water snakes and piscivorous birds during nursing. Among them 70% also faced the problem of bacterial, fungal, lice and dropsy. About 20% owners reported the problem of *Trichodina* sp. while only 5% encountered white and black spot diseases. The survey clearly showed that there are a number of challenges to overcome low survival of juveniles which should be given high priority to supply high quality seed. Hapa nursing, proper sanitation and disinfection of nursery ponds, more importantly feeds, feeding and water quality management are imperative.

Keywords: Carp seed, survival, health management, hapa, quality feed

1. Introduction

Carps are the world's most important group of aquaculture species by volume. Pond aquaculture is the major culture system in Nepal contributing 86.6% in aquaculture production, and carps are the major fishes, which occupied over 95% of total fish production in Nepal (Mishra and Kunwar, 2014; DoFD, 2014). The seven fish species of carps including three Indian major carps such as Rohu (*Labeo rohita*), Mrigal (*Cirrhinus mrigala*) and Bhakur (*Catla catla*), and three Chinese major carps such as Silver carp

(*Hypophthalmichthys molitrix*), Grass carp (*Ctenopharyngodon idella*), and Bighead carp (*Aristichthys nobilis*) along with Common carp (*Cyprinus carpio*) are grown under polyculture system for the best possible exploitation of usual foodstuff achieving highest yield. Average productivity of these major carps was reported as 3.89 mt/ha in 2012 and 2013 (Mishra and Kunwar, 2014).

Carp farming has the potential to expand in rural areas of Nepal including mid-hills and generate income up to four times (Bhujel, 2012). However, inadequate supply of fry has been the main constraint. High mortality (up to 70-80%) during early stages has been one of the major obstacles in expanding its culture in the country. There are several reasons of poor survival of fish larva e.g. infection or unavailability of suitable diet (Little et al., 2002a; Edwards, 2013). At early stages, hatchlings and larvae are more carnivorous and need high protein diets. Therefore, quality of larval diet is an important factor for the survival and growth of fish larvae (Horvath et al., 2015; Phelps 2010). In addition, there are other associated causes of unavailability of quality seed due to host- microbe interactions, poor growth, malformation, a sudden decrease in survival, and lack of reproductive capacity are the major causes for the unavailability of quality seed (Mohapatra et al., 2012; Vadstein et al., 2013).

Currently, various reports have indicated that private sector is supplying about 80% of the total fry/advanced fry. A reliable system that can produce sufficient fish seed is necessary and is one of the key factors for further aquaculture development in the sector. Nursing involves caring of one-week old hatchlings, which have just begun to feed and continues for a period of 20-30 days. These fry are further reared for a period of 2-3 months to produce fingerlings. It generally takes 3-4 months for rearing post larvae to fingerlings in the same ponds continuously. In general, slow growth and low survival (20-30%) at early stages of carps have been major problems in Asia (Jhingran, 1995). Bacterial infection in fish larvae may also cause mass mortality, which is still a bottleneck. In addition, good quality broodstock is essential to optimize seed production and improve the quality of eggs and larvae (Subasinghe et al., 2003; Routray, 2012). Information about the location of fish hatcheries and seasonal availability of fish seed is essential. Seed production systems of private fish hatcheries are very crucial and less studied. So far, no field surveys have been conducted scientifically at the private fish hatchery level. It has become very important to address this problem to develop aquaculture as an industry. This paper describes the status of carp seed production systems, their performances and the existing practices of fish seed health management in the private hatcheries situated in different parts of Nepal, especially in Terai and inner Terai regions.

2. Materials and methods

A survey of total of 40 private fish hatcheries from different regions of Nepal from Terai and inner Terai was conducted from March 2009 to April 2014 to collect detailed information on carp seed survival and health management practices (Fig.1, Table 1).

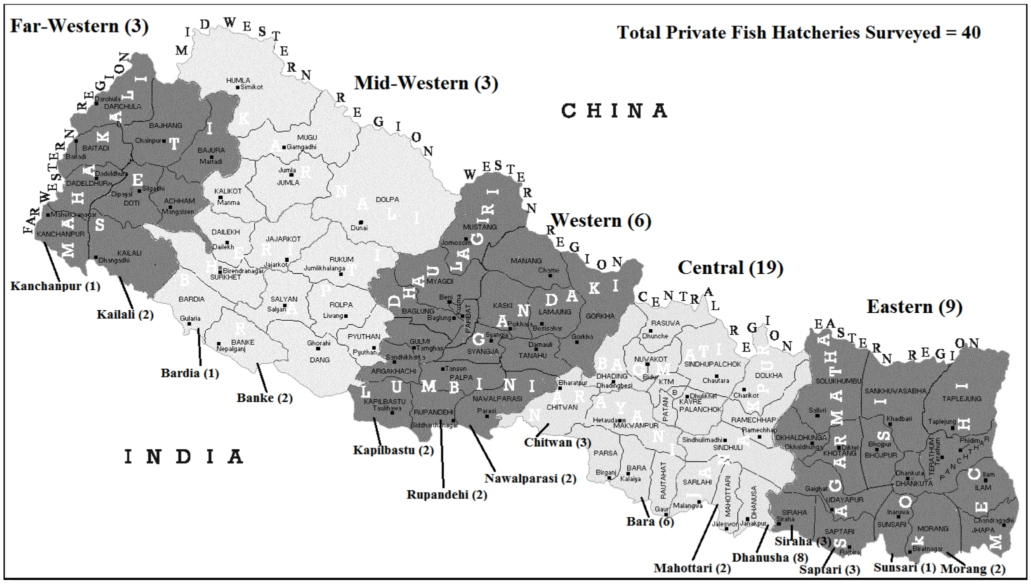

Figure. 1: Map of Nepal showing study area

Primary data were collected using semi-structured questionnaire. Questionnaire was prepared expecting the detailed information on the causes of low survival of juveniles. It was pre-tested through a field visit before finalizing it. The questions were specific but were open as well as free from any kind of influence. Hatchery owners were interviewed face-to-face in their own farms. In order to minimize errors, data were collected in local units. These were subsequently converted into appropriate units. Systematic sampling was adopted for the selection of the respondents of the survey site.

The secondary data related to the study were collected from Fisheries Development Centers (FDC) under the Directorate of Fisheries Development (DoFD), Kathmandu, Nepal and Fisheries Research Centers (FRC) under the National Agricultural Research Council (NARC). All of these centers were also visited during this study to find real field problems. Data were also collected through other Non-government organizations, journals and websites.

The data collected from private fish hatcheries were compiled and analyzed for descriptive statistics using Microsoft Excel.

3. Results

Almost all hatcheries in the study area involve in producing different stages of seeds of carps, mainly indigenous major carps, Chinese major carps and common carps. The hatcheries start their activities from February and continued up to September each year. There was species wise sequence in carp breeding starting from Common carp to other carps, namely; Grass carp, Silver carp, Bighead carp, Catla, Mrigal and Rohu. Demand for seed of these carps starts from March and ends in September. Highest demand of seed was observed during April - May as most of the growers follow carp polyculture. Generally, duration of hatchling cycle in most of the hatcheries was about 4-5 days and number of cycles per year varies between 20 and 40 depending on scale and facilities of each hatchery.

The field survey showed a high variation in farm size under different development regions. On the basis of area, farms were grouped as shown in Table 1. The smallest hatchery of 0.8 ha was found in Arnaha of Saptari district while two largest hatcheries of about 18 ha in land area were found in Biratnagar of Morang district and Mahendranagar of Dhanusha district. The survey also revealed that 57% hatcheries had an area of 1-2 ha. Only 5% hatcheries in Dhanusha district had ponds on lease (Table 1) while others own the farms.

Table 1. Area of private fish farm (ha) in the surveyed area (%)

Region	Hatcheries surveyed	Range of farm size (ha)				Remarks
		0.5-2	**2.1-4**	**4.1-6**	**> 6**	
Eastern	9	10	2.5	2.5	7.5	
Central	19	40	5.0	-	2.5	
Western	6	7.5	7.5	-	-	
Mid western	3	2.5	2.5	-	2.5	
Far western	3	2.5	2.5	2.5	-	

There were variations in the number of nursery ponds among the private hatcheries. The 40% hatcheries have 6-8 nursery ponds while 15-20% owned 9-15 ponds. It’s quite interesting that 2.5% hatchery has 20-30 ponds (Fig. 2). Most of the nursery ponds were in the range of 500-700m^2. Some hatcheries had nursery ponds of 1000m^2. Stocking density of hatchlings varied among the hatcheries 3-15 million per ha. The average stocking density was 3-6 million per ha (Table 2).

Table 2. Stocking of hatchlings in Nursery ponds (%) in different region

Region	Range (million/ha)		
	3-6	**6-9**	**12-15**
Eastern	17.5	5.0	0.0
Central	30.0	10	7.5
Western	12.5	2.5	0.0
Mid western	7.5	0.0	0.0
Far western	5.0	2.5	0.0
Total	72.5	20.0	7.5

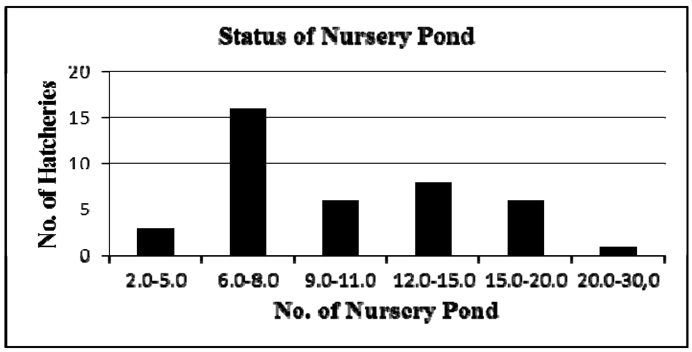

Figure 2: Number of nursery ponds in private hatcheries

The region-wise average percentage survival of hatchlings were lower than 30% which ranged from 22-28% (Table 3). Similarly, the survival of fry was found within the range of 50-53%. Likewise, the percentage survival of advanced fry was between 60 and 65% (Table 3).

Table 3. Percentage survival of hatchlings, fry and fingerlings (Mean ± SD)

Region	Hatchlings	Fry	Fingerlings
Eastern	28.1±5.99	51.7±3.53	62.8±6.67
Central	22.2±6.88	52.4±6.94	64.7±6.55
Western	26.8±2.89	52.5±10.0	62.5±10.0
Mid western	23.3±4.92	50.0±4.92	60.0±4.18
Far western	26.67±2.89	53.33±2.89	60.00±0.00

Hatcheries of central region had high variation in survival of hatchlings ranged from 10% to 35% (Table 4). About 21% owners reported only 10-15% survival while less than 21% hatcheries have achieved higher than 25% survival (Table 4).

Table 4. Survival of hatchlings in different farms of central development region

Survival of hatchlings (%)	Number of Hatchery	%
10 - 15	4	21.1
16 - 20	7	36.8
21 - 25	4	21.1
26 - 30	2	10.5
31 - 35	2	10.5

Almost all private hatcheries reported the problems faced during juvenile nursing as asphyxiation, predatory aquatic insects, frogs, water snakes and piscivorous birds. Seventy percent hatcheries faced the problem of bacterial, especially bacterial ulcer and fin rot, fungal (Saprolegniosis), lice (Argulosis), low DO (Asphyxiation), dropsy (Table 5). About 20% owners reported the problem of *Trichodina* sp while over 5% faced white and black spot diseases, 5% owners reported scoliosis mostly in silver and bighead carps.

Table 5. Occurrence of different diseases in private hatcheries

Name of the diseases	No. of hatchery	Percentage (%)
Bacterial+ Fungal+Lice+Asphyxiation+Dropsy	28	70.0
Scoliosis	2	5.0
Trichodina	7	17.5
Black spot	1	2.5
White spot	2	5.0

4. Discussion

In Nepal, considering the rapid expansion of fish farming at present and potential in the near future, adequate production and supply of fish seed should be the main focus. Present survey clearly indicated that there are some rooms for the improvement in existing private hatcheries to increase productivity and seed supply. It has been reported that collection and incubation of seed can result in high losses due to poor management. About 70% hatchery owners mentioned that they did not have practical hands-on knowledge for better management of their hatcheries. Technical backstopping better management practices would certainly increase survival of hatchlings, fry and advanced fry. In most of the cases mass mortality of hatchlings in rearing units occurs due to poor management of water. Most common problems encountered were low dissolved oxygen (DO) in water, predation and diseases and parasites. Problem of low DO in water could be managed by applying aerators or air-stones, but frequent disruption of electricity might be a problem. Alternatively, splashing the incoming water or pouring by gravity into tanks as well as in ponds may be a solution.

In addition to DO, physical and chemical properties of water are also important in fry nursing. Unfavorable conditions of water exert stress to the fish, which is more at younger stages. Stressed fish weak, therefore, they can be easily attacked by pathogens. Under the stress condition, Saprolegniosis poses a great problem and it may damage incubated eggs in fish hatcheries (Rayamajhi, 1998; Mandal and Prasad, 2011). 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, when stocking fish with high density. Metabolic stresses under low DO affect the health of fishes and make them susceptible to various harmful pathogens. Most of the hatchery owners do not have understanding of health issues in their systems. Some hatcheries stocked different stages of seed 3-5 times more than those of usual range, which affects survival.

