STANDARDIZATION ON APPROPRIATE CULTURE PACKAGE OF CARP-SMALL INDIGENOUS FISH SPECIES (SIS) POLYCULTURE IN NEPAL

A THESIS SUBMITTED TO THE

CENTRAL DEPARTMENT OF ZOOLOGY

INSTITUTE OF SCIENCE AND TECHNOLOGY

TRIBHUVAN UNIVERSITY
NEPAL

FOR THE AWARD OF

DOCTOR OF PHILOSOPHY

IN ZOOLOGY

BY

BASANT KUMAR KARN

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RECOMMENDATION

This is to recommend that **Basant Kumar Karn** has carried out research entitled "**Standardization on appropriate culture package of carp-SIS polyculture in Nepal"** for the award of Doctor of Philosophy (Ph.D.) in **Zoology** under our supervision. To our knowledge, this work has not been submitted for any other degree.

He has fulfilled all the requirements laid down by the Institute of Science and Technology (IOST), Tribhuvan University, Kirtipur for the submission of the thesis for the award of Ph.D. degree.

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CERTIFICATE OF APPROVAL

On the recommendation of supervisors **Prof. Dr Ranjana Gupta and Prof. Dr. Sunila Rai**, this Ph D. thesis submitted by **Basant Kumar Karn,** entitled **"Standardization on appropriate culture package of carp-small indigenous fish species (SIS) polyculture in Nepal"** is forwarded by Central Department Research Committee (CDRC) to the Dean, IOST, T. U.

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DECLARATION

Thesis entitled **"Standardization on appropriate culture package of carp-small indigenous fish species (SIS) polyculture in Nepal"** which is being submitted to the Central Department of Zoology, Institute of Science and Technology (IOST), Tribhuvan University, Nepal for the award of the degree of Doctor of Philosophy (Ph.D.), is a research work carried out by me under the supervision of Prof. Dr. Ranjana Gupta, Central Department of Zoology, Tribhuvan University and jointly supervised by Prof. Dr. Sunila Rai, Department of Aquaculture and Fisheries Agriculture and Forestry University, Rampur, Chitwan, Nepal.

This research is original and has not been submitted earlier in part or full in this or any other form to any university or institute, here or elsewhere, for the award of any degree.

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[Basant Kumar Karn]

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ABSTRACT

The present study was conducted to determine appropriate culture package of carp and Small Indigenous fish Species (SIS) polyculture in Nepal. The present research work consisted of field survey for SIS diversity and abundance and research experiments for determination of growth and production performance of three SIS and carp species. SIS are the fishes which acquire length of 25 cm even in fully matured condition. The field survey for SIS diversity and abundance was carried out in 8 districts or sampling stations, Saptari (S1), Sirha (S2), Dhanusha (S3), Mahottari (S4), Sarlahi (S5), Rauthat (S6), Bara (S7), Parsa (S8) of Terai Nepal and three sampling sites (fish markets) for each sampling station were S1-Bhardah, Hanumannagar & Rajbiraj; S2-Sirha, Lahan & Bandipur; S3-Janakpur, Mahendranagar & khajuri; S4-Jaleshwar, Ramgopalpur & Gaushala; S5-Malangwa, Lalbandi & Barhathwa; S6-Gaur, Gadura & Chapur; S7-Kalaiya, Nijgadh & Jitpur; S8-Birgunj, Chapkuiyan & Bindbasinimaisthan. Diversity and abundance of SIS was done by the identification of SIS on spot, weight & length measurement by the help of measuring scale and weight balance, landing of SIS week $^{-1}$ and by questionnaire interview methods from 50 fish traders and 35 fishermen. SIS were found between 5 to 25 cm in length. A few unidentified samples of SIS were preserved in 10 % formalin and they were brought for identification to the laboratory in Janakpur. The SIS survey was carried from 13th February to 15th June, 2012. The diversity of small indigenous fish species (SIS) was calculated by Shannon diversity index calculation (H) = - $p_i \sum \ln(p_i)$, Margalef index = (N-1)/LN (N), Simpson diversity index calculation = $\sum (p_i)^2$ (Magurran, 1988 ; McIntosh,1967 ; Rosenzweig, 1995) formula. A total of 55 species of SIS belonging to16 families and 38 genera were recorded from the sampling stations during the entire study period. *A. mola* was the dominant species followed by *P. ticto* and *E. denricus*. The Shanon index, Sampson index, Margelef index and species richness was high in S1 sampling station and these index were low in S4 sampling station. Out of three research experiments, first experiment was carried out for the growth and production assessment of three SIS species viz *A. mola*, *P. ticto* and *E. denricus*. It was done in earthen ponds, each of 100 m^2 size in Fisheries Development and Training centre Janakpur. The CRD experimental design was used for experiment 1. Prestocking and post stocking of fish pond's management was done according to Roy *et al*. (2002). SIS species *A. mola* was stocked in treatment T1, *P. ticto*, in T2 and *E.*

denricus in T3 treatments. Each SIS species was stocked at the rate of 20, 0000 ha^{-1}pond^{-1} according treatment's allocation per pond. SIS was reared for 120 days by monoculture method. *A. mola* stocked in T1 showed the best production performance of 2162.6 kg ha $^{-1}$ yr $^{-1}$. The production performance of SIS in T1 was significantly higher than T2 and T3 treatments (< 0.05). The cost benefit ratio was not significantly different among the treatments but it was the highest in T1 treatment Rs 289587(Nepalese Currency) ha^{-1}yr^{-1}. Experiment 2 was conducted for investigation of the growth and production performance of carps under three combinations with *A. mola*. Experiment was carried in three treatments and for each treatment there was three replications. T1 treatment (control) had combination of *H. molitrix, A. nobilis, L. rohita*, *C. mrigala*, *C. idella*, and *C. carpio* without of *A. mola,* T2 treatment had combination of *H. molitrix, A. nobilis, L. rohita, C. mrigala* and *A. mola*, T3 treatment had combination of *H. molitrix, A. nobilis, L. rohita, C. mrigala C. idella* and *A. mola* and T4 treatment had combination of *H. molitrix, A. nobilis, L. rohita, C. mrigala C. idella*, *C. carpio* and *A. mola*. Stocking density of carp for all treatments was 15, 000 ha $^{-1}$and *A. mola* was 50, 000 ha^{-1} in T2, T3 and T4. Prestocking and post stocking pond management was done according to method of experiment 1. Carp and *A. mola* were reared for 120 days by semi intensive polyculture. T2 treatment gave the best production and growth performance of 4559.4 kg ha $^{-1}$yr $^{-1}$. Cost benefit ratio was the highest in T2 treatment Rs 347658.0 (Nepalese Currency) ha^{-1}yr^{-1}. Experiment 3 was conducted for the investigation of best stocking ratio between *A. mola* and carp. *H. molitrix, A. nobilis, L. rohita, C. mrigala* were stocked at the rate of 15000 ha^{-1} in treatment ponds. *A. mola* was stocked at the rate of 50000 ha^{-1} in T2, 10, 0000 ha^{-1} in T3 and 20,0000 ha^{-1} in T4 treatments. Prestocking and post stocking pond management was done according to method of experiment 2. Carps and *A. mola* were reared for 120 days by semi intensive polyculture method. The growth and production of carps was higher in T2, T3 andT4 treatments than T1 (ctrl) but the highest production, 4991.3 kg ha $^{-1}$yr $^{-1}$ was obtained in T3 treatment. Cost benefit ratio was the highest in T3 treatment Rs 543533.7 rupees (Nepalese Currency) ha^{-1}yr^{-1}. Thus the present study demonstrated, appropriate culture package of carp- SIS polyculture in Nepal may be in combination of *Hypophthalmicthys molitrix, Aristichthys nobilis, Labeo rohita* and *Cirrhinus mrigala* when stocked at the rate of 15000 ha^{-1} and *A.mola* stocked at the rate of 100000 ha $^{-1}$. The technology is simple, cost effective and appropriate for poor farmers**.**

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LIST OFABBREVIATIONS

AGDP	Agricultural Gross Domestic Product
APP	Agriculture Perspective Plan
BCR	Benefit Cost Ratio
CRD	Complete Randomized Design
DOFD	Department of Fisheries Development
FPP	Fisheries Prospective Plan
HUFAs	Highly Unsaturated Fatty acids
IDA	Iron Deficiency Anemia
IDD	Iodine Deficiency
FAO	Food and Agriculture Organization
MAEP	Mymensingh Agricultural Extension Project
MOPH	Ministry of Health and Population
NC	Nepali Currency
PEM	Protein Energy Malnutrition
PUF	Poly Unsaturated Fatty acids
SIS	Small Indigenous fish Species
TWG	Total Weight Gain
USEPA	United States Environmental Protection Agency of Water Office
VAD	Vitamin A Deficiency
IMC	Indian Major Carp
CMC	Chinese Major Carp
DO	Dissolved Oxygen
SPP	Species
SE	Standard Error
ANOVA	One Way Analysis Of Variance