Other than environmental factors, predatory aquatic insects and parasitic diseases are also limiting the growth and survival of juveniles (Jha and Bhujel, 2012). During survey, it was found that majority (70%) hatcheries were facing problems of bacterial diseases such as ulcers and fin rots and also fungal diseases such as Saprolegniosis and dropsy (Table 5). Use of some antibiotics as well as multi-strain probiotics may improve survival of hatchlings, which was recently reported by Jha et al. (2015) in an on-station trial conducted in Nepal. Pradhan et al. (2008) reported that advanced fingerlings (about 12 cm in body length) of Rohu, Mrigal and Catla are highly susceptible to Epizootic Ulceratvie Syndrome (EUS) and with this age groups are likely to be at high risk. In Nepal, during winter and spring EUS caused by *Aphanomyces invadans* is the most devastating, affecting the majority of fish species (Lilly et al., 1998; Jha and Shrestha, 2003). 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., 2008). Recently too, EUS has been reported from tropical areas of Chitwan and Nawalparasi districts of Nepal where, Mrigal and Catla of different stages 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). Various diseases affect the survival in different stages of fish seed. A loss of 30-40% in seed production has reported due to various disease problems (Mandal and Prasad, 2011). There are also noninfectious diseases associated with poor water quality and nutrition are responsible for the mortality of fingerlings, table fish and brood fish (Mandal and Prasad, 2011).

In addition to bacterial diseases, parasites are also found in young fish. About 20% owners reported the problem of *Trichodina* sp while over 5% faced white and black spot diseases, 5% owner also reported scoliosis mostly in silver and bighead carps. Simple dipping in salt solution of concentration ranging from 5-10 ppt may help control parasites. Rock salt can be even added to the hatchery tanks directly to increase up to 5 ppt or so to get rid off parasites.

Predation is the most important factor causing low survival of young fish because a bird or a snake could eat several small fry at a time. Simple hapa nursing of fry and fingerlings significantly improves survival because predators such as snakes, insects and frogs found in ponds normally are prevented or reduced. If young fish are in hapas, it is easy to cover by net to protect from birds as well. Therefore, emphasis should be given to manage nursing fry and advanced fry in hapa in pond systems. Hapa or cage nursing has been proved very useful in other countries of Asia such as Bangladesh and Thailand. Specially, spawns in the early hatching period (up to four weeks) should be given more protection from predation, and rearing of such juvenile in hapa made by polyester cloth improved survival of common carp spawn (Chandra et. al., 2011; Sarkar et. al., 2007). Similar results were reported in the hatchlings of *Labeo rohita* when reared in hapas (Jha et. al., 2015).

Fish growers often complain about poor growth of fish procured from hatcheries as not reaching marketable size within the specified period. Marketing of substandard quality of seed is due to unhealthy competition among the hatcheries. For them quantity is important rather than the quality. There is a growing concern and need to develop standard norms for hatcheries and accreditation of hatcheries based on particular norms to maintain the supply of quality seed. Data recording systems are very poor as most of the hatchery operators are not well trained to keep proper records and manage hatcheries hygienically. There is no certification system for the hatcheries which exist in some countries.

There is no brood replenishment program followed in the hatcheries. Continuous uses of same broods and progeny of same parents might have resulted in inbreeding causing low seed quality of seed affecting the survival as well as the growth of the juveniles. Increased frequency of spawning and off-season production, both of which may increase stress on brood-fish and/or result in production of seed from immature gametes fish seed quality (Little et al., 2002b). Brood stock improvement should be considered as one of the most important management aspects of all seed production units that lead to good response in breeding, increased fertilization, and hatching and larval survival.

Relatively few hatchery operators reported fish health problem, which might be due to the lack of awareness about the problems. In order to improve seed availability there should be a collaborative approach and networking among different organizations of seed producers and all stakeholders. Quality feed with supplementation of multi-strain probiotics increases survival and growth of carp hatchlings. Use of live food enriched with amino acids can also improve growth and survival of fish larvae (Phelps, 2010). The networking of the reporting places should be established where they can get the advice and support service. Most of the hatcheries face enormous problems during seed production cycle. There is a need of collaborative approach among different organizations responsible for sustainable fish production in Nepal to take necessary actions to resolve the health and growth related problems in juveniles and table fish. Additionally, hapa nursing, proper sanitation and disinfection of nursery ponds, more importantly feeds, feeding and water quality management are very important for survival of juvenile.

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Effect of fish packing container on quality of fish flesh during transportation

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Abstract

The containers used in Nepal for storage and transportation of fish have poor insulation which is causing uncertainty in the shelf life and the products quality. Realizing the need, an experiment with three types of containers; namely, styrofoam box laminated with wooden plate and valve for water discharge (FWB), plain styrofoam box (SB), and high density plastic box (PC), was carried out to compare the insulation capacity and retaining the quality of fish. Twenty-four hour starved *Labeo rohita* (weight 500-700 g) were stored at a loading rate of 25 kg per box in each test container with 1:1 ice and fish ratio. Proximate analysis did not show remarkable differences in nutrient contents among the fish samples. Based on the temperature, the results indicated that the container styrofoam box laminated with wooden plate and discharge valve showed high insulation ability in maintaining consistently low chilling temperatures (-0.5 to -0.2°C) followed by styrofoam box (0.2-0.4°C). At the same time, although temperature was somewhat fluctuated in the PC, based on the peroxide value PC is better than others if the fish are needed store less than 36 hours.

Keywords: Fresh fish, insulation ability, temperature, microbial load, peroxide value

1. Introduction

Fish has been claimed to the best source of animal protein as it has all the essential amino acids, minerals and also omega-3 fatty acids. It is particularly important foodstuff among the agricultural products in developing countries due to its high protein content and diverse nutrients such as vitamin A, calcium, phosphorous iron, zinc, and son on. Fish is highly perishable, due to its high water activity and protein content, neutral pH and presence of autolytic enzymes, which cause rapid fish spoilage. Immediately after catching the fish start to spoil and the rate of spoilage depends on ambient conditions, fishing technology, fishing equipment, species of fish, catching season and handling and preservation activities (Hobbs, 1982).

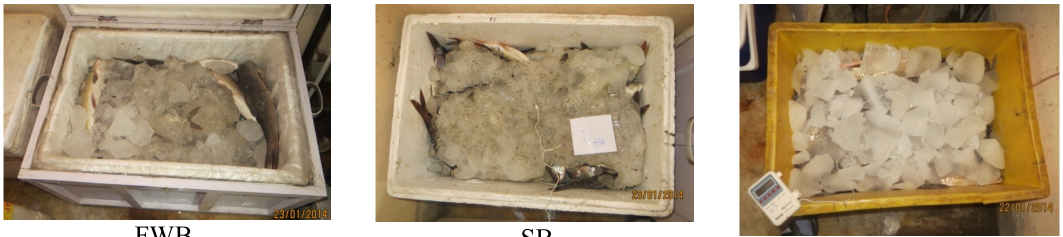
Temperature is the most important factor affecting post-harvest quality of the products. It is often critical to reach the desired short-term storage temperature rapidly to maintain the highest visual quality, flavor, texture, and nutritional content of fresh fish. Any delay in cooling the fish after harvest reduces shelf-life (Dunsmore and Thompson, 1981; Huss, 1992).

Fish muscles have less connective tissues and relatively higher moisture content than in red meat muscles; therefore, it is more susceptible to enzymatic autolysis and to microbial spoilage. The rate of spoilage due to the fat caused by oxidative rancidity, varies considerably with species and the composition of the fish. Higher the temperature faster would be the spoilage bacterial growth. Unhygienic water and insufficient cleaning may serve as a source leading to bacterial build up (Dunsmore and Thompson, 1981). Fish auction markets where fish are placed on dirty sacks, wooden, metal or plastic basins or planks in the open area may also serve as potential source of bacteria. Exposure to direct sunlight and polluted/dusty atmosphere provides conducive environment for the multiplication of spoilage organisms.

The most crucial factors determining the quality of fishery products are time and temperature dependent. Lowering the temperature by icing not only slows down the rigor mortis process, but also reduces the spoilage rate (Quang, 2005). A common way to chill the fish is to arrange it with ice in a box. For a box containing fish the thermal insulation is essential to minimize ice consumption and to keep inside temperature more independent of outside temperature. In Nepal fish are transported either in styrofoam boxes or plastic crates placing a layer of ice in between the layers of fish. However their effectiveness in terms of insulation or maintaining the chilling temperature, biochemical and microbial changes over the storage and transportation period has not been quantitatively addressed. Therefore, the present study was to compare the different types of fish storing containers on their suitability to preserve fresh fish.

2. Materials and Methods

Three types of containers (treatments) were chosen for the experiment: styrofoam box laminated with wooden plate (FWB), styrofoam box (SB) and high-density plastic crate (PC) (Figure 1). Styrofoam box (SB) and high density plastic crates (PC) are commonly containers by retailers and wholesalers.



FWB SB PC

Figure 1: Three types of boxes used for experiment: Styrofoam box laminated with wooden plate, (FWB), Styrofoam box (SB) and (c) plastic crate (PC)

Rohu*, Labeo rohita* with individual weight ranged between 500 -700g were harvested from the pond of RARS, Tarahara and conditioned for 24 hrs. Fish subjected to preservation was characterized as 24 hour starved, unwashed and with gut. Experimental containers were stocked with 25 kg fish in each box filled with pieces of ice slabs. The fish packing in the container involved a layer of fish was packed at the bottom followed by a layer of pieces of ice above it, in an alternate fashion ending with a layer of ice on top. Almost all the spaces between fish were filled with various sizes of pieces of ice. Fish were packed with ice in experimental containers at RARS, Tarahara and the preserved fish were brought to SEAM-MMA Lab at Biratnager and placed in the wet laboratory room. Fish were preserved for 66 hours and physical, chemical and microbial parameters were monitored specified time intervals.

Temperature (°C) of fish inside the experimental boxes was recorded from 6 am to 8 pm at the interval of 2 hours with sensory thermometer. One fish from each treatment was taken out each time of sampling at 6 hour intervals until the end. The samples were immediately possessed for microbiological and chemical analysis. Total Plate Count (TPC) was performed at 6-hour interval until the termination of preservation experiment by Most Probable Number (MPN) technique (APHA 1992). *Salmonella* and total colilform were counted by Pour Plate Method at the beginning and the end of the trial. Peroxide value was also measured at every 6-hour interval using the Titrimetric method. Proximate analysis of preserved fish involves the measurement of levels of crude protein (Kjeldahl method), total ash (Gravimetric method), oil content (Soxjlet method), acid insoluble ash (Gravimetric method) and moisture (Oven drying) which were analyzed at the beginning and end of the experiment.

Fish quality was evaluated by a panel of sensory experts comprised of four persons using Quality Index Method (QIM) (Martinsdottir et al. 2001). Whole fish samples were examined for appearance of skin, firmness of flesh, colour, and form of eye and finally color, smell and mucus formation of gills using QIM (as shown in following table).

Quality Index Method (QIM) scoring scale for whole Rohu (*Labeo rohita*)

Quality parameter	**Character**	**Score (ice/seawater)**
General appearance	Skin	0 Bright, shining 1 Bright 2 Dull
	Bloodspot on gill cover	0 None 1 Small, 10-30% 2 Big, 30-50% 3 Very big, 50-100%
	Stiffness	0 Stiff, in *rigor mortis* 1 Elastic 2 Firm 3 Soft
	Belly	0 Firm 1 Soft 2 Belly burst
	Smell	0 Fresh, seaweed/metallic 1 Neutral 2 Musty/sour 3 Stale meat/rancid
Eyes	Clarity	0 Clear 1 Cloudy
	Shape	0 Normal 1 Plain 2 Sunken
Gills	Colour	0 Characteristic, red 1 Faded, discolored
	Smell	0 Fresh, seaweed/metallic 1 Neutral 2 Sweaty/slightly rancid 3 Sour stink/stale, rancid
Sum of scores		(min. 0 and max. 20)

The sampled whole fish were filleted, skinned and cut into small pieces. Samples were steamed mixed with equal amounts of salt, which were blind coded before serving to the panelists of eight people. The changes in the taste and overall quality of cooked fish after preservation trial were assessed by Hedonic scaling (Table 1).

Table 1. Hedonic scale for freshness scoring of cooked Rohu (*Labeo rohita*).

Description	**Scores**
Like extremely	9
Like very much	8
Like highly	7
Like slightly	6
Neither like nor dislike	5
Unlike slightly	4
Unlike highly	3
Unlike very much	2
Unlike extremely	1

3. Results

Styrofoam box with wooden plate (FWB) showed consistent and high insulation ability in maintaining chilling temperature (-0.2 to -0.5°C) than the insulation ability of plastic crate i.e. PC (-0.7 to 3.8°C) and SB (0.2-0.4°C) containers (Figure 2). Ice melting was rapid in PC while slow melting was observed in FWB.

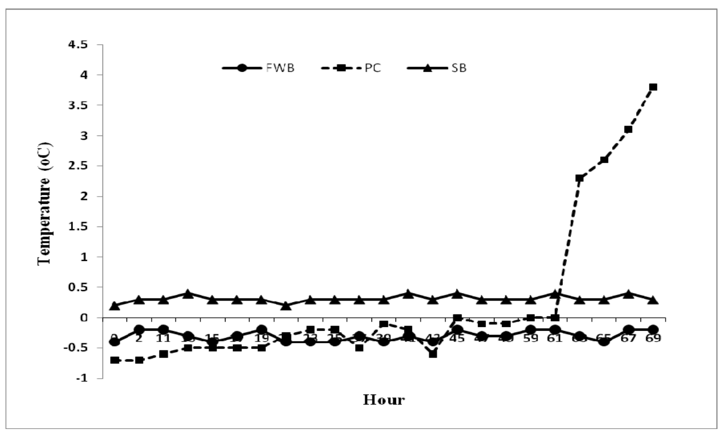


Figure 2: Trend of temperature of fish stored with ice in FWB, PC and SB

The amount of TPC, cfu/g was constant in fish preserved in FWB and PC up to 12 hours of the start of the experiment (Figure 3). After 12 hours, the amount of TPC increased rapidly up to the 36 hours of experiment in all three treatments. At the end point of 66th hour of preservation the TPC was log 5.53 cfu/g in FWB and log 5.40 cfu/g in PC which were not that significantly different. *Salmonella* was not found in all samples (Table 2).