CHAPTER 1

1. INTRODUCTION

1. General introduction

Of all the global food production systems, aquaculture is widely perceived as an important weapon in the global fight against poverty and hunger. Aquaculture production, especially pond aquaculture may be a dependable source of obtaining increased fish production in order to supply and feed the ever increasing population of the world (FAO, 2010). In recent years aquaculture is being projected as possible solution to food problems faced by masses. It gives higher productivity per unit as compared to agriculture and animal husbandry (Sinha & Srivastava 1991). Freshwater fishes dominate global aquaculture production 56.4%, (33.7 million tones), followed by molluscs 23.6%, (14.2 million tones), crustaceans 9.6%, (5.7 million tones), diadromous fishes 6.0%, (3.6 million tones) and other aquatic animals (FAO, 2012). The primary factors in aquaculture development are market demand and competition, the availability of environmental resource, the development or transfer of appropriate technology and a favourable business environment that allows entrepreneurs to profit from their investment in the sector (Bostoc et al., 2010). Typical aquaculture resource demands by species (Troe et al., 2004 and Tyedmers et al., 2007) and the underlying development of sustainable aquaculture of all types, but especially commodity products, is the need to improve the basic conversion of feed materials into edible fish flesh and minimize utilization and conversion of premium resource. This involves species selection, production systems, animal genetics, good health management and optimized feed and feeding. These are also linked to some extent through the developing approach to understand the animal welfare, which is also reaching into other physiological and environmental interactions. The interactions of aquaculture with the environment, with respect to both goods and services, are also critical and need to be evaluated in a rational way that allows the benefit of environmental services to be used but not over-exploited and impacted on (Bostoc et al., 2010).

Fish polyculture is practiced aiming to increase productivity. Complementary species of fishes can increase the maximum standing crop of a pond by allowing a wider range of available foods and ecological niches. The majority of freshwater aquaculture is pond based using semi-intensive methods that rely on controlled eutrophication for their productivity, using a wide variety of organic and inorganic fertilizers as well as supplementary feed stuffs Verdegm and Bosma (2009). Nepal ranks second in the water resources in global picture. Out of total 818,500 ha of total water surface area, about 6,000 rivers and rivulets cover 395,000 ha or 48 percent in Nepal (Sharma, 1997). Rivers are one of the major sources of capture fishery, contributing almost 50% of total captured fish production in recent years of Nepal. The large number of fishermen and their families are involved in capture fisheries which provide income and partial employment for them. Fisheries activities are split by policy guidelines into inland aquaculture and natural water fisheries. Aquaculture involves all activities where complete or partial control of the fish production cycle is undertaken. Natural water fisheries cover fish caught from natural water bodies where little or no control measures are taken over the fish production cycle (Pradhan & Pantha, 1995). Fishing activities in irrigation channels, rice fields, swampy areas and ghols is also a significant source of capture fisheries production. The total production of fish in 2013 /2014 was 64, 900 MT, out of which 21,500 MT production was from natural water bodies and 43,400 MT from ponds and aquaculture (DOFD 2013 /2014). The domestic production of fish is not sufficient to meet the domestic demand and there is a significant import every year from neighboring countries mainly India. Modern aquaculture practices started around the 1950s in Nepal (Rajbanshi, 1979). Fish cultivation using modern techniques started in the country recently around 1950s with the introduction of carps. Freshwater fish production is dominated by various species of carp, although tilapia, pangasius, catfish and later trouts for cold water fisheries have become more significant in Nepal. Soon after modernization the fisheries sector progressed rapidly and its contribution to GDP began to reflect (Mathema, 1992). Fisheries sector shared in AGDP was from 1% in 1990s to 2.47% in the decades of 2000s. One of the primary reasons for success of carp cultivation in Nepal was probably break through in artificial breeding technology and its spread in mid Terai and eastern Terai districts. As a result Nepalese fish products have also partially occupied the market in Indian boarder area.

Aquaculture activities are mainly conducted in the plain region of Nepal consisting of carp production in ponds. Warm water fish species, rohu (*Labeo rohita*), bhakur (*Catla catla*), naini (*Cirrhinus mrigala*), common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella),* silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*Aristichthys nobilis*) are the major seven carp species commonly used by the farmers for commercial production. The number and variety of fish species and other aquatic organisms are drastically declining in the natural fresh water bodies of Nepal, due to existing over pressure of increased population in the country. In spite of very rich fish biodiversity in Nepal, the main attention have been given only in the traditionally established techniques used for production of Indian major carps and Chinese major carps from commercial point of view by semi intensive fish farming method. The small scale farmers are affording the practice of semi intensive aquaculture only and they cannot afford the practice of intensive aquaculture system due to highly expensive production cost and sophisticated technology which cannot be supported by the economy of Nepalese fish farmers. The carp fish production in Nepalese context at present is only 4352 kg ha^{-1} yr^{-1} and it contributes about 1.53% of the AGDP and 0.5% in GDP (DOFD, 2013/2014). Agriculture Perspective Plan (APP) has categorized fishery sector as a small but important and promising sub sector of agriculture, contributing about 2.47% of agricultural gross domestic product (AGDP) in the country (DOFD 2005/'06). Three years interim program (2007/'08-2009/10), under the APP a Fisheries Prospective Plan (FPP) has given priority to increase fish production and productivity providing income generation and poverty alleviation to the poor people by aquaculture enhancement using swampy area or ghols for aquaculture to the local people in community basis, post harvest management, marketing, ornamental fish promotion, and commercial production of high value of cold water fish e.g. trout culture. It has given emphasis on biodiversity conservation management of indigenous fish species, as well as community river management.

The long term goal for fisheries and aquaculture development is to enhance livelihoods through sustainable fisheries and aquaculture technology for food, employment and income. The prevailing method of aquaculture system cannot fulfill the demand and target of fish production in the country as proposed by fisheries prospective plan (FPP). If some new species are introduced in fish production policy it may support to prevent reduction of resource footprints and improve integration which could lead to new developments as well as reversing decline in some more traditional systems. Fishes are considered auspicious and symbolize as sign of fertility, power and prosperity in Nepal. Fish is acceptable to every segment of the population, but still Nepal has a low per capita consumption compared to neighboring countries despite of the increasing trend of fish production. The per capita consumption of fish per gram per day was 5.39 in 2010/2011 (Environment Statistics of Nepal, 2013). The majority of rural and urban peoples have less access to the fishes in spite of increase in insufficient fish production. So the problem of fish consumption is concerned with the production of fish at national level. There is urgent need of changes in the existing method of fish farming practices as well as of natural water fisheries management that may be a problem solving approach. The use of piscicides before stocking of carps in present fish farming system removes almost all indigenous fishes including catfishes and small indigenous fish species (SIS) which were also earlier called as weed fish. The small indigenous fish species (SIS) are generally considered to be those fishes which grow to be length of about 25 cm or 9 inches (Hossain & Afroze, 1991; Felts et al.1996; Hussain et al.1999). SIS were abundantly available in the rivers, streams, ponds, beels, ditches, and floodplains in the past, but due to over exploitation of these species from natural water bodies they have been gradually disappearing from the natural systems, which in turn severely affects ictyobiodiversity of the country. An essential prerequisite to any broad programme of resource conservation is the proper taxonomic study of fish species occurring in the concerned area and to prepare a full checklist time to time indicating the status of each species. Such a list would enable the IUCN to prepare an international list of endangered species that can be included in the Red Data Book. The sustainable utilization of genetic resources, including fish, is a vital part in improving the living standard of life in Nepal which is very rich in water resource from the world point of view. The underlying development of sustainable aquaculture of all types, but especially commodity products, is the need to improve the basic conversion of feed materials into edible fish flesh and minimize utilization and conversion of premium resource. This involves species selection, production systems, animal genetics, good health management and optimized feed and feeding. These are also linked to some extent through the development of understanding the animal welfare, which is also reaching into other physiological and environmental interactions. The interactions of aquaculture with the environment, in respect to both goods and services, are also critical need to be evaluated in a rational way that allows the benefit of environmental services to be used but not over exploited and impacted on (Bostoc et al., 2010). Concern over decline in harvests and an obvious reduction in biodiversity of fish species have led to a more holistic approach to fisheries management and research. About 11% (2,200) of the total world fin fish species (more than 2,000) have been recorded from the Indian subcontinent (Sarkar & Lakra, 2008). Unfortunately, many fish species are in decline and some have become endangered due to a combination of overexploitation, pesticide and aquatic pollution, spread of disease, uncontrolled introduction of exotic fishes, and habitat modification, industrialization, river-valley projects, excessive water abstraction and siltation due to clearing. The early concept of food competition between large carp species and SIS may be major cause for removal of SIS without scientific study in Nepalese context and condition of pond polyculture practice.