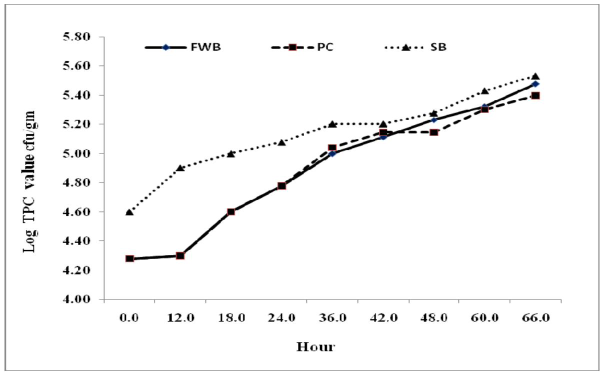


Figure 3: Log TPC contents of fish in ice stored in FWB, PC and SB

Table 2. *Salmonella,* cfu/g and total coliform in fish preserved in fabricated wooden box, plastic crate and styrofoam box.

Parameters		WFB	PC	SB	ICMSF, 1978
Salmonella cfu/g	Initial	0	0	0	
	Final	0	0	0	Not detected
	Difference				
Total coliform MPN/gm	Initial	21	21	21	
	Final	23	39	39	None
	Difference	2	18	18	

Peroxide level (Figure 4) was recorded always higher in SB as compared to other containers with the value of 0.43 meq O_2/kg at 66th hour of storage. Peroxide value was low and constant in PC up to 36th hour.

Proximate analysis did not show remarkable differences in nutrients content among the fish samples from test containers (Table 3).

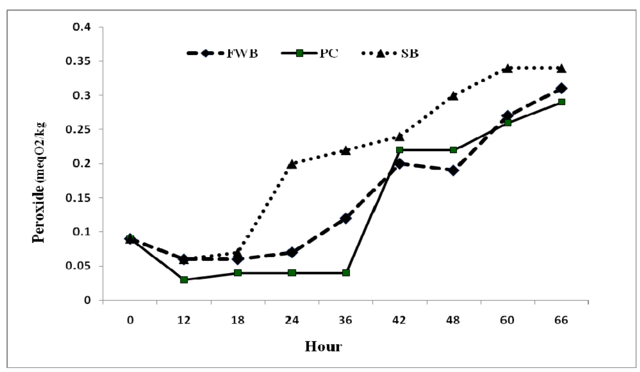


Figure 4: The trend of rise in peroxide (meq O_2/Kg) level of fish in ice stored in FWB, PC and SB

Table 3. Proximate analysis of fish preserved in ice in stored in FWB, PC and SB.

Parameter (%)		FB	PC	SB
Moisture	Initial	83.09	83.09	83.09
	Final	81.35	80.82	82.94
	Difference	1.74	2.27	0.15
Total ash	Initial	8.26	8.26	8.26
	Final	7.75	8.35	8.57
	Difference	0.51	-0.09	-0.31
Crude protein	Initial	18.4	18.4	18.4
	Final	18.56	19.87	18.56
	Difference	-0.16	-1.47	-0.16
Acid insoluble ash	Initial	0.47	0.47	0.47
	Final	0.81	0.77	0.86
	Difference	-0.34	-0.3	-0.39
Oil content	Initial	1.43	1.43	1.43
	Final	1.34	1.18	2.15
	Difference	0.09	0.25	-0.72

The sensory quality showed that the sum of QIM score was six in PC at the end of experiment, highest amongst the test containers (Table 4).

Table 4. Demerit scores from Quality Index Method for whole Rohu preserved in FWB, PC and SB.

Quality parameter	Character	Average score of preserved fish		
		Fabricated wooden box (FWB)	Plastic crate (PC)	Styrofoam normal (SB)
General appearance	Skin	0.0	0.5	0.5
	Bloodspot on gill cover	0.0	0.0	0.0
	Stiffness	1.0	1.5	1.75
	Belly	0.4	0.75	0.75
	Smell	0.8	1.0	1.0
Eyes	Clarity	0.0	0.25	0.0
	Shape	0.2	0.5	0.25
Gills	Colour	0.0	0.25	0.25
	Smell	0.6	1.25	1.0
Sum of scores		3.2	6.0	0.6

Eating quality was found best in cooked fish preserved in FWB (Table 5).

Table 5. Eating quality evaluation of Rohu preserved in FWB, PC and SB

	FWB	PC	SB
Colour	6.6	7.1	7.5
Texture	7.4	6.5	7.1
Flavor	7.8	6.5	6.9
Taste	8	7	7
Average	7.7	6.8	7.1

4. Discussion

Bacterial growth is the main cause of fish spoilage therefore it is logical to use bacterial number as an index of fish quality. The amount of TPC cfu/g was constant in fish preserved in FWB and PC up to 12 hours of the start of the experiment (Figure 3). After 12 hours, the amount of TPC increased rapidly up to the 36 hours of experiment in all three treatments. The chilling temperature of around 0°C can maintain freshness for a long time (Quang, 2005). Proliferation of microorganisms occurs at higher temperatures, while at lower temperatures close to 0°C, their activity is reduced; that helps extend the shelf-life of fish products. The rate of spoilage is dependent upon the holding temperature and is greatly accelerated at higher temperature due to increased bacterial activities (Amos, 2007).

At the end point of 66^{th} hour of preservation the TPC was log 5.53 cfu/g in FWB and log 5.40 cfu/g in PC which were not that significantly different. According to the International Commission on Microbiological Specification for Food (ICMSF, 1986), total plate count (TPC) only above the value of log 6 cfu/g is regarded as microbial spoiled fish muscle not fit for human consumption. TPC, cfu/g counts recorded in the fish preserved in all the three different containers were therefore within the limits of acceptability. Although the most dangerous bacteria *Salmonella* was not found in all samples, higher counts of total coliform in the fish sampled from PC and SB (39 MPN/g) than in FWB (23 MPN/g) (Table 2) suggests that FWB is safer than other containers. Exposure of microorganisms to stable low temperatures at the beginning in FWB might have helped reduce their growth and reproduction (Fig. 3 & Table 2).

Peroxide level (meq O_2/kg) (Figure 4) was recorded always higher in SB as compared to other containers with the value of 0.43 meq O_2/kg at 66^{th} hour of storage. More interestingly, peroxide value was low and constant in PC up to 36^{th} hour, which might be because PC contains less air. In other words, it is more airtight than others. Therefore, from the point of view of peroxide value, PC is better than others, especially if the fish are required to store up to 36 hours. In addition to presence of oxygen, high temperature is partly responsible for the speed of the oxidation processes in SB. In addition, direct sunlight, wind, heat, light (especially UV-light) and several organic and inorganic substances may also accelerate oxidative processes.

Apparent perceived quality of fish is defined as the aesthetic appearance and freshness or degree of spoilage, which the fish has undergone (Huss, 1995). Freshness to a certain degree is subjective but it can be measured against an agreed scale by assessment of appearance, odor and taste. Sensory quality attributes of fish samples were evaluated by panel using the Quality Index Method (QIM) (Martinsdottir et al., 2001) where each quality attribute were rated on a 0-3 demerit point scores. Lower scores signify higher quality and the total score can show the general fish quality with a total score of 0-20 for whole fish. Scores from each individual fish were added and the sum of the individual fish averaged to give the overall sensory score (quality index) of the fish from the same post-mortem age (post-catch days).

The sensory quality showed that the sum of QIM score was six in PC at the end of experiment, highest amongst the test containers (Table 4). Ice melting in PC might have resulted in high QIM score, however, the fish were still considered to be fit for human consumption when the score is lower than 18 (Martnsdottir et al., 2001).

In conclusion, FWB showed high insulation ability in maintaining stable chilling temperature (-0.5 to -0.2°C) than that of PC (-0.7 to 3.8°C) and plain SB (0.2-0.4°C) containers. The results suggested that the container FWB should be promoted in future for storage and transportation of fresh fish. At the same time, peroxide value found in the present study indicates that PC is better than other two for up to 36 hours of storage of fish, although temperature was somewhat fluctuated in the PC. More research is needed to explore better containers and methods of fish transportation.

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Polyculture of mixed-sex Nile tilapia (*Oreochromis niloticus*) with pangas catfish (*Pangasius hypophthalmus*)

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Abstract

Polyculture of Nile tilapia (*Oreochromis niloticus*) with predatory fish is an approach to control tilapia recruits and enhance tilapia growth. An experiment was conducted in 6 earthen ponds of 200 m^2 size for 150 days at the Center for Aquaculture Research and Production farm, Kathar, Chitwan to assess the polyculture performance of Nile tilapia with omnivorous catfish, pangas (*Pangasius hypophthalmus*). The experiment had 2 treatments with 3 replications. The treatments were: (1) Nile tilapia monoculture at 1 fish/m^2; (2) Nile tilapia at 1 fish/m^2 + Pangas at 0.5 fish/m^2. The stocking size of mixed-sex tilapia and pangas were 23-28 g and 31-52 g, respectively. Fish were fed with NIMBUS pellet feed (24.0% crude protein) at 3.0% of body weight per day and were adjusted based on monthly sampling. At harvest, the gross and net fish yields were significantly higher in Nile tilapia + Pangas treatment (8.3 and 7.2 ton/ha/year, respectively) than monoculture of Nile tilapia (3.8 and 3.1 ton/ha/year, respectively) ($p<0.05$). Similar survival rate (>98%), significantly lower feed conversion ratio (2.1), and tilapia recruits were resulted in tilapia-pangas polyculture. This study demonstrates the possibility of Nile tilapia and pangas polyculture to increase fish production for small-scale farmers.

Key words: Nile tilapia, Pangas catfish, Recruits, Fish yield

1. Introduction

Nile tilapia (*Oreochromis niloticus*) is a popular aquaculture species all over the world. It is considered an ideal species for small to large-scale aquaculture (Pillay, 1999). Being a lower trophic level species, it represents the greatest potential for efficiency and is commonly cultured in semi-intensive systems (Welcome, 1996). It was introduced in Nepal during 1985 (Pantha, 1993), but did not recommended to farmer for commercial culture for a long time because of its prolific breeding behavior that causes threat to the natural aquatic environment (Shrestha and Bhujel, 1999). Recently, mixed-sex Nile tilapia culture has been expanding to areas of the central Terai and among small-scale farmers. However, over production of recruitment in mixed-sex culture causes stunted growth and under sized fish production for market (Focken et al., 2000). Polyculture of mixed-sex Nile tilapia with predatory fish species such as sahar, pangas, snakehead, etc. might be a better approach to control the Nile tilapia recruits as well as expanding aquaculture of these species (Shrestha et al., 2011).

Pangasius hypophthalmus is a newly introduced exotic fish species in Nepal and is commonly known as “pangas” or “baikhi” in Nepal, belonging to the family Pangasiidae, under the order Siluriformes. Commercial culture and production of pangas has recently been expanded dramatically in many Asian countries especially in China, Thailand, Vietnam and Bangladesh. This species gained popularity because of its rapid growth, easy culture system, high disease resistance and tolerance to a wide range of environmental change (Sarkar et al., 2007; Khan et al., 2009). There is a huge demand for pangas in local Nepalese markets due to lower market price. Moreover, the vast majority of people consume pangas due to its delicacy and taste with high fat content. It indicates that this fish could have a significant contribution increasing fish production in Nepal. Pangas are generally cultured completely on supplemental feed in intensive aquaculture system. In monoculture, due to the use of large quantity of supplemental feed, pond water receives high quantity of inorganic nutrients from the microbial decomposition of unused fish feed and metabolic wastes. These nutrients favor excessive production of phytoplankton in pond water that can support additional number of planktivorous fishes without further feed or management cost (Azad et al. 2004; Sayeed et al., 2008). Thus, polyculture of pangas with planktivorous fishes might have advantageous to improve water quality and fish production. Moreover, the omnivorous nature of pangas might have ability to control tilapia recruitment in mixed-sex Nile tilapia culture. The purpose of this study was to create a polyculture system of pangas with mixed-sex Nile tilapia fitted to local conditions of Nepal.

2. Materials and methods

This experiment was conducted in 6 earthen ponds of 200 m^2 size for 150 days at the fish farm of Center for Aquaculture Research and Production (CARP), Kathar, Chitwan, Nepal. The experiment had 2 treatments with 3 replications of each treatment. The treatments were: (1) Nile tilapia monoculture at 1 fish/m^2 and (2) Nile tilapia at 1 fish/m^2 + Pangas at 0.5 fish/m^2. The experimental ponds were completely drained about 2 weeks before fish stocking. Then, ponds were filled with canal water and the water depth in all ponds was maintained at 1 m. Then, ponds were fertilized at the rate of 4 kg N and 1 kg P/ha/day for 7 days dose with di-ammonium phosphate (DAP) (18% N and 46% P_2O_5) and urea (46% N). The stocking size of mixed-sex Nile tilapia and pangas were 23-28 g and 31-52 g, respectively. Fish were fed with NIMBUS pellet feed (24.0% crude protein) at 3.0% of body weight per day. No additional fertilizers were applied throughout the experiment. Feeding trays of 1m x 1m size were fixed in each pond and feed were provided on daily basis at 9-10 am. Feed rations were adjusted based on monthly sampling weight of fishes. At harvest, fish were counted and separated, and their batch weight was taken.

In situ water temperature, dissolved oxygen (DO) and pH at 0.2 m depth, and Secchi disk depth, respectively were measured weekly using a Thermo Orion DO Meter (810A+Model), Microprocessor pH meter (WTW, pH 539 Model) and Secchi disk.

Data were analyzed statistically by paired T-test using SPSS (version 16.0) statistical software package (SPSS Inc., Chicago). Microsoft Excel was used for data calculation. All means are given with ± standard error (S.E.).

3. Results

3.1 Fish growth and production

The growth performance of Nile tilapia and pangas in the present experiment are presented in Table 1 and Figures 1-2. There were no significant differences in gross and net yield of Nile tilapia between two treatments (P>0.05). The daily growth rate of Nile tilapia was not significantly different between tilapia monoculture (0.88 g/fish/day) and tilapia-pangas polyculture (0.91 g/fish/day). Similarly, the survival of Nile tilapia was not significantly different between treatments (98.0% and 99.5%).

The pangas grew well in polyculture with Nile tilapia. The mean daily growth rate was 2.3 g/fish/day (Table 1). The mean survival was 97%. The pangas alone contributed the NFY of 4.02 ton/ha/year (Table 1).

At harvest, the gross fish yield and net fish yield were significantly higher in Nile tilapia + Pangas treatment than tilapia monoculture treatment (P<0.05; Table 2). There were no significant differences in overall survival between T_1 and T_2. The apparent food conversion ratio in T_1 (2.7) was significantly higher than in T_2 (2.1).

Table 1. Performance of Nile tilapia and pangas in different treatments during the experimental period of 150 days. Data based on 200 m^2 water area. Mean values with different superscript in the same row are significantly different (P<0.05).

Parameter	Treatment	
	Nile tilapia only (T_1)	Nile tilapia + Pangas (T_2)
Nile tilapia		
Stock number	200±.0.0 [a]	200±0.0 [a]
Total stock weight (kg)	5.7±0.3 [a]	4.6±1.0 [a]
Harvest number	196.0±4.0 [a]	199.0±1.0 [a]
Total harvest weight (kg)	31.4±1.3 [a]	31.6±3.3 [a]
Gross fish yield (kg/ha/cycle)	1571.7±65.8 [a]	1581.7±163.2 [a]
Net fish yield (kg/ha/cycle)	1288.5±53.2 [a]	1351.7±112.3 [a]
Daily weight gain (g/fish/day)	0.88±0.02 [a]	0.91±0.07 [a]
Survival (%)	98.0±2.0 [a]	99.5±0.5[a]
Pangas		
Stock number	-	100±0.0
Total stock weight (kg)	-	4.2±0.6
Harvest number	-	97.0±1.0
Total harvest weight (kg)	-	37.2±4.5
Gross fish yield (kg/ha/cycle)	-	1858.3±225.9
Net fish yield (kg/ha/cycle)	-	1650.0±200.3
Daily weight gain (g/fish/day)	-	2.27±0.24
Survival (%)	-	97.0±1.7

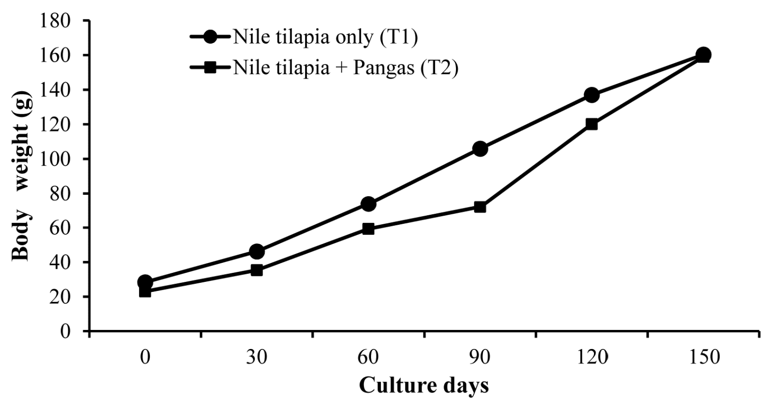

Figure 1: Monthly mean weight of Nile tilapia in two treatments during 150-days experimental period.

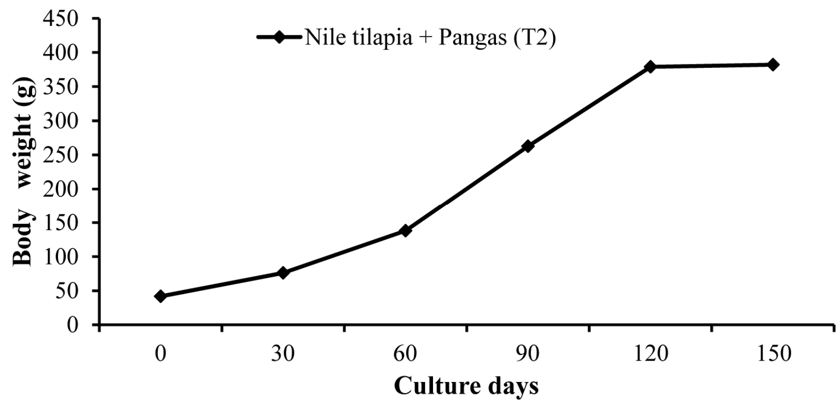

Figure 2: Monthly mean weight of Pangas during 150-days experimental period.

Table 2. Combined performance of Nile tilapia and pangas in different treatments during the experimental period of 150 days. Data based on 200 m^2 water area. Mean values with different superscript in the same row are significantly different (P<0.05).

Parameter	**Treatment**	
	Nile tilapia only (T_1)	**Nile tilapia + Pangas (T_2)**
Total stock weight (kg)	5.7±0.3	8.8±1.5
Total harvest weight (kg)	31.4 ± 1.3^a	68.8 ± 7.7^b
Gross fish yield (kg/ha/cycle)	1571.7 ± 65.8^a	3440.0 ± 383.2^b
Net fish yield (kg/ha/cycle)	1288.5 ± 53.2^a	3001.7 ± 308.8^b
Extrapolated gross fish yield (ton/ha/year)	3.8 ± 0.2^a	8.3 ± 0.9^b
Extrapolated net fish yield (ton/ha/year)	3.1 ± 0.1^a	7.2 ± 0.7^b
AFCR	2.7 ± 0.1^a	2.1 ± 0.0^b
Survival (%)	98.0 ± 2.0^a	98.7 ± 0.9^a

3.2 Recruit control

The total weight of Nile tilapia recruits were significantly higher in tilapia monoculture than in tilapia-pangas polyculture treatment (p<0.05; Table 3).

Table 3. Nile tilapia recruits in different treatments. Data based on 200 m^2 water area. Mean values with different superscript in the same row are significantly different ($P<0.05$).

Parameter	Treatment	
	Nile tilapia only (T_1)	**Nile tilapia + Pangas (T_2)**
Total weight (kg/200 m^2)	24.5 ± 1.9^{b}	14.9 ± 4.0^{a}
Gross yield (kg/ha/cycle)	1225 ± 95.0^{b}	743.8 ± 199.0^{a}

3.3 Water quality

There were no significant differences in water temperature, dissolved oxygen (DO), pH and Secchi disk depth between treatments (Table 4).

Table 4. Water quality parameters in different treatments. Mean values with different superscript in the same row are significantly different ($P<0.05$).

Parameter	Treatment	
	Nile tilapia only (T_1)	**Nile tilapia + Pangas (T_2)**
Water temperature (°C)	29.3 ± 0.0^{a} (22.2-32.0)	29.5 ± 0.1^{a} (23.4-31.8)
Dissolved oxygen (mg/L)	5.7 ± 0.4^{a} (3.7-10.8)	5.3 ± 0.4^{a} (2.7-11.3)
pH	7.0 (6.2-9.2)	7.3 (6.7-8.8)
Secchi disk depth (cm)	34.7 ± 0.2^{a} (21.4-52.3)	31.8 ± 2.2^{a} (22.4-45.3)

4. Discussion

Carp polyculture is the long established aquaculture in Nepal. Recently, Nile tilapia culture has been initiated by small farmers in some areas in Chitwan. Similarly commercial pangas monoculture has been started since last few years with limited fish farmers. This study looks the option to increase the production and productivity of fish to increase profits using those commercial species for the benefit of small fish farmers. Results showed there were no significant differences in gross and net yield of Nile tilapia between treatments ($p>0.05$). This indicates that addition of pangas in Nile tilapia ponds up to 50% of its stocking density does not affect the yield of Nile tilapia. The daily growth rate of Nile tilapia attained in this experiment (0.88 and 0.91 g/fish/day were similar to the growth rate of Nile tilapia (1.15 g/d) in polyculture with sahar at a 1:1 stocking ratio conducted in a concrete pond (Acharya et al., 2007).

The pangas grew well in polyculture with Nile tilapia. The mean daily growth rate was 2.3 g/fish/day. This growth rate was very high compared to 0.3-0.5 g/fish/day in different polyculture combinations with carps and Nile tilapia reported by Azad et al. (2004). The mean survival of pangas in the present study was 97%. Azad et al. (2004) reported the 88% survival of pangas in polyculture with carps and Nile tilapia by stocking the fingerlings of 4.3-5.6 g size. The better growth of pangas in the present study might be due to stocking of larger size fingerlings (42 g size). Pangas alone contributed the NFY of 4.02 ton/ha/year. It was due to better utilization of resources such as space, natural food, etc.

Addition of pangas effectively controlled the number and biomass of tilapia recruits. Although there are lack of evidences that indicates that pangas can control the tilapia recruits, some previous studies reported that sahar is an excellent fish to control recruits in mixed-sex tilapia ponds and the number of tilapia recruits decreased linearly with increasing stocking density of sahar (Yadav et al., 2007; Shrestha et al., 2011; Gurung et al., 2013).

Increased fish density with pangas in pond did not deteriorate water quality compared to tilapia alone and rather increased FCR and productivity.

5. Conclusion

This study indicates the possibility of pangas catfish to polyculture with Nile tilapia with the existing semi-intensive tilapia culture system to increase pond productivity. It might be a suitable aquaculture system to small-scale aquaculture to increase existing pond productivity and to reduce input costs that occurs in intensive pangas monoculture system. Further experiment is recommended to fine tune the stocking ratio of the Nile tilapia with pangas and the economics of this system.

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Growth and production of carp and tilapia in polyculture at different altitudes of Nepal

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Abstract

Water temperature varies with the altitudes and fish growth with temperature. An experiment to assess the effect of different altitudes on growth and production of carp and Nile tilapia in polyculture was conducted in Makawanpur district of Nepal with three treatments based on altitude: Daman as T_1 (1870 msl), Bharta as T_2 (700 msl) and Manahari as T_3 (350 msl) with three replications for each treatment. In overall, growth and production of all the species decreased with increasing altitude with significantly better performance in lower altitude (T_3), intermediate in mid altitude (T_2) and lowest in higher altitude (T_1). Based on daily weight gain (DWG) and production, common carp showed over all best performance in all treatments; Nile tilapia was second to common carp in T_2 and $T_{3;}$ grass carp was second to common carp followed by Nile tilapia in T_1. The growth rate of silver carp and bighead carp was comparatively lower in all treatments. Survival was significantly lower and apparent food conversion ratio (AFCR) was significantly higher ($p<0.05$) in $T_{1,}$ compared to T_2 and T_3. The results suggests that carp-tilapia polyculture seems possible in all locations up to November but may not be possible in T_1 throughout the year.

Keywords: Polyculture, carp, tilapia, altitude

1. Introduction

The fisheries and aquaculture have emerged as potentially an important sector of Nepalese agriculture (Gurung, 2014) with an annual growth rate of 8.4% (Mishra, 2015). The current domestic production is 64,900 metric ton which meets about 67% of its total demand. This sector shares about 2.62% of the agriculture GDP and 0.93% of the total GDP utilizing less than 2% of the available water resources (Mishra, 2015). Semi-intensive carp polyculture is the major and established system of aquaculture in Nepal with an average productivity of about 3.6 t/ha/year (MoAC, 2010). Carp polyculture alone contributes more than 90% of total production which is mainly fulfilled by fish production in the southern part of the country, where 94% of the fishponds are located. However, the hills and mountains, despite having huge diverse water resources in the form of rivers, rivulets, streams, lakes, ponds, tanks and reservoirs contribute little to aquaculture production. The aquaculture production potential of the cold water sector has not been exploited to its fullest

(Gurung, 2014) except some development in trout farming in recent years. In the upland waters particularly in hills and mountain areas, Indian major carps do not grow well due to the low thermal regime. Thus, introduction of composite fish farming using Chinese carps and common carp for mid-altitude could be a major success in increasing the fish production from the hilly regions (Shrestha et al., 2012).Chinese carps (silver carp, bighead carp and grass carp) are recommended for culture in hilly region due to their wide range of temperature tolerance which can tolerate as low as 0.5^{o}C to as high as 38^{o}C with optimum temperature range from 25-32^{o}C for grow outs. Similarly, Nile tilapia, one of the promising aquaculture species emerging in recent days, are suggested to grow in hilly areas during summer taking the advantages of hot summer for its grow out (Yadav, 2006). Moreover, there is a very little information regarding the culture of tilapia in higher altitude. With a view to observe the effect of altitude on growth and production of carp and tilapia in polyculture, an experiment was conducted at three different locations at an altitude of 350 msl in Manahari, 700 msl in Bharta and 1870 msl in Daman in Makawanpur district of central Nepal during June to November 2014.

2. Materials and methods

This experiment was conducted at three different locations (treatments) with different altitude range including Daman(T_1), Bharta (T_2) and Manahari (T_3). There were three replications for each treatment. All treatments were stocked with five fish speciesmixed in a ratio of common carp (36%), silver carp (18%), bighead carp (18%), grass carp (18%) and Nile tilapia (10%) and were stocked at a density of 2.6 fish/m^2. The research was conducted in farmers' earthen ponds for a period of 153 days beginning from 9 June 2014 and was harvested during November 2014. The pond size ranged from 42 m^2 to 240 m^2 with an average size of 115 m^2.All fingerlings were procured from Fisheries Development Center (FDC), Hetauda.