Fish farming generates direct and indirect employment. Moreover majority of the fish producers in Nepal are small scale farmers. The family member of fish farmers and fishermen remain deprived to access the fish consumption though, they produce the large carp fishes in the ponds but sell them to earn money which is required to fulfill family needs. There is clear sign and symptoms of malnutrition and existence of hidden hunger especially among the rural and urban children and women. Fish accounts for about one fifth of world's total human consumption of animal protein. This has risen five folds over the last 40 years from 20 million MT in the 1950s to 98 million mt in 1993 and it was exceeded 150 million MT by the year 2010 (Olangunja et al., 2007). FAO, Fisheries and Aquaculture Department had recorded 8.6 percent per year increase in production volume of fish by 2012 and fish production trend is in the increasing order in recent years (FAO, 2014).

Nepalese women and children suffer from malnutrition of animal source of protein and micronutrients; vitamin A, iron, calcium, phosphorus, zinc etc (MOPH, 2014). Experience from some Asian countries particularly Bangladesh, Myanmar etc encouraged for small scale farming system of carp fishes with small indigenous fishes, where SIS made the significant contribution in fish production, insured for animal origin food production and supply, the income generation etc for the country. Therefore, this is the very commonly realized need for the promotion of fisheries sector in order to increase the fish production and consumption which will ultimately be helpful for the improvement in problem solving approach of malnutrition, emphasized to ensure micronutrient supply and source of animal protein in the daily diet and increase in income generation for people.

The present existing semi-intensive carp polyculture system in Nepal can not promote to the household fish consumption rapidly. Present trend in fish polyculture of Nepal shows once fingerlings of fishes are stocked by the farmers for fish rearing for one or two year, they have to wait for harvest and to sell them till the fish do not grow into the size of table fish. They keep the family members unfed from the fishes and the farmers can not get short time monetary return from the fish culture duration. If Indigenous and carp fishes could be cultured together, farmers would have opportunity to harvest small indigenous fishes several times within a year. They can feed the family members by protein and micronutrient enriched small fishes or will have option to sell them before selling large carps as cash crop. Hence, the semi intensive aquaculture system in which the carp and SIS (small indigenous fish species) can be grown together seems to be a new approach in the fish farming sector for Nepal. It has great scope for the poor farmers who have their own small ponds or to the fishermen group who are involved either directly or indirectly in the fishing activities. Farmers need technology such as selection of suitable SIS species, stocking density of carps with SIS, partial harvesting of SIS species to maintain optimum stocking density of carps for ideal condition of growth etc, for high fish production from the low investment of input. The most important part for high fish production is the lack of appropriate technology packages in sustainable fish culture that will ensure the poverty alleviation and nutritional security of rural people. The Carp SIS culture practices have raised the economy of many countries and have shown improvement in the malnutrition condition of people of Cambodia, Mynmar, Bangladesh etc. The carp SIS culture system is cost effective and it gives relatively high fish production, monetary return etc than the traditional semi intensive fish culture system. The carp-SIS fish culture practice may have great potential significance in rural aquaculture of Nepal.

1.1 Statement of the problem

National health policy-2014 has nutrition direction towards use and promotion of quality and nutritious food generated from community level to fight against malnutrition. Improvement in nutrition status has been seen as some of the most powerful and cost effective investment for the overall socio-economic development by enhancing the optimal physical growth and cognitive development especially of women and children. Malnutrition is a multi-sectorial issue which is intimately concerned with food supply, distribution and food consumption by the people. The malnutrition problem of Nepal chiefly includes protein, vitamins and minerals deficiency among the poor women and children (MOHP, 2014). The major and essential micronutrients related with malnutrition problem in Nepalese people are; vitamin A, Iron, Calcium, and Zinc deficiency etc. Protein energy malnutrition (PEM), iron deficiency anemia (IDA), iodine deficiency (IDD), vitamin A deficiency (VAD) are the most common form of malnutrition in the Nepalese women and children. The government of Nepal, MOHP (2014) pointed out that 41% of children who were less than five years age had stunted growth due to protein deficiency in 2011 but it was decreased from 49% of 2006. Nepal has the prevalence of anaemia among women of reproductive age by almost 35% in 2011. Anaemia rates were higher among pregnant women (48%) and breast feeding women (38%) compared to none pregnant and none breast feeding women. The prevalence of anaemia among adolescent girls has remained stagnant at around 39 percent over the last five years. Similarly, 46 percent of children under-five years of age still remain anaemic, with younger children under 2 years of age having the highest burden (69%), which is a very serious concern. Compared to improvement in macronutrient deficiency status, Nepal is globally recognized in the high rate of micronutrient deficiencies (IDA, IDD and VAD) through its successful community based supplementation programs.

The supplementation programs of micronutrients; vitamin A, iodine, iron, calcium etc have been in community based practice since last few years till now. The situation is very much horrible, especially in the rural area, ethnic minority women and children as they are poor and have very little education status. The rural people have prevalence of traditional concept that women eat after men and very often eat what is left over after the family has eaten up. Therefore, women suffer from malnutrition more commonly than the men. Fish are known to be an important source of myofibrillar proteins of high biological value. Fish also provides essential components for the human body, namely polyunsaturated fatty acids (PUFAs) and highly unsaturated fatty acids (HUFAs), which fight illnesses like cardiovascular disease and osteoporosis. Fish is also the only naturally available form of omega 3 fatty acids which seems to be essential for healthy body. Small fishes are the rich source of iron calcium, vitamin A, potassium etc inspite of protein. Small fishes such as mola, murrels, catfishes, climbing perch, etc have the very high concentration of potassium. The vitamin-A, calcium and iron contents of *A.mola* are approximately 1,960 mg, 1,071 mg and 7.0 mg respectively (Thilsted et al., 1997).

Out of 206 species of fishes reported from Nepal many small fishes were considered as the small indigenous fish species (Shresth, 2008). Some of the common SIS species are *Amblypharyngodon mola*, *Esomus denricus, Puntius sophore, Puntius ticto, Barilus bendelensis, Cirrhinus reba, Colisa fasciatus* etc. These SIS species live in running water and shallow well oxygenated areas developed by flood or rain or runoff water for the breeding purpose as well as habitat purpose. The small fishes were considered undesirable into fish ponds for the fresh water aquaculture practice in the past because they were believed to compete for food and space with large carp (Wahab et al., 2003). Therefore they were eradicated from fish ponds prior to stocking. In fact in the past the fisheries technicians and fish farmers were not aware about the nutritional value of SIS. So the knowledge of SIS for nutritional significance, to solve malnutrition problem, to increase fish production for nation, fish export, high income generation oppurtuinity to fish farmers, an alternative practice of carp-SIS polyculture seems to be more effective than the semi intensive carp polyculture in Nepal.

1.2 Rationale of the Study

Several rivers originating from Himalayan region of Nepal have now impact on fish catch due to over fishing and fisheries allied activities that took place in the past by several ethnic caste people who depended for their livelihood on fishing. The alteration of habitats and over fishing pressure are some of the threats to the conservation of small indigenous fish bio-diversity in Nepal. The increasing unconventional pressure such as use of explosives, fish poison and electricity in aquatic habitats are some of the dangerous threats to the small as well as large indigenous fishes in Nepal. Moreover, invasion of invasive fish species in recent years have increased the vulnerability of existing minor carps or small indigenous fishes in Nepal. Therefore, the new approach, like carp-SIS culture practice seems to be appropriate for the conservation of small indigenous fishes in the country. The proposed plan for the carp-SIS polyculture will definitely able to reduce over fishing pressure in the rivers, streams, lakes, reservoirs etc in Nepal.

The nutritional value of SIS has excellent performance. All small fish are good sources of calcium because they are eaten whole (with the bones). Calcium is also available in bigger fish, but the bioavailability is not as high as in the case of small fish. The SIS species are normally cooked and eaten whole. Their effect on the diet is further enhanced by the consumption of bones which provide source of calcium (Larsen et al., 2000). *Esomus longimanus* has the highest content of iron, with the highest bioavailability and it has the same degree of bioavailability for zinc also. Iron is one of the key essential limiting nutrients for human being. *A. mola* is particularly important due to its high vitamin A content (Ahmed, 1981). Zafri and Ahmed (1981) reported that *A. mola* contain 200 IU of vitamin A per gram of edible protein. Climbing perch, catfishes, murrels, and *A. mola* are some small indigenous fishes which have very high concentration of potassium. Thus, these small indigenous fishes when cultured with carp fishes could make an excellent contribution to the diet of rural poor. The farmers can use these fish to feed their family or can sell some SIS spesies in the market even in more costly price than the large carps.

Despite of the considerable work done on semi intensive polyculture system of various carp species belonging of CMC (Chinese Major Carps) , IMC (Indian Major Carps) groups, tilapia, trouts and cold water fishes in Nepal, there is hardly any systematic attempt to explore on the standardization of carp-SIS polyculture technology. So this study is basically designed therefore to explore the diversity and abundance of SIS species of Nepal, growth and production performance of SIS species in pond condition, to find out the suitable combinations of carps which can be reared with SIS without negatively affecting one another in growth and production, to develop a cheap technology for carp-SIS polyclture by investigating the appropriate stocking ratio between SIS with carps and the technology would be financially accessable for the Nepalese.