All experimental ponds were drained, dried, and limed (agricultural grade $CaCO_3$) at 250 kg/ha. Cow dung was applied at 500 kg/ha (Bhujel, 2008). The ponds were filled with surface water in Daman (T_1) and Bharta (T_2) and with boring water in Manahari (T_3). Water depth was maintained 1.0 m for all ponds throughout the experimental period. A week prior to stocking, ponds were fertilized with Urea 60 kg/ha and diammonium phosphate (DAP) 125 kg/ha (Bhujel, 2012), respectively and were applied as basal dose. No additional fertilization was done in the ponds after basal dose.

Feeding was done using locally made feed (23% CP) with mustard oil cake (50%), rice bran (20%), soyameal (20%) and maize flour (10%) as ingredient. Daily feeding was done at the rate of 5% body weight (BW) for first month which was then reduced to 3% BW throughout experimental period.The quantity of feed was adjusted on the basis of biomass sampled at monthly basis.

The fish were netted monthly for growth observation. At least 10% of the fish were netted for sampling and weighed to measure the growth on monthly basis while the water quality parameters (Temperature, pH, Dissolved Oxygen (DO) and Transparency) were measured on fortnightly basis. Final harvesting was done by draining ponds starting from 5 November 2014 to 16 November 2014 in different ponds at different locations.

Experimental data were analyzed using one-way analysis of variance (ANOVA) to find difference among treatments. Differences were considered significant at an alpha level of 0.05 ($P<0.05$). All means were given with mean ± 1 standard error (S.E.). Data of survival rate of different species were transformed into square root before analysis.

3. Results

3.1 Growth and yield of fish

Growth and production of both carps and Nile tilapia were directly correlated with the altitude; highest growth and production at low altitude and vice versa.

Table 1: Growth and production parameters of different fish species at different altitudes.

Parameters	Treatment		
	T_1	T_2	T_3
	Common Carp		
Mean stocking weight (g)	2.0	2.0	2.0
Total stocking weight (g/100m^2)	185.1±0.9	185.2±11.4	195.1±0.3
Mean harvesting weight (g)	106.5±7.6^c	134.1±5.1^b	205.7±7.7^a
Total harvesting weight (kg/100m^2)	3.2±1.3^c	11.5±1.4^b	18.2±0.9^a
Mean DWG(g/fish/day)	0.7±0.1^c	0.9±0.0^b	1.4±0.1^a
Mean TWG (kg/100m^2)	3.0±1.2^c	11.4±1.4^b	18.2±0.9^a
Survival (%)	30.1±9.9^b	93.3±3.4^a	92.7±1.4^a
Extrapolated GFY (kg/ha/yr)	801.5±317.0^c	2,803.7±344.8^b	4,219.7±209.3^a
Extrapolated NFY (kg/ha/yr)	752.7±316.9^c	2,758.6±342.4^b	4,174.8±209.4^a
	Silver Carp		
Mean stocking weight (g)	0.4	0.4	0.4
Total stocking weight (g/100m^2)	19.2±0.2	19.2±0.1	19.2±0.1
Mean harvesting weight (g)	8.8±0.7^b	63.4±2.7^a	54.9±3.4^a
Total harvesting weight (kg/100m^2)	0.1±0.0^b	1.8±0.1^a	2.2±0.2^a
Mean DWG (g/fish/day)	0.1±0.0^b	0.4±0.0^a	0.4±0.0^a
Mean TWG (kg/100m^2)	0.1±0.0^b	1.8±0.1^a	2.1±0.2^a
Survival (%)	28.6±7.2^b	59.9±1.6^a	81.7±1.7^a
Extrapolated GFY(kg/ha/yr)	30.6±10.1^b	444.7±19.7^a	496.8±40.0^a
Extrapolated NFY (kg/ha/yr)	25.9±10.1^b	440.1±19.7^a	492.4±40.1^a

Parameters	Treatment		
	T_1	T_2	T_3
Bighead Carp			
Mean stocking weight (g)	0.4	0.4	0.4
Total stocking weight (g/100m^2)	19.2±0.2	19.2±0.1	19.2±0.1
Mean harvesting weight (g)	10.5±0.9^c	74.2±1.9^a	53.1±1.5^b
Total harvesting weight (kg/100m^2)	0.2±0.1^b	2.5±0.2^a	2.2±0.1^a
Mean DWG (g/fish/day)	0.1±0.0^c	0.5±0.0^a	0.3±0.0^b
Mean TWG (kg/100m^2)	0.2±0.1^b	2.5±0.2^a	2.2±0.1^a
Survival (%)	33.5±8.7^b	70.9±5.2^a	87.8±2.5^a
Extrapolated GFY(kg/ha/yr)	42.8±14.7^b	615.2±42.6^a	515.0±26.6^a
Extrapolated NFY (kg/ha/yr)	38.1±14.7^b	610.5±42.6^a	510.6±26.6^a
Grass Carp			
Mean stocking weight (g)	4.0	4.0	4.0
Total stocking weight (g/100m^2)	192.5±1.5	192.5±1.2	191.9±1.1
Mean harvesting weight (g)	65.6±±3.8^c	90.0±7.0^b	117.7±0.9^a
Total harvesting weight (kg/100m^2)	1.3±0.5^c	3.8±0.3^b	5.0±0.1^a
Mean DWG (g/fish/day)	0.4±0.0^c	0.6±0.1^b	0.8±0.0^a
Mean TWG (kg/100m^2)	1.1±0.5^c	3.6±0.3^b	4.9±0.1^a
Survival (%)	39.9±13.9^b	87.2±4.3^a	89.7±0.4^a
Extrapolated GFY(kg/ha/yr)	319.2±130.7^b	918.8±83.8^a	1,165.6±13.5^a
Extrapolated NFY(kg/ha/yr)	272.3±130.8^b	871.9±83.7^a	1,121.5±13.4^a
Nile Tilapia			
Mean stocking weight (g)	5.2	5.2	5.2
Total stocking weight (g/100m^2)	124.8±2.6	124.4±0.8	125.1±0.4
Mean harvesting weight (g)	33.9±0.9c	105.4±7.7^b	129.9±3.5^a
Total harvesting weight (kg/100m^2)	0.4±0.1^b	2.0±0.2^a	2.1±0.1^a
Mean DWG (g/fish/day)	0.2±0.0^c	0.7±0.1^b	0.9±0.0^a
Mean TWG (kg/100m^2)	0.3±0.1^b	1.9±0.2^a	2.0±0.6^a
Survival (%)	45.2±4.8^b	79.6±3.0^a	66.7±16.7^{ab}
Extrapolated GFY(kg/ha/yr)	93.0±13.1^b	494.6±55.7^a	488.9±137.6^a
Extrapolated NFY(kg/ha/yr)	61.9±12.6^b	464.3±55.5^a	460.1±137.5^a

Values with different superscripts in row are significantly different at $p<0.05$

Mean harvesting weight, total harvesting weight, daily weight gain, extrapolated gross fish yield (GFY) and net fish yield (NFY) of common carp was significantly ($p<0.05$) higher in T_3 (low altitude, 350 msl), medium in T_2 (medium altitude, 700 msl) and lower in T_1 (high altitude, 1870 msl) (Table 1).

Similarly, mean harvesting weight, total harvesting weight, daily weight gain, total weight gain, survival rate extrapolated GFY and NFY of silver carp and bighead carp in T_1 was significantly lower than T_2 and T_3. But, there was no significant difference in these parameters between T_2 and T_3.

Mean harvesting weight, total harvesting weight, daily weight gain and total weight gain of grass carp in T_1 was significantly lower than T_2 that in turn was significantly lower than T_3 (Table 1). Similarly, survival rate, extrapolated GFY and NFY of grass carp in T_1 was significantly lower than T_2 and T_3.

Nile tilapia in average performed quite better in all treatments after common carp. It ranked second in T_2 and T_3 after common carp and third in T_1 after common carp and grass carp.However, mean harvesting weight and DWG of Nile tilapia in T_1 was significantly lower than T_2 that in turn was significantly lower than T_3. However, total harvesting weight, total weight gain, survival rate, extrapolated GFY and NFY of Nile tilapia between T_2 and T_3 were not significantly different but significantly higher than in T_1.Recruitment of Nile tilapia was recorded at lower altitudes i.e. T_2 and T_3 while there was no recruitment at higher altitude.

Combined and extrapolated GFY and NFY in T_1 were significantly lower than T_2 that in turn was significantly lower than T_3while the overall survival of fish in T_1 was significantly lower than T_2 and T_3 (Table 2). The apparent food conversion ratio (AFCR) in T_1 was significantly higher than T_2 and T_3.

Table 2. Combined yield, AFCR and survival of fish in different treatments.

Parameters	**Treatment**		
	T_1	**T_2**	**T_3**
Combined GFY (t/100 m^2/crop)	0.005 ± 0.002^c	0.022 ± 0.002^b	0.030 ± 0.000^a
Combined NFY (t/100 m^2/crop)	0.005 ± 0.002^c	0.021 ± 0.002^b	0.029 ± 0.000^a
Extrapolated GFY (t/ha/yr)	1.29 ± 0.46^c	5.28 ± 0.45^b	6.89 ± 0.07^a
Extrapolated NFY (t/ha/yr)	1.15 ± 0.46^c	5.15 ± 0.45^b	6.76 ± 0.07^a
AFCR	6.88 ± 1.73^a	2.34 ± 0.14^b	1.98 ± 0.06^b
Overall Survival	33.66 ± 8.54^b	80.55 ± 3.13^a	86.92 ± 0.95^a

Values with different superscripts in row are significantly different at $P<0.05$

3.2 Water quality

Average morning water temperature in T_1 was significantly lower ($p<0.05$) than in T_2 which in turn was lower than T_3 (Table 3). However, average day and evening water temperature in T_2 and T_3 was not significantly different ($p>0.05$) with significantly lower ($p<0.05$) in T_1.

Average morning, day and evening DO of T_3 was significantly lower compared to T_1 and T_2, whereas there was no significant differences between T_1 and T_2. Average transparency in T_1 was significantly higher than in T_2 and T_3.

Table 3. Average water quality parameters of different treatments taken at different times during the experimental period. Figures in parenthesis show range value.

Parameters	Time	Treatment		
		T_1	**T_2**	**T_3**
Temperature (°C)	Morning	15.6 ± 0.5^{c} (13.0-17.0)	21.9 ± 0.7^{b} (17.0-25.0)	26.1 ± 1.4^{a} (18.0-29.0)
	Day	18.0 ± 0.7^{b} (15.0-24.0)	25.7 ± 1.1^{a} (20.0-29.0)	28.6 ± 1.5^{a} (20.0-31.0)
	Evening	17.6 ± 0.8^{b} (14.0-22.0)	24.9 ± 1.1^{a} (19.0-28.0)	27.8 ± 1.6^{a} (19.0-32.0)
Dissolved Oxygen (mg/L)	Morning	7.8 ± 0.2^{a} (6.5-9.5)	7.8 ± 0.4^{a} (6.3-8.6)	6.9 ± 0.3^{b} (5.1-8.5)
	Day	8.1 ± 0.3^{a} (7.2-10.2)	7.8 ± 0.1^{a} (7.1-8.0)	7.1 ± 0.2^{b} (5.5-8.2)
	Evening	8.2 ± 0.3^{a} (7.6-10.1)	8.1 ± 0.1^{a} (7.5-10.0)	7.2 ± 0.1^{b} (5.5-8.2)
pH	Morning	6.3 (5.8-9.0)	6.9 (6.4-7.8)	5.7 (5.8- 9.5)
	Day	6.4 (5.6-9.3)	7.7 (7.0-9.5)	6.2 (5.6-10.0)
	Evening	6.0 (5.6-9.8)	7.8 (7.0-9.3)	7.0 (5.9-9.0)
Transparency (cm)		42.1 ± 4.5^{a} (20.0-70.0)	30.6 ± 2.2^{b} (25.0-50.0)	27.7 ± 1.2^{b} (20.0-40.0)

Values with different superscripts in row are significantly different at $p<0.05$

4. Discussion

There was significant difference in water quality parameters among different treatments. Variation in morning water temperature among treatments may be due to colder nights with increasing altitude while variation in day and evening water temperature can be simply attributed to difference in altitude. However, difference in altitude between T_2 and T_3 (350 m) was lower than difference in altitude between T_1 and T_2 (1170 m) which may be the reason behind no significant difference in day and afternoon water temperature between these two treatments. The difference in DO of water among treatments may be attributed to the relationship between temperature and DO. According to Murphy (2005) cold water holds more dissolved oxygen than warm water in similar conditions. Difference in water transparency may be due to newer ponds and lower rate of fertilization.

The slow growth of Common carp at the high altitude might be due to two factors: temperature and new pond. Result showed that the average water temperature of T_1 was significantly lower ($p<0.05$) than T_2 and T_3 throughout day-time during whole experiment (Table 3). It is proven that lower temperature decreases the fish's metabolic rate resulting into lower feed intake and thus lower growth rate. Moreover, newly constructed ponds in T_1 had less amount of bottom debris resulting into less availability of natural food to common carp since it feeds on bottom debris (Ali et al., 2010). However, it can switch feeding habit to other alternatives as well and can adapt to a wider range of temperature (Froese and Pauly, 2011). Therefore, growth rate of common carp in T_1 was comparatively better than other carp species. Significantly lower survival rate of common carp in T_1 (30.1±9.9%) can be simply attributed to low temperature. This can be justified by findings of Hossain et al. (2014) which also showed low survival rate of mirror carp in winter compared to summer. Depending on culture conditions and environment, the growth rate of common carp is reported to be around 2.0 g/day (Dabbadie and Lazard, 1992). In present study growth rate of around 1.0-1.5 g/day was recorded in culture at higher temperature (T_2 and T_3) while it was around 0.7 g/day in cultureat lower temperature (T_1). However, this growth is also satisfactory as compared to growth rate of other species in similar condition.