The scope of present study is to provide cost effective fish farming technology providing high fish yield which will help to solve the vitamins and micronutrients malnutrition problems among the people. It will also help in conservation of indigenous fish species from rapidly declining conditions.

1.3 Research questions

1) What are small indigenous fish species (SIS) of Terai Nepal?
2) What are the present status, abundance and diversity of SIS in Nepal?
3) What is the growth and production performance of selected SIS in aquaculture ponds?
4) How do the carp species interact with SIS for food competition?
5) Which carp species in combination with SIS is suitable for production?
6) What is the suitable stocking ratio of SIS along with carp species?
7) Is carp-SIS farming method economically cheaper than traditional carp polyculture method?

Limitations of the study

Fish farming technology of the present research work couldnot be conducted in farmer's pond.

1.4 Objectives

1.4.1 General Objectives

To find out the appropriate culture package of carp-SIS polyculture in Nepal.

1.4.2 Specific objectives

1) To explore the SIS diversity and abundance from SIS survey.
2) To identify the best SIS in the terms of production.
3) To determine suitable combinations of carps for rearing with SIS.
4) To determine the best stocking ratio between carps and SIS.

CHAPTER 2

2. LITERATURE REVIEW

2.1 Small indigenous fish species (SIS)

Fishes have significant role in nutrition, income generation, employment and foreign currency earning from fish export. It is widely accepted by all segments of people in nations as the good source of protein and other elements (Andrew, 2001). The small indigenous fish species (SIS) have received attention recently. It is included in the traditional carp-polyculture system in some south Asian countries such as India, Mynmar, Laos, Bangladesh etc with the argument that large carp species could be sold in the market for income generation and small fish could be fed to the household members for nutritional security thereby improving the livelihoods of the fish farmers (Alim et al., 2004), Alim et al.(2005), Kadir et al.(2006) and Milstein *et al*.(2006). The indigenous fishes which grow to the length of about 25 cm or 9 inches even in gravid condition are generally considered as small indigenous fish species (SIS) according to Hossain and Afroze (1991), Felts et al.(1996) and Hossain et al.(1999). SIS were termed as minor carps in Nepal earlierly (Bist et al., 2005), small indigenous freshwater fish species (SIF) in India by Sarkar and Lakra (2010). According to Bist et al. (2005) minor carp grow about one feet size not more than 30 cm in length even in adult stage in Nepal. Sarkar and Lakra (2010) defined small indigenous freshwater fish species (SIF) to those fishes which grow to the size of 25-30 cm in mature or adult stage of their life cycle. Study of fishes in Nepal is interlinked highly with fish fauna of Ganga river system because Nepalese rivers drain the water into Ganga River. In India about 450 indigenous fish species were categorized as small indigenous freshwater fish species, out of 765 native fresh water fishes (Sarkar and Lakra, 2010). The maximum diversity of the (SIF or SIS) has been recorded from the North East region of India whose border is interconnected with Nepal and it is followed by Western Ghat and Central India. Based on the assessment of Sarkar and Lakra (2010) in India out of about 450 SIS 23% (104 species) are highly important for food and other local significance, also play a significant role in aquarium trade and in providing local livelihood security. Again from 104 species, about 62 species have been categorized as food fish while 42 species as ornamental fish. Hanif et al.(2016)

reported 40 species of SIS belonged from 19 families, in which 2 species were critically endangered, 7 species vulnerable, 18 species not threatened, 2 data deficient and 4 species were not in evaluated category from the study of, current status of SIS of river Gorai a tributary, of river Ganga from Bangladesh. Borah et al.(2017) studied the length-weight relationships for six small indigenous fish species, namely: *Trichogaster chuna* (Hamilton, 1822), *Trichogaster lalius* (Hamilton, 1822), *Trichogaster fasciata* (Bloch & Schneider,1801), *Chanda nama* (Hamilton, 1822), *Prambassis laala* (Hamilton, 1822) and *Macrognathus aral* (Bloch & Schneider,1801) for the first time from Deepor beel, a Ramsar site of Assam.

Nepal has diversified habitat of fish species. The native fish diversity including endemic have been reported by Shrestha (1981), 120 species, Rajbanshi (1982), 181 species, Shrestha (1995), 202 species, Rajbanshi (2005), 187 species Sherstha (2007), 226 species and Shrestha (2008) 206 species of large and small indigenous fish species from Nepal. Bista et al.(2005) reported that approximately 90% catches are composed of minor carps especially in the season when bigger fishes are not captured adequately in the capture fishery of lakes Phewa and Begans of Pokhara valley and it contributed substantially in the total production and livelihood of fishermen. Karn (2014) reported 55 species of SIS belonging to16 families from Nepal. SIS species such as *Puntius sophore* (pothi), *Esomus denricus* (dedhuwa), *Amblypharyngodon mola* (mara), *Channa punctatus* (garai), *Mystus tengra* (tengra), *Mastacembalus armatus* (gaincha), *Baralius* barila (faketa) and others inhabit in rivers and tributaries, floodplains, ponds, lakes, streams, lowland areas, wetlands and paddy fields. Although rural people largely depend on indigenous fish species for nutrition in many parts of Nepal, but very little attention has been paid on their role in aquaculture enhancement, nutritional significance, fish processing and preservation, biology, induced breeding, livelihood security and conservation needs. Consequently, many small indigenous fishes have become stake due to pollution, over exploitation coupled with habitat destruction, water abstraction, siltation, channel fragmentation, diseases and introduction of exotic varieties (Wagle et al., 2008). Efforts at enhancing fish production from freshwater aquaculture have mainly focused on increasing carp production, despite of the fact that Nepal has a very strong gene pool of freshwater fish, which is virtually neglected. In order to achieve sustainable utilization, the appropriate planning for conservation and management strategies for small indigenous fish species are of utmost importance in recent time. Small indigenous fish species are excellent source of essential macro and micro-nutrients so they play important role in the elimination of malnutrition problem of south Asian country Bangladesh (Thilsted et al., 1997). *A. mola* has high protein vitamin and mineral contents, which may be compared favorably with the common Indian major carps. Taking 3 whole *A. mola* fish per day can save a child from blindness due to shortage of vitamin A (BSS, 1998). Studies on 16 varieties of fish in Cambodia have shown that most of the indigenous varieties of fish have great iron content, which is also highly bioavailable (Bioavailability is the degree to which an agent, such as a drug or nutrient, becomes available at the site of activity in the body). Out of 16 varieties screened, *Esomus longimanus* (Mekong flying barb) had the highest content of iron, with the highest bioavailability. The same degree of bioavailability was also found for zinc. World Food Programme (WFP) promoted the use of *Esomus longimanus* as supplementary food for small children in Cambodia. Research has also shown that if one fish is added to rice (the way fish is usually consumed), the bioavailability of iron increases considerably. Calcium is also available in bigger fish though the bioavailability is not as high as in the case of small fish. Studies comparing *A. mola* and milk as sources of calcium have shown that though the bioavailability from both sources are almost the same, *A. mola* is a much better source because of the higher concentration of calcium (Roos et al., 2007). Considering the wild nature of *A. mola* species, rice fields seem to be more appropriate culture systems although this species is well adapted in carp polyculture pond systems (Wahab et al., 2003). Mookerjee and Basu (1946) reported that *A. mola* was generally surface feeder fish and the food consisted of unicellular and filamentous algae, protozoans and rotifers. Mamun et al.(2004) reported that *A. mola* is mainly planktonivorous fish species so, it takes phytoplankton and zooplankton foods such as rotifers, crustaceans etc. So from the knowledge of feeding habit of small indigenous fish species culturing of SIS should be encouraged. This will help in food and nutritional security, poverty alleviation and biodiversity conservation.

2.2 Fresh water aquaculture and semi intensive aquaculture

Freshwater aquaculture is by far the most ancient aquatic living resource production system known in the world. Fish is the main component of freshwater aquaculture and earthen pond is historically the first and still the most utilized aquaculture production facility (contribution for more than 80–85% of the total freshwater production). In recent years aquaculture is being projected as possible solution to food problems faced by masses (FAO, 2010). It gives higher productivity per unit area in comparision to agriculture and animal husbandry. Freshwater aquaculture differs from other aquaculture system by its some specific characteristics. Such as water use, animal wastes recycling into the fish ponds as fertilizers, agricultural by-products as fish feed (Kesmont, 1995). Freshwater aquaculture production is mainly based on the culture of short food chain fish (carp, tilapia etc.). Freshwater aquaculture is mainly based on extensive and semi-intensive aquaculture production systems where polyculture, fertilization, and supplementary feeds are the key points. Aquaculture is fairly a new activity in Nepal. It began in the 1940s with pond culture of Indian major carps (Rai *et al,* 2008). Over the years, carp polyculture in ponds has developed as the most viable and popular aquaculture production system in the world and in 2011/2012 it accounted for over 56.4 percent of total aquaculture production (FAO, 2012).

2.3 Monoculture versus Polyculture

Polyculture is proved to be more suitable aquaculture system than monoculture. Fish polyculture is practiced aiming to increase productivity. In order to increase fish production and harvest, the polyculture of several species of fish should be practiced according to their feeding habits and a suitable stocking density. Complementary species can increase the maximum standing crop of a pond by allowing a wide range of available foods and ecological niches (Kesmont, 1995). Both survival and growth of fish are higher in polyculture than monoculture due to synergistic interactions among fish species and improvements of environmental conditions (Yashouv, 1971), Hepher et al.(1989), Milstein (1992) and Wahab et al. (1995). The overall growth percentage of three species of Indian major carps rohu (*Labeo rohita*), catla (*Catla catla*), mrigal (*Cirrhinus mrigala*) was higher in polyculture than monoculture in an experiment of growth and production performance of yearling of Indian major carps *Catla catla, Cirrhinus mrigala* and *Labeo rohita* (Khan et al., 2012). Economically monoculture is very expensive than polyculture and it is not suitable for carp fishes however, polyculture is the best for overall production and economic point of view (Khan et al., 2012). The production performances of SIS species *A. mola*, *Puntius sarana* and *Chela cachius* etc. have been carried out time to time from monoculture experiments. The fish production per hectare per annum seems to be economically unsuitable in monoculture of SIS. The production from monoculture of SIS species *A. mola*, *Puntius sarana* and *Chela cachius* was 1,110, 2,240 and 1,018 kg $ha^{-1}yr^{-1}$in Bangladesh. The SIS production of *A. mola* was 1,335 kg $ha^{-1}yr^{-1}$ from monoculture in Nepal (*Karn* et al., 2012).The production of SIS species from polyculture is far more than the monoculture (Kohinoor et al., 2001). The production of carp polyculture from semi intensive method varies in different countries. It is more than 5.0 t yr^{-1} in India, Bangladesh etc countries (FAO, 2012). The annual production of carp fish from semiintensive fish farming method in Nepal is lying between 3.5 to 4.3 t yr^{-1} DOFD, (2006) and DOFD (2014). Culturing different carp species in the same pond optimizes the utilization of the food available in the ecological niches of the pond ecosystem (Kestmont, 1995). In addition, the polyculture aims to increase productivity by a more efficient utilization of the ecological resources in the aquatic environment (Lutz, 2003). Thus, stocking two or more complementary species can increase the maximum standing crop of a pond by allowing a wider range of available foods and ecological niches in polyculture. In polyculture systems, only a proper combination of different fish species feeding in different ecologically niches of pond, at adequate stocking densities will utilize the available resources efficiently due to the maximization of synergistic fish–fish relationships and minimization of antagonistic ones (Milsten, 1992). All the ecological resources in the aquatic environment remain unexploited in monoculture system than the polyculture method of fish farming. The polyculture of carps with *A. mola* increase in house hold consumption of small fish which have very high content of calcium, iron and vitamin A (Roos et al., 1999). In addition to the nutritional benefits the present carp-SIS polyculture method can also increase additional income through the sale of carps and surplus small fish (Wahab et al., 2002).

2.4 Over view of carps-SIS aquaculture system trials

The early concept of SIS species was as the weed fish because these fishes either compete for food with carp fishes or some of them are carnivorous, hence were eradicated from the ponds by using piscides (Wahab et al., 2003). With the increasing demand for fish and decline in capture fish production, SIS farming in Bangladesh has become very common in the homestead pond as an important valuable cheap protein and vitamin suppliers (Ahmed et al., 2007). However at present, SIS species are cultured with the Indian major carps and Chinese major carps in many countries of the world. It was proved that *A. mola* can be successfully cultured in seasonal ponds with carps. There is an increase in the household consumption of small fishes *A. mola*, which have a very high content of calcium, iron and Vitamin A (Roos, 1997). Evaluation of culture potentials of three small indigenous fish species (SIS), *Amblypharyngodon mola*, *Puntius sophore*, and *Chela cachius* with Indian major carps gave high fish production when *Puntius sophore* was combinely stocked with carps and it was partially harvested time to time (Kohinoor & Wahab, 1998). SIS can be introduced for rearing with existing carp polyculture without negative environmental effect by low cost methods (Roos, 2001) and Roos et.al.(2003). The polyculture of *Puntius sophore* with *L, rohita, Catla catla, C. carpio* and *C. mrigala* by semi-intensive polyculture increased a 60% of higher yield of *L. rohita* with *C. carpio* in comparision to *C. mrigala* (Wahab et al., 2002).

The addition of *Puntius sophore* did not affect rohu (*Labeo rohita*), catla (*Catla catla*), mrigal (*Cirrhinus mrigla*), common carp (*Cyprinus carpio*) and total yield from an experiment to access the effects of addion of *Puntius sophore* in polyculture of carps and to compare the effects of *C. mrigala* and *C. carpio* production performance (Wahab et al., 2002). The production performance of rohu, improved by 50% and in total the fish production increased by 20%. Akhteruzzaman and Kuiya (2003) found that composite culture of only SIS gave a relatively low production with a higher food conversion ratio of 5.0 to 5.45 in contrast culture of SIS with other fast growing fishes gave the high production with a lower food conversion rate of 2.9 to 3.0 and it offers a better financial return. No negative effect in the production performance of *Cyprinus carpio* and *Hypophthalmicthys moltrix* were found when *Puntius sophore* and *Amblypharyngodon mola* were added into the polyculture system of large carps *Labeo rohita*, *Catla catla* and *Cyprinus carpio* but *A. mola* alone reduced production performance of *Labeo rohita* by 15%, both the SIS *Puntius sophore* and *Amblypharyngodon mola* reduced catla's production performance by 20–24% in the experiment to test the effects of SIS species in polyculture system of large carps in pond ecology (Kadir et al., 2007). Complex responses produced in the pond ecosystem by affecting the large carps growth and production performances in an experiment "Observation of the effects on production of fish performance and pond ecology interference in the water column or in the bottom through changes in the polyculture composition by introducing the small fish *A. mola"*. The reproduction and harvested biomass of small fish *A. mola* did not get affected significantly from result of experiment (Milstein et al., 2009). Large fish species diversity was appropriate to obtain a larger amount of small silver carps that can be sold in the shortest time after of stocking. The addition of tilapia (*Oreochromis niloticus*) with or without at different stocking densities in the polyculture of *Hypophthalmicthys moltrix, Catla catla, Labeo rohita,* prawn and *A mola* in the pond condition gave an increase in combined net yield significantly with the increasing stocking density of tilapia (Shahin et al., 2011). Contribution in species wise production of carps and SIS silver carp 98.5 %, rohu (95%), *A. mola* (91.5%), prawn (89.3%) and bighead carp (85.4%) among the cultured species of carps and SIS in large category of ponds on the basis of technology practice is the recent finding from the study of certain region of Bangladesh where carp-SIS culture has established as viable polyculture system (Hossain, et al., 2013). This practice has satisfied the family protein requirement, reduced the buying cost and also has high growth rate of profit level as well as high market demand.

2.5 Culture species of fishes

Carps are the principal aquaculture species in south Asia (Rahman, 2006). Carps contribute more than 87% of total inland aquaculture production (FAO, 2012). Carp polyculture was dramatically improved in the 1960s when Chinese major carps were widely introduced into many countries of Europe and Asia. Today, it is a widely practiced pond fish culture technique, in the countries of all climatic conditions. (Woynarovich *et al.*, 2010). Almost all production of Indian major carp had come from India on the past but in recent years a growing proportion is cultured in Myanmar, Thailand, Bangladesh, Pakistan, Nepal, Philipines and Laos. Recent country reviews of FAO support the view that characteristics of pond fish culture make it very suitable to produce fish in an inexpensive integrated way. The limited carp species can be used in carp sis polyculture system. The carp species and SIS species which will not compete for the food and affect the growth and production performance of one another can be used only in the carp SIS polyculture system. Kohinoor and Wahab (1998) used Indian major carp and small indigenous fish *Puntius* in carp-SIS polyculture system. Kadir et al.(2007) used carp species rohu (*Labeo rohita*), catla (*Catla catla*) and common carp (*Cyprinus carpio*) and the SIS puntius (*Puntius sophore*) and mola (*Amblypharyngodon mola*) in carp-SIS polyculture system experiment. Shahin et al.(2011) used *Catla catla*, *Labeo rohita*, *Hypophthalmythys molitrix* as the carp species, *A. mola* and prawn as the small indigenous fish species in addition of tilapia (*Oreochromis niloticus*) in a carp-SIS polyculture system at different stocking densities trials. Hossain et al. (2013) reported the use of silver carp, bighead carp and rohu in farmer's level carp SIS polyculture practice from Bangladesh. Aquaculture is mainly done in the Terai-plain of Nepal consisting of carp species Rohu (*Labeo rohita*), Bhakur (*Catla catla*), Naini (*Cirrhinus mrigala*), common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*) silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*Aristichthys nobilis*). The warm water fish species such as Rohu (*Labeo rohita*), Bhakur (*Catla catla*), and Naini (*Cirrhinus mrigala*) and common carp (*Cyprinus carpio*) were introduced into Nepal in 1956 from India. The herbivore grass carp (*Ctenopharyngodon idella*) was introduced in 1966 from India, phytoplankton feeder the silver carp (*Hypophthalmichthys molitrix*) in 1968 from Japan and zooplankton feeder bighead carp (*Aristichthys nobilis*) in 1971 from Hungary for the development of aquaculture system in Nepal. These seven carp fish species are the main species commonly used by the farmers for commercial production (Rai et al., 2008).