The lower growth of silver carp and bighead carp in T_1 might have been influenced by low temperature and newly constructed ponds. The transparency in T_1 was significantly higher compared to T_2 and T_3 (Table 3) indicating that there was less plankotnic density which serves as food for these species (Robinson and Buchanan, 1988; Kolar et al., 2005). Higher stocking density may be another factor affecting the growth rate of silver and bighead carp (Prein, 1993). It has been reported that these species has significantly lower growth rate with higher stocking rate (Bakeer and Tharwat, 2006; Hepher et al., 1989). Growth rate of bighead carp was found higher than silver carp which might have been due to its wide food spectrum (Xie and Liu, 2001). Extremely slow growth of silver and bighead carp in T_1 denotes that these species have relatively narrow range of temperature tolerance that make them unsuitable for culture at high altitudes where average temperature remains lower in most part of the year. These species might be suitable up to medium altitude as the growth was not significantly different with low altitude treatment (T_2 and T_3).

Similarly, differences in growth parameters of grass carp could be attributed to low temperature at high altitudes, similar to common, silver and bighead carps. However, similar survival rate of grass carp in T_2 and T_3 have resulted into similar extrapolated GFY and NFY among these treatments with differential growth rates.

Differences in growth parameters and recruitment of Nile tilapia can also be attributed to significantly low average temperature of T_1. Lower temperature suppresses the reproduction of Nile tilapia. Water temperature in ponds of T_1 ranged from 13-24°C, which is critically lower than temperature suitable for Nile tilapia breeding (El- Naggar et al., 2000).

Raising density above a certain level decreases the growth rate of fish in semi-intensive aquaculture results into lower growth rate of some species (Abdelhamid, 2011). This may be the reason that the growth rate of carps and tilapia in present study was affected.

Comparatively better growth of common carp and Nile tilapia at higher altitudes indicates that these species are more cold tolerant than other species used in present study. They can also be stocked at higher densities as they are also recommended for intensive culture (Viola et al., 1982; Bahnasawy et al., 2009). Although common carp and Nile tilapia performed better than other species, using cold tolerant variety will be better for proper development of aquaculture of these species at higher altitude.

Difference in combined and extrapolated GFY and NFY may have been due to low production and high mortality with increasing altitude. Temperature during most of the time remained lower in T_1 due to which there may be decrease in feed intake by fish than calculation based supplied feed. This may have led to wastage of feed in T_1 thus increasing FCR. Overall survival of fish in T_1 was also significantly lower than T_2 and T_3 that may have been due to problem in acclimatization of warm water fish to low water temperature. Extrapolated GFY and NFY in T_2 and T_3 was comparable to that reported by Pandey (2002) and Jena et al. (2002). Pandey (2002) reported that total fish production in four species culture system (silver carp, grass carp, bighead carp and common carp) was 4.63 t/ha/yr in Chitwan condition. Jenaet al. (2002) reported that combination of catla, rohu, mrigal, silver carp, grass carp and common carp in the ratio of 2:2:2:2:0.5:1.5, at a combined stocking density of 10,000 fingerlings/ha produced fish yield of 5.8 t/ha/yr. However, since stocking density was higher than other studies, it was obvious to get more productivity.

5. Conclusion

From results of present study it can be concluded that growth and production of all experimental species decreased with increasing altitude which might have been due to low temperature and newly constructed ponds. However, culture of common carp, silver carp, bighead carp, grass carp and Nile tilapia is feasible up to the altitude of 1870 msl with best performance of common carp at all altitudinal range. Growth of common carp, grass carp and Nile tilapia is comparatively better than silver and bighead carp at higher altitudes. Thus it can be concluded that these three species combinations, i.e., common carp, grass carp and Nile tilapia is suitable for culture at higher altitudes of Nepal.

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Fish growth and production in relation to integration models in Nuwakot, Nepal

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Abstract

Integrated fish farming is a system that synergizes between components for economic utilization of scarce land resources and productive utilization of byproducts from agricultural activity into aquaculture. A study under participatory research was carried out on grass-fish, pig-fish and fish polyculture models of integrated fish farming at Chhatrephat, Nuwakot, Nepal. Fish survival rate from grass-fish (77.7%) and pig-fish integrated (80.0%) systems were significantly ($P<0.05$) higher compared to the non-integration (69.6%). Mean fish yield of 3442.7 kg/ha and 3212.0 kg/ha from grass-fish and pig-fish integrated system, respectively obtained in this study was 45.8% and 36.1% higher than the yield from non-integrated system (2360.2 kg/ha). Feed conversion ratio (FCR) was low in pig-fish (1.24) followed by grass-fish (1.51) and the highest FCR was for non-integrated polyculture system (2.47). Apparently poor performance of common carp in all integrated system found in this study suggests that evaluation of omnivore fish species is needed to efficiently utilize benthic fauna resulting from grass and manure detritus for improving the productivity of fish from integrated fish farming system.

Key words: Integrated fish farming, grass-fish, pig-fish, polyculture, detritus.

1. Introduction

Integrated agriculture-aquaculture systems occur when an output from one subsystem in an integrated farming system, which otherwise might have been wasted, becomes an input into another subsystem resulting in a greater efficiency of output of desired products from the land/water and are controlled by a farmer (Little and Muir, 1987; Edwards et al., 1988). Integrated farming involving aquaculture defined broadly is the concurrent or sequential linkage between two or more activities, of which at least one is aquaculture (Mukherjee. 1995; Little and Muir, 2003). The key characteristic of integrated agriculture-aquaculture systems is the flow of resource or synergisms among subsystem in such systems (Dalsgaard and Prein, 1999; Prein, 2002).

Integrated fish farming system (IFF) was conceived in late 1970s in Nepal. Integrated livestock-agriculture-aquaculture approach envisages the integration of fish farming with agricultural components in a design allowing byproducts and or wastes from one system to be used as inputs in another system (FAO/UN, 1979; Ayinla, 2003; Eyo et al., 2006;). Several forms of aquaculture integration with livestock, duck, horticulture/vegetables and grass have been practiced by the small farmers in the country. Among the different forms of integration, pig-fish and grass-fish integration is becoming popular among farmers of hill and Tarai region irrespective of caste and poor technical know-how and management. Farmers have been raising pig, grass and vegetables in fish pond dike with the aim of economic utilization of scarce land resources, productive utilization of wastes from these non-aquaculture commodities into aquatic products (Jha and Wagle, 2015). The pond-dike system, where fish are raised in ponds and crops and or livestock are grown on the dikes or in the immediate vicinity of the pond, is well known for its ability to maximize energy input and minimize wasted energy output through the recycling of organic wastes among components of the system (Ruddle and Zhong, 1988). The system integrates agriculture and aquaculture, two separate component of farming systems into one physically linked ecosystem (Lo, 1996). Integrated pond-dike systems have met with variable success in different parts of the World (Little and Muir, 1987). Traditional management of pond-dike systems in China show an intensive nutrient cycling over the pond-dike interface, resulting in a much higher nutrient retention of 50-70 % in the combined crops of aquatic and terrestrial produce (Gongfu et al., 1997). Ponds can be used to process many forms of agricultural waste, including livestock manure and crop residue and convert these wastes into high-grade fish protein. But such practices of integrated fish farming in Nepal are rarely quantified into input-output relations. Inadequate database on biological processes, ecological systems, farming systems and economic aspect of IFF in local context is constraining the wider dissemination of the integrated fish farming systems. Thus the present work aimed to elucidate the effect of pig and grass integration on growth and yield of carp fish in mid hill ponds.

2. Materials and methods

A 200 days (March to October) participatory study on three different types of pond integrated fish farming (1) fish only with concentrate feed, (2) grass-fish and (3) pig-fish was carried out in river basin at Chhatrephat, Nuwakot, Nepal for the two consecutive years. Three ponds (replicate) with an average size of 357±112 m^2 and mean water depth of 95±12 cm was employed for each type of integrated fish farming (IFF) system. Oat (*Arrhenatherum elatius*), kikkyu (*Pennisetum clandestinum*) and peanut grass (*Arachis glabrata)* was cultivated respective to their growing season in 65% of the pond dikes. Pigs were raised in pig sty constructed on the respective pond dike at a density of 60 pig/ha of pond (Table 1). Pre-stocking management of pond involved the pond drying, liming with calcium carbonate ($CaCO_3$) at 500 kg/ha, manure application with cow dung at 3 ton/ha in a single dose and water filling subsequently. Large size fish fingerlings (17.5±6.1 g) of four carp species, silver carp (*Hypophthalmicthys molitrix*), bighead carp (*Aristchthys nobilis*), grass carp (*Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*) were stocked in different proportion at 10000 fish/ha in the ponds (Table 1). Stocked fish were fed daily at 3% and 1% of total live body weight for fish in non-integrated and integrated system, respectively, with a ration comprised of rice bran, wheat flour and corn containing approximately 18% crude protein. Grass grown in the pond dike was cut and fed to the fish, and pig excreta were daily discharged to the respective integrated ponds. Integrated ponds did not apply chemical fertilizer while non-integrated ponds was applied 15 kg/ha di-ammonium phosphate and 15 kg/ha urea. The total amount of chemical fertilizer was applied in respective pond in two split doses at equal proportion during the fish growing period. Byproducts and/or wastes from integrated system loaded in respective ponds are given in Table 1.

Table 1. Stocking number and initial biomass of fish and production input for fish in different integrated fish farming systems

Attributes	**IFF system**		
	Fish only	**Grass-Fish**	**Pig-Fish**
Fish stocking, No./ha	10000	10000	10000
Silver carp	2500	2000	2000
Bighead carp	2500	1500	3500
Grass carp	3000	4000	2000
Common carp	2000	2500	2500
Mean individual wt. at stocking, g	14.8±6.1	17.7±2.9	19.2±4.7
Silver carp	24.3±2.3	27.9±4.9	27.3±3.2
Bighead carp	11.5±3.9	11.4±2.5	14.6±2.1
Grass carp	11.1±2.4	15.1±4.8	16.1±2.7
Common carp	12.1±7.3	16.6±3.1	18.7±7.6
Gross weight at stocking, kg/ha	148.8	174.9	184.8
Dike area occupied by the subsystem, %	-	65.0	7.0
Cropping intensity `	1	3*	1
Grass and pig excreta load, t/ha pond	-	4.3	5.2
Concentrate feeding rate, % of fish biomass (daily basis)	3.0	1.0	1.0
Chemical fertilizer, kg/ha pond			
Di-ammonium phosphate (DAP)	15.0	-	-
Urea	15.0	-	-

* Cultivated grass includes oat, kikkyu and forage peanut

Water quality which includes temperature, dissolved oxygen, pH, alkalinity, hardness and conductivity was measured in-situ between 8-9 am at monthly interval from all the experimental ponds using Vernier analogue meter (Model LABQUEST2). Species wise fish growth was measured and data were collected at monthly interval and yield and survival data were obtained at harvest. Differences in mean growth, yield and fish survival among integrated fish farming systems were analyzed with ANOVA using SPSS (ver. 20).

3. Results

Water quality based on physico-chemical parameters from integrated ponds is presented in Table 2. The mean value of water quality parameters among IFF models were not significantly different (P>0.05) throughout the fish growing period. Water temperature and dissolved oxygen increased and the value of rest of the parameters decreased as the fish growing period progressed from March to October in all integrated fish farming models. Water temperature increased from 21.2°C in March to 32°C in October and dissolved oxygen from 5.1 mg/L to 8.7 mg/L, while water pH decreased from 8.8 to 6.6, total alkalinity from 94.6 mg/L to 23.6 mg/L, total hardness from 85.0 mg/L to 25.0 mg/L and conductivity from 145.2 µs/Sec to 32.9 µs/Sec, irrespective of the types of integration.

Table 2. Mean and range (in parentheses) value of water quality parameters in different integrated fish farming system

Water quality parameters	Fish only	Grass-Fish	Pig-Fish
Temperature, ^{o}C	26.0±2.7	26.0±2.3	26.0±2.8
	(21.2-32.0)	(22.5-31.0)	(21.5-30.0)
Dissolved oxygen, mg/L	6.8±0.4	7.0±0.7	6.9±8.7
	(5.8-7.3)	(5.9-8.2)	(5.1-8.7)
pH	(6.6-8.8)	(6.6-8.6)	(6.7-8.8)
Alkalinity as $CaCO_3$, mg/L	55.3±7.4	58.9±18.2	61.6±15.5
	(45.7-83.3)	(23.6-94.6)	(35.4-89.0)
Hardness as $CaCO_3$, mg/L	45.7±18.6	47.5±21.2	51.8±20.2
	(25.0-80.0)	(25.0-85.0)	(26.0-85.0)
Conductivity, µs/sec	86.2±23.7	71.0±35.4	79.7±27.6
	(51.3-114.8)	(40.8-145.2)	(32.9-125.9)

Figure 1 showed that the grass carp grew better amongst fish species in fish only and grass-fish integration, while the growth of silver carp was high in pig-fish integration. The growth of common carp was lowest amongst fish species in different growth measurement period in all types of integrated fish farming. The growth of common carp was significantly higher (P<0.05) in regularly manure loaded system (pig-fish) (Table 3). Mean harvest weight of grass carp was significantly (P<0.05) higher in grass-fish integration. Although wide variation exist within the IFF systems (P>0.05), the growth of silver carp and bighead carp was highest in pig-fish integration. Mean growth of fish across the species was consistently high over the different growth check time intervals in pig-fish and grass-fish integration (Figure 2). Collectively fish in all types of integration showed highly significant increase (P<0.001) in weight during the seven months (March-October) of fish rearing.