Table 1.1 Fish species used in carp- sis culture

Species	Culture system	Culture unit	Feeding behaviour	References
Nile tilapia	Monoculture	Tank	Plankton, detritus, macrophyte	Philippart and Ruwet (1982)
Rohu	Monoculture Polyculture	Pond Tank	Plankton, vegetable debris, periphyton	Azim et al. (2001a)
Silver carp	Polyculture	pond	Phytoplankton	Woynarovich (1975)
Catla	Monoculture Polyculture	Pond	Plankton mainly zooplankton	Ahmed (1993)
Bighead carp	Monoculture Polyculture	Pond	benthos, plankton zooplankton	Woynarovich (1975)
Common carp	Polyculture	Pond Tank	Detritus, benthos, zooplankton, aquatic plants	Woynarovich (1975)
Grass carp	polyculture	Pond	Phytoplankton, vegetable matter, zooplankton,	Jhingran(1985), Woynarovich (1975)
Mrigal	Polyculture	Pond	Plankton, Detritus	Jhingran (1985)
Mola	polyculture	Pond, Reservoir	Filamentous algae, protozoans, rotifers etc.	Mookerjee and Basu(1946) and Piska et al.(1991)

2.6 Stocking density and ratio

The optimum stocking density of a fish pond is that amount of fish released into the pond at the beginning of the production period, which guarantees the highest possible economic income. The assessment of the fish pond stocking is one of the most important parameters for making the success of the breeding. Only a proper combination of different cultiviable species of fishes, in adequate densities, will utilize the available resources efficiently in polyculture systems. The variations in stocking densities of carp and SIS species have been used time to time in the carp-SIS polyculture experiments. Kohinoor and Wahab (1998) used the stocking density of carps and SIS at the rate of 7, 500 ha^{-1} and 50,000 ha^{-1} in an experiment to explore the result of culture potentials of small indigenous fish species in semi intensive polyculture with carps. Ponds were stocked at a stocking density of 10000 large carps ha^{-1} and 25000 (SIS) Puntius ha^{-1} in carp-SIS polyculture experiment Wahab et al.(2002). Dewan et al.(2003) used the stocking density of *A. mola* 30,000 ha^{-1}, 40,000 ha^{-1} and 50,000 ha^{-1}, *O. cotio cotio* 15,000 ha^{-1} and 5,000 ha^{-1} for both *B. gonionotus* and *C. carpio* to determine the suitable species combination. Da Silva et al.(2006) used the stocking density of fishes 2875 to 5750 ha^{-1} in the species ratio of 35% common carp, 35% grass carp, 15% silver carp and 15% bighead carp. They tested stocking ratio of 20% an indigenous fish jundia by adjusting the ratio of carp species. Kadir et al.(2007) used stocking density of carps from 7500 ha^{-1} to 10000 ha^{-1} and SIS 20000 to 50000 ha^{-1} in carp-SIS polyculture system. The stocking density of prawn between 10,000 to 25,000 ha^{-1} and the stocking density of *A. mola,* 20,000 ha^{-1} was tested by Amin and Salauddin (2008). Milstein et al.(2009) used the stocking density of carps (rohu, catla, common carp, silver carp) between 3.3 to 3.4 m^{-2} and SIS *A. mola* 25000 ha^{-1}.

2.7 Fertilization

Use of organic manure in fish culture is an age-old practice. The use of organic and inorganic fertilizers provides basic nutrients and elements required for the production of phytoplankton and zooplankton which serve as a major source of food for fish under the polyculture system (Javed et al., 1992). The use of fertilizer is an integral part in carp polyculture system. The growth of fish is strongly correlated with increase of phytoplankton and zooplankton productivity as a result of fertilization.

Fish culture with manures as the main nutritional input is a long-time practice in China (Tang, 1970). Fertilizers increase the level of primary productivity, dissolved oxygen, pH and total phosphorus (Qin et al., 1995). The study of fertilization in the carp polyculture has focused to address issues about the effect of organic manure and chemical fertilization on water quality and growth of carp (Vromant et al., 2002) and Dhawan (2002). Fertilization enhances phytoplankton productivity in rearing and stocking ponds (New & Fedoruk, 2003) and Bhakta *et al.*(2004 & 2006). Fertilizers increase fish production without risk of dietary diseases and also play an important role in the formation of soil structure. The growth of fish is strongly correlated with increase of phytoplankton and zooplankton productivity as a result of fertilization. The ultimate goal of fertilization is to achieve suitable environmental conditions for the production of natural food for fish, but in comparison with organic manure, fertilizers increase the level of primary productivity, algae abundance, dissolved oxygen, pH and total phosphates. (Afzal et al., 2007), Hussein (2009), Jana et al. (2001) and Ponce Palafox (2010). Organic manures and chemical fertilizers can be used to increase the planktonic biomass, in which fish mainly feeds. It stimulates the growth of natural food by providing essential elements, which are utilized by the phyto-and zooplanktons. The fertilization in fish farming is to improve water quality and to increase the variety and quantity of phytoplankton and zooplankton, which eventually leads to high fish yield and economic returns. The production of fish ponds depends mainly on the vegetation, which is dependent on the nutrients in ponds. It is not possible to increase the production of cultivated fish by giving them the greater quantities of natural food directly. Presently fish culture mainly depends on the application of organic fertilizers and to some extent on inorganic fertilizers (Hussein, 2012). Das and Jana (1996) found that one of the most important problem concerned in fish-pond fertilization was the determination of the optimal amount of fertilizer to be added to a pond system. Fertilizers used in fish ponds are of two categories, inorganic and organic. The major fertilizing elements are nitrogen, phosphorus, potash and calcium whereas, the minor elements are manganese, boron, sulphur, iron, copper, zinc etc. The advantages of inorganic fertilizers are that they have a definite chemical composition of nutrient elements and are instantly soluble in water (Das, 1996).

Current fertilization practices in the Asian-Pacific region include a fixed-rate of fertilization and the fertilization is based on water color. These methods have been practiced with limited success (Kumar et al., 2004). Variation seems in protocol of fertilizers use in regional basis. Initial dose of 1000 to 3000 kg organic manure followed 200 to 400 kg on 8^{th} and 14^{th} day (Sarkar, 1983) The fertilization rate seems to be region specific. The moderate rate of fertilization is used in India and Bangladesh. Ramesh et al.(1999) have applied cow dung and urea at rate of 3000 kg ha^{-1} yr^{-1} and 150 kg $ha^{-1}yr^{-1}$. Fertilization protocol used by Wahab et al.(1999) used the protocol of fertilization in which initial dose of cow dung 5500 kg ha^{-1}, urea and TSP 125, 125 kg ha^{-1} while subsequent fortnight dose was 5000, 50 and 50 kg ha^{-1} respectively. Pathak et al.(2000) applied cow dung 4500 kg ha^{-1}, urea 150 and TSP 150 kg ha^{-1} into the ponds that gave the yield of 5000 kg fish $ha^{-1}yr^{-1}$. Azim et al.(2001) has optimized fortnight doses of cow dung, urea and TSP at 4,500, 150 and 150 kg ha^{-1} in ponds for periphyton-based aquaculture system, the doses have been later reduced to 1,000, 50 and 50 kg ha^{-1} in subsequent experiments due to phytoplankton bloom in the ponds. Fertilizer is the main nutrient input of the system in absence of supplementary feed. Plankton density increases with increasing fertilization rate (Azim et al., 2001). Mridula et al.(2003) have used 2000 kg chicken manure ha^{-1} as initial dose followed by 2000 kg ha^{-1} $month^{-1}$. Dewan et al.(2003) used the fertilizers urea, TSP, MP and gypsum at a rate of 200 kg ha^{-1}, 150 kg ha^{-1}, 75 kg ha^{-1} and 160 kg ha^{-1}, respectively in mono-culture of *Amblypharyngodon mola, Osteobrama cotiocotio* and *Barbodes gonionotus* and *Cyprinus carpio*. Bhakta et al.(2004) optimized fertilizer dose for the production of rearing stage of carps under polyculture in seven different input doses 105, 211, 422, 844, 1689, 3378 and 6757 g $tank^{-1}$ (4.5 m^3) $week^{-1}$ of mixed fertilizers poultry droppings (PD), cattle manure (CM), single super phosphate (SSP) and urea (U). Comparatively higher fertilization doses of 6250, 125 and 188 kg ha^{-1} for cow dung, urea and SSP have been reported by Sahu et al.(2006). Sayeed et al.(2007) suggested use of inorganic fertilizers at the rate of 100 kg ha^{-1} $month^{-1}$ in carp polyculture system for better production performance of carp fishes. Bagherpour et al.(2013) found the effect of urea use at the rate of 200 kg ha^{-1} and phosphate use 300 kg ha^{-1} and organic manure cattle dung 300 kg ha^{-1} yr^{-1} with inorganic fertilizer urea use at the rate of of 100 kg ha^{-1}, phosphate 150 kg ha^{-1} gave the result of high production of fish with high mortality in second time use.