Table 3. Body weight gain of different fish species stocked in different types of integrated fish farming

Attributes	Fish only	Grass-fish	Pig-fish
Mean individual weight at stocking, g	14.8	17.7	19.2
Mean individual weight at harvest, g	319.4±18.2[a]	385.5±15.2[b]	407.7±10.7[b]
Silver carp	350.3±53.1	375.1±109.2	504.0±65.9
Bighead carp	330.0±34.1	301.0±60.6	373.4±64.0
Grass carp	442.6±77.7[a]	608.7±40.6[b]	376.7±52.3[a]
Common carp	154.7±15.2[a]	257.2±23.6[b]	376.5±50.3[c]

Superscripted letters denote significant different within row at α0.05.

Percentage of survival was monitored at harvest for all the four species under study. Mean survival rate of fish was significantly different (P<0.05) among integration types. The highest survival rate was in pig-fish (80.0%) followed by grass-fish integration (77.7%). Survival rate of fish in fish only system (69.6%) was severely affected by the poor survival of common carp (Table 4). The survival rate of silver carp, grass carp and common carp was significantly high (P<0.05) in pig-fish and grass-fish integration and the survival rate of bighead carp was significantly higher (P<0.05) in pig-fish integration.

Fish yield indicators including gross and net yield and growth rate all were significantly (P<0.05) higher in integrated fish farming compared to that of the non-integrated fish farming. Total and corresponding net fish yields were high in grass-fish integration by 45.8% and 47.6% and pig-fish integration by 36.1% and 36.8% to that of the total and net yield obtained from non-integrated fish farming (estimated from Table 4). The yield of silver carp was not significantly different (P>0.05) among the types of integration despite of their wide variation in stocking biomass (Table 4 and 5). The performance of bighead carp in total yield was high for manure loaded system (pig-fish) and feed based system (fish only) and gave proportionate yield to that of the initial stocking biomass. Similarly, grass carp contributed significantly (P<0.05) higher proportion (59.0% and 40.2%) to the total fish yield of grass fed system (grass-fish) and fish only system despite of its low proportion (34.6% and 22.7%, respectively) of stocking biomass (Table 5). Although harvest yield of common carp was significantly higher (P<0.05) in pig-fish and grass-fish integration, its proportionate contribution to the total yield was low in all fish farming systems in comparison of the proportion of stocking biomass.

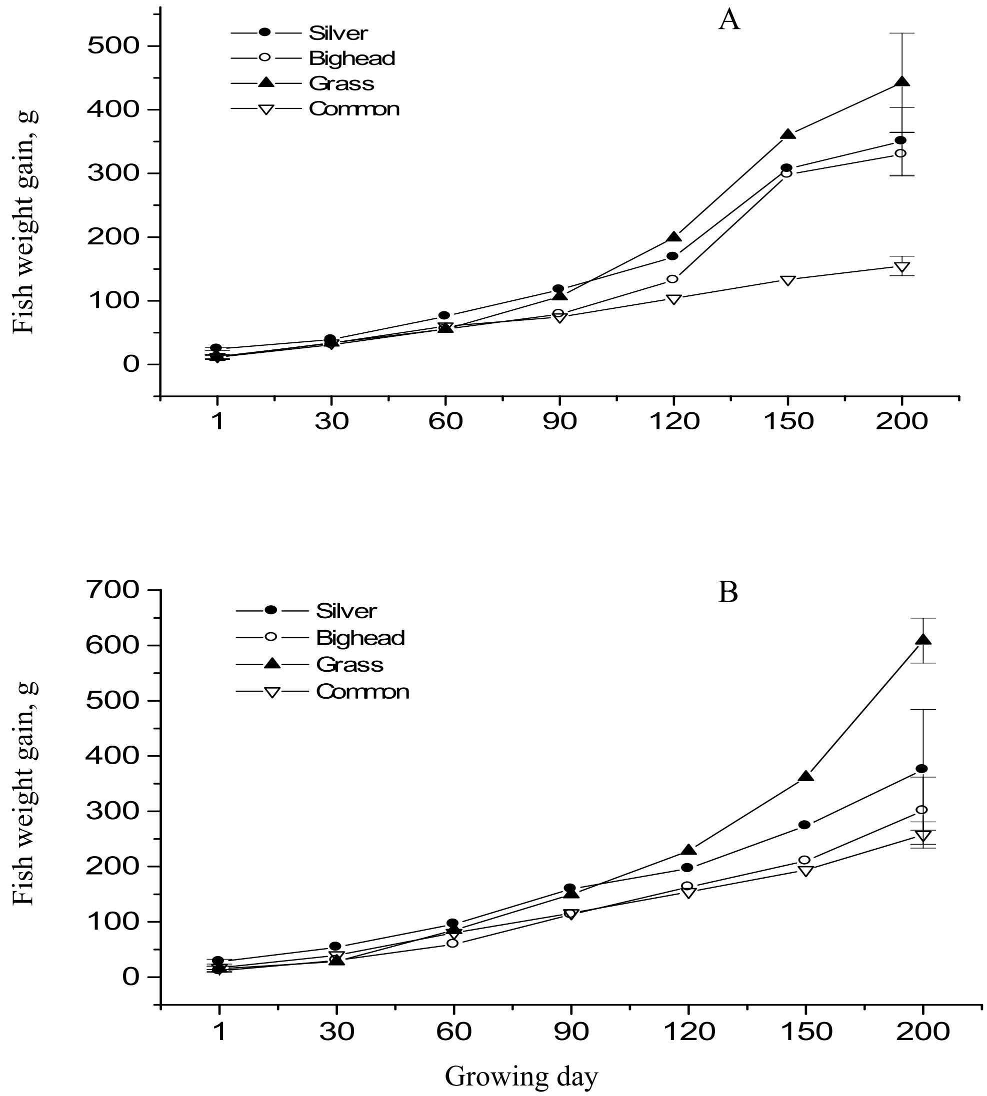

Figure 1: Fish growth trend in different types of integrated fish farming: (A) fish only, (B) grass-fish and (C) pig-fish

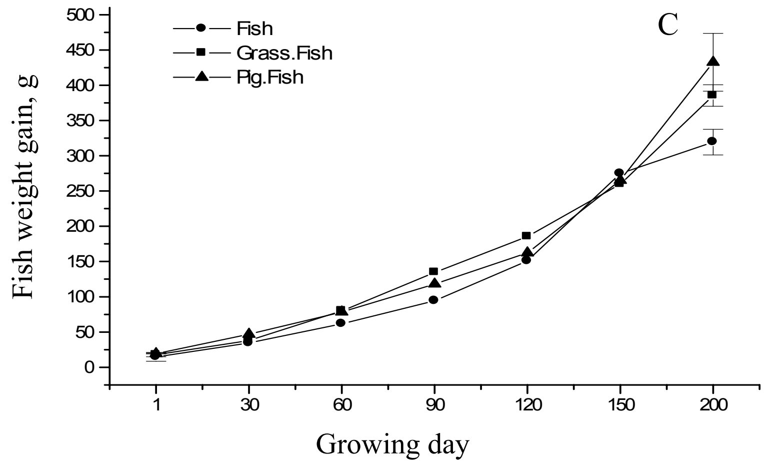

Figure 2: Across species fish growth trend in different types of integrated fish farming

Table 4. Fish survival rate, yield, growth rate and feed conversion ratio from different fish farming systems

Yield attributes	Fish only	Grass-fish	Pig-fish
Fish survival, %	69.7 ± 0.5^{a}	77.7 ± 2.6^{b}	80.0 ± 1.4^{b}
Silver carp	69.0 ± 1.9^{a}	80.3 ± 3.2^{b}	76.6 ± 3.2^{b}
Bighead carp	74.2 ± 2.6^{a}	72.6 ± 2.8^{a}	83.7 ± 3.0^{b}
Grass carp	71.8 ± 2.6^{a}	83.3 ± 3.6^{b}	82.3 ± 2.6^{b}
Common carp	63.6 ± 2.5^{a}	74.7 ± 1.4^{b}	77.4 ± 2.0^{b}
Total fish yield, kg/ha	2360.2 ± 119.4^{a}	3442.7 ± 288.7^{b}	3212 ± 23.8^{b}
Silver carp	603.2±79.7	604.8±194.1	773.4±113.1
Bighead carp	610.7 ± 42.1^{b}	326.4 ± 55.7^{a}	1090.7 ± 157.4^{c}
Grass carp	949.9 ± 133.8^{b}	2031.2 ± 218.8^{c}	620.6 ± 91.1^{a}
Common carp	196.4 ± 11.6^{a}	480.2 ± 37.7^{b}	728.3 ± 86.2^{c}
Net fish yield, kg/ha	2212.7 ± 87.9^{a}	3267.7 ± 305.0^{b}	3028.1 ± 22.8^{b}
Silver carp	542.3±80.3	549.0±197.0	718.6±118.0
Bighead carp	581.8 ± 48.0^{b}	309.3 ± 59.5^{a}	1039.5 ± 150.0^{c}
Grass carp	916.4 ± 96.7^{b}	1970.9 ± 240.1^{c}	588.5 ± 68.2^{a}
Common carp	172.1 ± 4.2^{a}	438.5 ± 35.7^{b}	681.5 ± 69.0^{c}
Growth rate, g/day	1.59 ± 0.1^{a}	2.10 ± 0.1^{c}	1.9 ± 0.1^{b}
Silver carp	1.57±0.3	1.70±0.6	2.34±0.4
Bighead carp	1.57±0.2	1.43±0.3	1.78±0.3
Grass carp	2.13 ± 0.3^{a}	2.95 ± 0.2^{b}	1.78h $\pm0.2^{a}$
Common carp	0.67 ± 0.1^{a}	1.17 ± 0.1^{b}	1.76 ± 0.2^{c}
Feed conversion ratio	2.47 ± 0.3^{b}	1.51 ± 0.1^{a}	1.24 ± 0.2^{a}

Figures with different superscripted letters are significantly different within row ($P<0.05$)

Table 5. Relative contribution of fish species in stocking and harvest yield on biomass basis

Fish species	**Percent contribution**					
	Fish only		**Grass-fish**		**Pig-fish**	
	Stocking	**Harvest**	**Stocking**	**Harvest**	**Stocking**	**Harvest**
Silver carp	41.3	25.6	31.9	17.6	29.6	24.1
Bighead carp	19.6	25.9	9.8	9.5	27.7	34.0
Grass carp	22.7	40.2	34.6	59.0	17.4	19.3
Common carp	16.5	8.3	23.7	13.9	25.3	22.7

Integrated fish farming exhibited significantly higher ($P<0.05$) mean absolute growth rate across fish species (Table 4). The growth rate of 2.1 g/day in grass-fish and 1.9 g/day in pig-fish integration are comparable whereas the fish only system had lowest growth rate of 1.59 g/day. The growth rate of silver carp and bighead carp did not differed ($P>0.05$) among the integration system practiced in the study. Mean growth rate of grass-fish integrated system was largely contributed by the growth rate of grass carp (2.95 g/day). The growth rate of common carp was poor amongst fish species within fish farming system, despite of significant difference in its growth rate exist among the systems. Feed conversion ratio (FCR) based on concentrated feed fed was reduced by 38.8% and 49.8% in grass-fish and pig-fish integration than the FCR calculated for fish only system, respectively.

4. Discussion

Clear differences in fish yield exist in integrated fish farming system. Present study revealed that fish integration with livestock and forage crop in pond could enhance fish productivity by 36.1 to 45.8%. Robiul et al. (2009) even reported higher fish yield (330.92%) from integrated pond management with two additional enterprises viz., poultry and year round vegetables. In tropical fish farming, animal husbandry wastes serve both as food and fertilizer. The microbial decomposition of pig and small ruminant excreta, enriches the water with nutrients which contribute to nutrients for producing phytoplankton, zooplankton and, finally supporting to the fish **(**Singh, 1996**)**. In the present study the growth of carps in pig-fish integration was higher with lower FCR (Table 4), it supports the findings of Ansa and Jiya (2002). They discovered that although the specific growth rate (SGR) values of tilapia fed the formulated diet were high, the SGR (0.81%/day) for pig manure pond was even higher and an indication that tilapia can achieve reasonable growth under pig-fish integration without addition of supplementary feeds. A pig weighing about 60 kg can approximately void 2 to 2.5 kg of fresh dung daily and the optimum dose of pig manure per hectare has been estimated as five tons for a culture period of one year (Kumar and Ayyappan, 1998). Such a quantity may be obtained from 50-60 well-fed pigs (TNAU, 2013). The fish yield of 3028.1 kg/ha in 200 days of rearing obtained in this study with estimated pig manure load of 5.2 t/ha from 60 pigs/ha might be the upper limit of pig number to ensure optimum manure load without undermining the pond water quality and surrounding environment.

Grass-fish integration gave the highest yield (3442.7 kg/ha) corresponding to high fish growth rate of 2.1 g/day amongst fish farming system adopted in this study. Feeding grass for fish has two fold advantages that the herbivorous fish directly feed the grasses and the resulting excreta fertilize the pond water to support the growth of planktivorous fish (Yang, 1989). This principle of grass-fish integration was demonstrated in this study by the fact that grass carp (herbivore) contributed 59% and planktivore 27.1% to the total yield of fish. Sixty-five percent of pond's dike (22% of the pond size) area was occupied for the cultivation of seasonal grasses. An area roughly one-half the size of the pond is needed to produce sufficient grass for supplemental feeding to fish (Yang et al., 2001). Potential exists to improve the productivity of fish in this type of integration if more area for forage cultivation is available near by the pond. The relevance of the grass-based system for small farmers may be limited due to considerable requirements for additional space for growing large amounts of grass to adequately feed the fish. However, the resource costs of growing the necessary high-quality pasture grasses need to be considered.

Proportion of stocking biomass of fish species and corresponding proportion in total yield approximately harmonized in manure loaded system (pig-fish) in the present study. Percentage harvesting biomass of planktivore was at low level whereas high proportion of harvest of herbivore achieved compared to their proportion in stocking biomass in grass-fish integration indicating that adjustment is needed in balancing stocking biomass of fish species to achieve higher yield. The proportionate contribution of common carp at harvest in non-integrated and grass-fish integration greatly lower to that of the percentage biomass stocked. Wagle and Pradhan (2004) reported that stock deterioration of common showing inbreeding depression in reproductive performance, growth and morphological deformities. A high quality stock might be needed to improve the productivity of this species in integrated fish farming. There is possibility that the largest part of the grass and manure added to the integrated system is removed as sediments in the form of grass and manure detritus (Van Dam et al., 1993). This top level of food wed, mainly consists of macrobenthos, may not utilized properly by the existing stock of common carp. Addition/substitution of omnivorous fish species could remove this problem and lead to increased production.

On farm waste recycling, an important component of integrated fish farming, have shown high advantageous to improve the fish production and decrease the adverse environmental impact of farming management. In most cases the embankment of a pond is not utilized properly. The present study suggests that these unutilized spaces could be used for cultivation of grass and pig for increased fish yield through interdependencies among the integrated components of a pond based farming system. This practice increases the efficiency of livestock farming, forage crops and fish culture through the profitable utilization of animal and crop byproducts or wastes (Vincke, 1988). Evaluation of stocking pattern of fish species and their initial biomass, and addition of more efficient omnivore fish species would improve the productivity of these types of integrated fish farming.

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Evaluation of income generation and consumption pattern of fish by women and children in Chitwan and Kailali

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Abstract

In order to evaluate the impact of Carp-Small Indigenous Fish Species (SIS)-Prawn polyculture on income of women and fish consumption pattern by women and children, a household survey was carried out in Piple, Bhandara, Khaireni and Kathar Village Development Committee (VDC) of Chitwan and Hasuliya VDC of Kailali during 2011. Altogether 202 households were selected for the household survey comprising of 126 adopters (women farmers) and 76 non-adopters. Survey was based on the collection of primary data through semi-structured questionnaire interview, focus group discussion and field observation, and secondary data through published and unpublished reports. Findings showed that Carp-SIS-Prawn polyculture was successful to increase fish consumption among adopters. Per caput fish consumption of adopters in Chitwan and Kailali were 5.30 kg/y and 2.68 kg/y and those of non-adopters were 1.6 kg/y and 1.5 kg/y, respectively. Net income generated by women was Rs 2,260 and 2,020 per year by adopting Carp-SIS-Prawn polyculture farming system in 100 m^2 pond in Chitwan and Kailali, respectively. Hence, growing carp, SIS and prawn in homestead pond increases family fish consumption and empowers women financially through income generation.

Keywords: Carp, SIS, Prawn, polyculture, income

1. Introduction

Small Indigenous Fish Species (SIS) is widely available in natural waters as well as in household ponds, irrigated paddy fields, etc. making them popular fish of rural farmers. SIS such as Dedhuwa (*Esomus danricus*), Mara (*Amblypharyngodon mola*) and Pothi (*Puntius sophore*) are rich in vitamin A, calcium, iron and zinc which are needed for cognitive development of human (Roos et al., 2006 and 2007). Regular intake of such nutrient dense SIS can address existing malnutrition problem in the country. In Nepal, about 41% of children less than five years of age are stunted (UNICEF, 2012) and 48% are anemic (MoHP, 2006) and 36% of women age 15-49 are anemic (MoHP, 2006).

Realizing the role of nutrient rich SIS to combat micronutrient deficiency among poor women and children in the country, Institute of Agriculture and Animal Science launched a pilot project “Improvement of women’s livelihoods, income and nutrition through Carp-SIS-Prawn polyculture in Terai, Nepal", in Chitwan and Kailali District in collaboration with Bangladesh Agricultural University (Bangladesh) and University of Copenhagen (Denmark) on December 2008 for three years (Rai, 2012). The project aimed to improve the health and nutrition of women and children through increased consumption of nutrient-dense SIS and thus the livelihoods of women through the sale of fish and Prawn. The approach was found to be appropriate for rural farmers as it increased household nutrition and income (Gupta and Rai, 2014; Yadav and Rai, 2014). The project was basically launched to 126 households from Tharu community, who catch fish from natural waters for consumption. Post project evaluation has not been made whether this approach of Carp-SIS-Prawn polyculture has been generating satisfactory level of income and contributing to the household nutrition. The present study aimed to evaluate the impact of the project intervention on farmers’ income and household fish consumption.

2. Materials and Methods

Survey was carried out to assess the impact of Carp-SIS-Prawn pilot project on income and nutritional contribution among small-scale farming community in Chitwan and Kailali districts during 2011. The study covered four VDCs (Bhandara, Kathar, Khaireni and Piple) in Chitwan and one VDC (Hasuliya) in Kailali. All 126 adopters, and 76 non-adopters were randomly selected for the survey (Table 1).

Table 1. Sample size for impact assessment survey in different VDCs of Chitwan and Kailali districts

District	VDC	Ward no.	Village	Adopters	Non-adopters
Chitwan	Bhandara	4	Phulloria	23	10
		5	Mudovar	16	10
	Piple	1	Jeetpur	7	5
		2	Simara	8	5
	Khaireni	3	Majhui	21	10
	Kathar	3	Phaphini	25	10
Kailali	Hasulia	5	Lalpur	26	26
Total				126	76

The primary data on fish production, household consumption and income were collected from farmers, key informants, cooperatives, farmer’s groups through field observation, household survey using semi structured questionnaires, key informants’ interview and focus group discussion whereas secondary data were collected from published books, journals, proceeding, and unpublished reports, documents, training manuals. Data collected from survey were entered into Microsoft Excel and were analyzed by using SPSS 16 and

Excel. Student's t-test was used to compare income and fish consumption between adopters and non-adopters. Descriptive statistics were used to analyze the household´s income, fish production, consumption, sold amount etc. Differences were considered significant at α 0.05.

3. Results

Household total fish production was 36.3 and 29.5 kg/HH/y in Chitwan and Kailali respectively (Table 2). Production of Carp, SIS and Prawn in Chitwan were 33.9, 2.3 and 0.07 kg/HH/y and that of Carp and SIS in Kailali were 25.8 and 3.7 kg/HH/y, respectively. Farmers consumed 68.6% and 52.9%, and sold 31.4% and 47.1% of total fish production in Chitwan and Kailali, respectively.

Table 2. Fish production, consumption and sold by adopters (Mean ± S.E.).

Description	**Chitwan**	**Kailali**
Pond area (m^2)	100.8±3.1	109.2±2.4
Carp production (kg)	33.9±2.1 ^{a}	25.8±0.7 ^{b}
SIS production (kg)	2.3±0.22	3.7±0.6
Prawn production (kg)	0.07±0.02	0.0
Total fish production (kg)	36.3±2.2 ^{a}	29.5±0.9 ^{b}
Fish consumption by HH (kg)	24.9±1.6 ^{a}	15.6±0.9 ^{b}
Fish sold (kg)	11.4±1.2	13.9±0.7
Productivity (t/ha/y)	3.6±0.2 ^{a}	2.7±0.1 ^{b}

Significant differences (P<0.05) are denoted with different superscripted letters between row.

The per capita fish consumption of adopters and non adopters in Chitwan were 5.30 kg and 1.63 kg, respectively, which was relatively higher than the fish consumption in Kailali by adopters (2.68 kg) and non-adopters (1.52 kg) (Table 3). Farmers obtained fish from different sources for consumption. Farmers consumed largest amount of fish from pond than capture and market. Farmers consumed 24.9, 1.8 and 3.7 kg fish/HH/y from Pond, market and capture in Chitwan whereas those of Kailali were 15.6, 4.3 and 4.3 kg/HH/y, respectively. Total fish consumed and pond fish consumed was significantly higher (P<0.05) in Chitwan than in Kailali. Mean fish consumed by adopters through pond, market, capture and total amount were 22.9, 2.4, 3.9 and 29.2 kg/HH/y and those by non adopters were 0, 5.3, 5.1 and 10.4 kg/HH/y, respectively.

Table 3. Sources of fish for household consumption among adopters and non adopters (kg/HH/y) (Mean ± S.E.).

Description	Chitwan		Kailali		Mean	
	Adopter	Non adopter	Adopter	Non adopter	Adopter	Non adopter
Pond	24.9±1.7	0.0	15.6±0.9	0.0	22.9±1.1	0.0
Market	1.8±0.3[a]	6±1.0[a]	4.7±0.6[a]	3.9±1.1[a]	2.4±0.3[a]	5.3±0.8[a]
Capture	3.7±0.3[a]	4.4±0.9[a]	4.3±0.6[a]	6.5±1.1[a]	3.9±0.3[a]	5.1±0.7[a]
Total	30.4±1.8 [a]	10.4±1.1[b]	24.6±1.0[a]	10.4±1.7[b]	29.2±1.1[a]	10.4±0.9[b]

Significant differences ($P<0.05$) are denoted with superscripted letters between adopters and non adopters.

Carp was the major fish consumed by adopters both in Chitwan and Kailali, which was followed by SIS and Prawn in Chitwan and SIS in Kailali. Total fish consumption per household was significantly higher ($P<0.05$) in Chitwan than in Kailali (Table 4).

Table 4. Species wise fish consumption by adopter's household (Mean ± S.E.).

Description	Chitwan	Kailali
Carp	22.6±1.6 [a]	11.9±0.57 [b]
SIS	2.3±0.2	3.7±0.6
Prawn	0.07±0.02	0±0
Total	24.9±1.7 [a]	15.6±0.9 [b]

Significant differences ($P<0.05$) are denoted with different superscripted letters between row.

Better part of fish (middle part of body excluding head and tail) was found to be consumed by men in both adopter's and non-adopter's families. Men were found to consume better part of fish in 82.5% adopter's households, The situation was better among non-adopter's households as of only 57.9% households was found to consume better part by men. Majority of women and children were found to consume mixed and extreme parts (head and tail) of fish (Table 5).

Table 5. Intra household distribution of fish in the meal (%).

Description		Mixed part		Head and tail	
	Adopter	Body	Adopter	Non adopter	Adopter	Non adopter
Child	14.3	39.5	39.7	26.3	46.0	34.2
Men	82.5	57.9	7.9	15.8	9.5	26.3
Women	3.2	2.6	52.4	57.9	44.5	39.5
Total	100	100	100	100	100	100

Women were found to consume cooked fish at last whereas men were found to consume at beginning and children in the middle in both adopters and non adopters household. It was found that in 98.4% and 94.7% adopters and non adopter's families, men were served first and children were served second. Similarly, in 100% adopter's and non adopter's families women were served at last.

Women's income from Carp-SIS-Prawn polyculture

Adopters earned Rs. 2,260 and 2,032 per 100 m^2 from pond fish sale in Chitwan and Kailali, respectively. Farmers sold most of fish to neighbors and some to middlemen who sold to local market. They sold fish at rates of Rs. 200/kg and Rs. 160/kg in Chitwan and Kailali, respectively. Income from aquaculture among non adopters was zero because they did not possess any fish pond.

Table 6. Contribution of Carp-SIS-Prawn polyculture on household income (Rs.)

	Chitwan		Kailali	
	Adopter	Non adopter	Adopter	Non adopter
Area used for crop farming (m^2)	4,968.6	3,718.0	22,544.6	6,760.0
Income from crop farming (Rs.)	193,361 (96.4)*	145,055	622,093 (99.1)	187,412
Area used for Carp-SIS-Prawn farming (m^2)	101.4	0	101.4	0
Income from Carp-SIS-Prawn farming (Rs.)	7,266 (3.6)	0	5,400 (0.9)	0
Total income	**200,627**	**145,055**	**627,493**	**187,412**

*Figure in parenthesis indicates income in percentage (%).

4. Discussion

Farmers consumed fish from different sources i.e. household pond, capture fisheries and market. Total household fish consumption was significantly higher among adopters than non adopters. The per capita fish consumption of the adopters of Chitwan and Kailali were 5.3 kg/y and 2.7 kg/y respectively whereas those of non adopters were 1.6 kg/y and 1.5 kg/y, respectively. This showed that growing fish in the backyard ponds and regular partial harvesting of SIS increased household fish consumption of adopters over non adopters. Adopters' fish consumption rate was higher than national average of 2.1 kg/caput (DoFD, 2013). Intra-household fish distribution in the meal was unequal; men got priority over women and children. This affected consumption pattern in the family.

The major sources of income of the non adopters were almost same as adopters except aquaculture. The average income of women from aquaculture was 2,260 and 2,032 Rs./100 m^2, which contributed 4 % and 1 % to the total household income in Chitwan and Kailali respectively. The contribution made by fish farming was very little because farming was done in small area of 100 m^2 and around 69% of fish produced was consumed by family. However, the income was significant in terms of financial empowerment to women (Rai, 2012). Production and income can be increased further with increased area of pond and sustainable use of dike (Rai and Shrestha, 2014). Moreover, women shared income from agriculture with family members but income from aquaculture was hers only.

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