2.8 Water quality and Planktons

.Water quality (physico-chemical factors) plays a key role in aquaculture because the maximum production can be obtained only when physico-chemical factors of pond water are at optimum level (Sinha & Srivastava, 1991). Objective of aquaculture is to produce the maximum fish or (other marketable species) in a given volume of water in the shortest time. The lowest possible cost of fish production cannot be attained because of poor water quality (Barnabe, 1994). Diana et al.(1996) emphasized that the efficient use of supplementary feed at a limited rate, along with fertilizer and natural feeds does not adversely affect water quality. Therefore water quality is a paramount factor in ecosystem productivity. Using biological methods of water assessment are a very useful tool since they can reflect overall ecological quality, integrate variations in the environment and indicate biologically available nutrients whose chemical analysis cannot be measured in the ponds (Lyngby, 1990) and Gol'd et al.(2003). Plankton diversity and physico-chemical parameters are an important criterion for evaluating the suitability of water for aquaculture. In order to analyze the water quality in carp ponds beside physical and chemical analysis of water phyto and zooplankton organisms can be used as bio indicators (Dulic et al., 2006 & 2009). Phytoplankton organisms are also very valuable indicators of water quality (Wu, 1984) and Webber and Webber (1998). Planktons are highly responsive to nutrient loadings due to their rapid reproduction and short life cycles. Since they are at the bottom of the food chain, algal responses are mostly attributed to physical and chemical changes (USEPA, 1990). High algal abundance may cause increased photosynthetic activity during the day resulting in high pH values, a condition that can be directly lethal to fish (Bergerhouse, 1992), or indirectly by increasing the proportion of unionized ammonia (Stickney, 1994). Zooplankton are small and rapidly reproducing organisms that respond quickly to environmental changes and may be effective indicators of subtle alterations in water quality (Attayde & Bozelli, 1998), Pontin and Langley (1993) and Zakaria et al.(2007). Tabinda and Ayub, (2009 & 2010) suggested that phytoplankton and zooplankton are rich sources of protein (40-60%) on dry weight basis, so zooplanktons are sufficient for fish growth at low stocking densities (Tabinda & Ayub, 2009 & 2010) and Sun et al.(2010). By integrating the effects of anthropogenic and natural influences, the additional information provided by bio indicators gives a more refined measure of water quality that does chemical sampling alone (Keeler & McLemore, 1996). Water quality parameters under the range of limitation are essential factor for polyculture. The pH of water ranging from 6.5-9.0 is suitable for fish culture (Swingle, 1967). The highly productive water for fish production has to be more than 100.0 ppm alkalinity (Alikunhi, 1957). The taxonomic compositions of planktonic species have been carried out in the aquaculture experiments mostly to estimate the available of food for phytoplankton feeder fishes. Azim et al.(2002) observed the highest planktonic diversity of total 47 genera, in which phytoplanktons belonged from 35 genera and zooplanktons belonged from 25 genera in periphyton based aquaculture experiment. The quantitative and qualitative studies of phytoplanktonic species may provide good indices of water quality and capacity of water to sustain heterotrophic communities (Mahoor & Beena, 2010). Zooplankton abundance and distribution has high ecological importance, as they are very sensitive for the change in water quality parameter, therefore zooplankton make ideal indicators of aquatic ecosystem (Joseph & Yamakanamardi, 2011). The abundance of rotifer, cladoceran, cyclopoid-copepod and ostracod were in zooplanktons in study of Joseph and Yamakanamardi (2011). Raghunathan (1989) reported 106 species and Sharma (1991) updated the list of 103 species of zooplanktons from India which was confirmed latter on by Murugan *et al.*(1998). Rajagopal et al.(2010) reported 24 rotifers, 9 copepods, 8 cladocerans, 4 ostracods and 2 protozoan groups from total 47 taxa of zooplanktons in a study. The study revealed positive significant correlation with physico-chemical parameters like, temperature, alkalinity, phosphate, hardness and biological oxygen demand, whereas negatively correlation with rainfall and salinity of zooplankton.

2.9 Carp–SIS culture versus polyculture of carps

Fresh water polyculture of carp species has been practiced in world since last many years ago. If polyculture originates from Asia, it is now practiced on all continents. In traditional polyculture of Eastern Europe, carps remain the dominant species and the other fish; hardly represent more than 10%: tench (6–7%), pike (0.9–1.7%), salmon (3.2–5.5%) and others (1.2–4.8%). Because of their growth performances and their short food chain feeding regime, the herbivorous Chinese carps *Ctenopharyngodon idella*, macrophytophagous and phytoplanktonivorous *Hypophthalmichthys molitrix*, are frequently included in the polyculture. The mixed-fish farming is associated with the Nile tilapia (*Oreochromis niloticus*), catfish species *Heterobranchus isopterus*, *Clarias* spp), one osteoglossid (*Heterotis niloticus*) and the predator (*Hemichromis fasciatus*) to eliminate undesirable fry in stocking ratio of 0.03 *Heterotis niloticus*, 0.04 *Heterobranchus isopterus*, and 0.2 *Hemichromis fasciatus* for each stocked tilapia in Africa (Woynarovich, 1975). Under these conditions, the secondary species can increase the total fish yield by more than 40%. In South America, experiments were led with *Colosso mamacropomum* as main species and *Prochilodus* spp, *Cyprinus carpio* and tilapias as secondary ones. However, the South American references describing powerful associations are rare and the practices used are rather the result of the empirical experiment of the fish farmers (Dabbadie & *Lazard*, 1995). Principle methods used in the fresh water polyculture of carps are; pond preparation, fertilization, stocking of carp species, regular supplementary feeding, water quality monitoring, growth checkup and harvesting. The traditional carp polyculture system has received attention recently in the farming of carp species with (SIS) small indigenous fish species (Alim et al., 2005). Several species of SIS; puntius (*Puntius sophore*), mola (*Amblypharyngodon mola*), chela (*Chela cachius*), *Esomus denricus* (dedhuwa) etc have been cultured with Chinese carps and Indian major carps in carp- SIS polyculture system in South east Asia. The existing carp polyculture methods which are in practice now a days are used for carp-SIS polyculture system in south Asia with mainly modifications with carp SIS stocking density and selection of suitable SIS species. Production performance of fishes from only carp polyculture and carp-SIS polyculture comparision shows less investment in carp-SIS polyculture in second year after of the stocking of fries in first year. The net yield of fishes in carp polyculture system shows large variations. Singh and Singh (1975) reported 4500 kg carp fishes $ha^{-1}yr^{-1}$ from polyculture of *Catla catla*, *Labeo rohita* and *Cirrhinus mrigala* using chemical fertilizers and cow dung. A maximum fish production from freshwater ponds was reported 7.5 T $ha^{-1}yr^{-1}$ (Lin, 1982). Islam and Dewan (1986) estimated pond fish production ha^{-1} from 1700 to 3889 kg $ha^{-1}yr^{-1}$ through semi-intensive culture of Indian major carps and Chinese major carp. Ameen et al.(1984) obtained 4,490 kg ha^{-1} per 8 month of mola, punti and carps species. The net investment in carp-SIS culture after of first year of stocking and production seems to be always cheaper than the only carp polyculture system (Wahab et al., 2002). The fish yield return is achieved only after of few weeks in carp-SIS polyculture (Wahab et al., 2002 & 2003).

2.10 Effects of supplemental feeds in Carp-SIS polyculture

With the intensification of aquaculture practices, there is a shift from using supplementary fish feeds comprised of agricultural wastes and by-products to using complete feeds developed to meet the complete nutritional requirements of the cultured species. These feeds usually have other additives in the form of pigments, vitamins, chemo-attractants, and preservatives, like mold inhibitors and antioxidants. Previous researches have shown that supplemental feeding in fertilized ponds resulted in significantly higher growth rates and greater yield than fertilization alone (Green, 1992) and Diana et al.(1994). Diana et al.(1996) emphasized that from a pond management perspective, fertilization is essential in early grow-out stage of fish, then adding supplemental feed once per day, Nile tilapia reached 100-150 g which is the efficient way to grow large tilapia. In semi-intensive pond-based farming systems the dietary nutrient requirements of the cultured fish species is largely met through the consumption of natural food organisms produced endogenously within the pond and through the direct consumption of exogenously supplied supplementary feed inputs (Tacon & De Silva, 1997). Supplementary feed usually consists of cheap and locally available raw ingredients (Ghosh et al., 1984). Improvement in semi-intensive system is provided by better quality of supplemental feed. There is a big array of ingredients that can be used as feed stuffs such as, sunflower seed cake, maize bran, cotton seed cake, soyabean, and other plants as well as different quality fish meal depending on the part of fish used in now a day. Natural foods (zooplankton and macro zoobenthos) are the main source of protein component while energy requirements are fulfilled by carbohydrates from row cereals (wheat, barley, corn etc.) as supplementary feed in fish culture (Markovic & Tutundzic, 2003). In semi-intensive systems, artificial feed benefits the ponds through either directly eating by cultured fish or indirectly supplying nutrients due to decomposition by benthos, fungi and protozoa (Moriarty, 1986), Milstein (1992) and Moriarty (1997). On an average 21% of the nitrogen and 19% of the phosphorous of the artificial feed are retained by the fish use while 14% of the nitrogen and 21% of the phosphorous is used by phytoplankton (Neori & Krom, 1991) and Siddiqui and Al-Harbi (1999) and the remaining nitrogen and phosphorous mainly stimulates bacteria, fungi and protozoa production, which in turn may be consumed by zooplanktons in pond fish culture (Tang, 1970) and Langis et al.(1988). Green (1992) applied artificial feed that contained 24% crude protein only as input offered to tilapia stocked at 2 fish m^{-2} in El Caro, Honduras. Wahab et al.(2002) used the supplementary feed which consisted of rice bran and soaked oil cake (2:1) at the rate of six times per week in a daily rate of 3% of large carp's body weight. Sayeed et al.(2007) applied the mixture of fine rice bran, wheat bran and mustard oil cake at the ratio of 1:1:1 from the second day of stocking fries and supplementary feed was applied at a rate of 8% body weight of the fry up to 15 days beginning from the first day, then 5% up to two months and finally 2.5% of the body weight until the fish harvest. Pelleted floating fish feed containing 25% crude protein was introduced to fish tilapia in an experiment, Influence of fertilizer's types and stocking density on water quality and growth performance of Nile tilapia-African catfish in polyculture system (El nagger et al., 2008). The excessive increase in variable cost due to the high price of formulated feed is a growing concern among fish producers as this could lead to a negative net return and thus, an economically unviable practice cannot be adopted for long term. One of the most significant influences on a fish pond ecosystem in semi-intensive carp production is changing the characteristics of pond by adding low quality supplemental feeds. Therefore, the type of fish feed, its physical and chemical characteristics can considerably change the water quality of a fish pond (Dulic et al., 2010).

2.11 Economics of Carp-SIS polyculture system

Profitability is an important determinant in any industry or commercial enterprise. Economy must dictate which method or technology a farmer should adopt to derive benefit from a particular production practices or situations. The carp – SIS polyculture system is considered as low cost fish culture technique because once the appropriate SIS species is used for the stocking with carp species in a suitable stocking density, the expense for purchasing SIS species for the next time stocking requirement become solved due to the self-recruiting habit of SIS species. Again the partial harvesting of SIS species time to time after of few weeks of initial stocking to keep the maintaining stander stocking density of carps with SIS species within the pond during the whole culture period provides additional benefits. It is difficult to prove its economic viability without the economic analysis of carp-SIS culture. Despite this, very few studies have been done on economics of carp–SIS polyculture system. Shang and Costa-Pierce (1983) advocated the necessity of economic analysis of fish culture operation with a view to find out different alternatives for ensuring high level of net revenue earning. Economic analysis provides information not only in the decision making of individual farmer but also in the formulation of aquaculture policies. Sharma et al.(1999) find out the economic efficiency and stocking densities in fish polyculture of some Chinese fish farms on the multi-output multi-input production approach in terms of four output categories; black carp, grass carp, filter-feeders, and other species, and four input categories; seed, feed, labor, and other costs. Finding of study showed the high technology developed Chinese fish farms, on the average, had adjusted quite well to the prices of the different fish species in the market in selecting the proper species combination. Preliminary investigation carried out by Roy et al.(2003) into the economics of polyculture of Indian major carps with small indigenous fish species (SIS) *A. mola* and *Chela crassius*. The economic feasibility of three different combinations was analyzed on the basis of expenditure incurred and total return from the price of fish in the local market. The analysed data gave only carp polyculture system provided higher benefit (Tk 94,925 ha^{-1}) followed by carps-mola polyculture (Tk 88,330 ha^{-1}) with none significant differences but the net benefit in carp-chela polyculture was significantly ($p<0.05$) lower than others. Benefit cost ratio was higher only in carp polyculture, followed by carp-mola and carp-chela polyculture systems but farmers were no need to stock mola for next year in carp-mola polyculture system, in that condition benefit was higher in carp-mola polyculture than other systems. So carp-mola polyculture was better than other system as it ensured higher production of nutritionally enriched *A. mola* and also from economic point of view the system is encouraging for rural people because they can get *A. mola* regularly for family consumption or sell in the shortest time after stocking and carps as the cash crop. Fingerling is the most influential cost item for total income in fresh water aquaculture system; feed, harvesting and marketing cost hold the second position (Rahaman et al., 2012). Embankment construction, nursery, land lease and labor cost have small influence on total income from fish farming.

2.12 Harvesting

Harvesting is the important procedure in fresh water aquaculture system. The partial harvesting and complete harvesting is used in fresh water aquaculture system. The partial harvesting is used to check the growth rate of stocked fingerlings. Wahab et al.(2002) applied the partial and complete harvesting both in carp SIS polyculture system. The partial repeated harvesting technique is essential in carp SIS polyculture because it helps to maintain the stocking density throughout the culture period of fishes for the growth and also to sell or consume the SIS for additional benefit in the short time period before of final harvest. Repeated partial harvesting of SIS species were used largely in carp-SIS polyculture in Bangladesh (Wahab et al., 2003), Kadir et al.(2006), Kunda et al.(2008) and Gupta and Rai (2011). Friendly harvesting technique must be applied in carp SIS polyculture practice because many sensitive gravid SIS species may get stress due to repeated rough netting process and from the large carp's activities during netting and hand pick up. Wahab et al.(2002) observed the effect of repeated general netting in the reproduction of gravid puntius *(Puntius shophore*).

CHAPTER 3

3. MATERIALS AND METHODS

3.1 Study Area and Research Plan

The present study included two parts: 1. SIS survey 2. Fish culture experiments (Table 3.1). The survey was to assess the abundance and diversity of small indigenous fish species (SIS) in peripheral part of research station Janakpur between Saptari to Parsa district (figure 2). It was conducted from 13th February to 15th June 2012 in between summer to monsoon season in which flooded water contains high fish diversity migrating from Ganga river system. It included 8 districts i.e 8 sampling stations: Saptari (S1), Siraha (S2), Dhanusha (S3), Mahottari (S4), Sarlahi (S5), Rautahat (S6), Bara (S7) and Parsa (S8). The SIS survey was carried by regular visit at 3 sampling sites (fish markets) in each district (sampling station) once in a month (Table 3.2). SIS are brought for sale into the nearby markets by fishermen soon because SIS donot remain in good edible condition for more than 3 to 4 hours after the catch. The sampling station S1 (District Saptari) has 906 ha water surface area and 2120 ponds. The district has Koshi, Khandkhola, Balan, Triyuga etc rivers. The sampling station S2 (District Siraha) has 595 ha water surface area and 1570 ponds. The district has Kamala, Balan etc rivers. The sampling station S3 (District Dhanusha) has 775 ha water surface area and 1985 ponds. The district has Kamala, Jalad, Jamuni etc rivers. The sampling station S4 (District Mahottari) has 587 ha water surface area and 1428 ponds. The district has Bigahi, Ratu, Jangha etc rivers. The sampling station S5 (District Sarlahi) has 280 ha water surface area and 760 ponds. The district has Bagmati, Lakhandehi, Jhim etc. rivers. The sampling station S6 (District Rautahat) has 231 ha water surface area and 560 ponds. The district has Bagmati, Lalbakaiya etc rivers. The sampling station S7 (District Bara) has 872 ha water surface area and 2276 ponds. The district has Dhudhuna, Anarwa, Gambariya, Bageri, Bangari etc rivers. The sampling station S8 (District Parsa) has 272 ha water surface area and 1275 ponds. The district has Rapti, Rewa, Reu, rivers. Sources of SIS species are basically rivers in the study area so it is shown in figure 3. Fish culture experiments were conducted for the assessment of growth and production of combination of carp and SIS. It included three experiments: 1). Growth and production assessment of SIS species by monoculture method. 2). Growth and production assessment from different combination of carp with selected SIS and 3). Production assessment, to obtain, best stocking ratio of SIS with suitable combination of carp. All research experiments were settled and carried in the twelve earthen constructed experimental ponds of Fisheries Development and Training Centre, Janakpur (figure 4). Summary of the experiments, the research frame work and schematic outline of the present study are shown in Table 3.1 and Fig 1.

Table 3.1 Summary of research plan

Survey & Expt.	SIS survey from fish markets	SIS Survey area	Duration of study
Part 1		**Districts for survey**	**SIS Survey**
SIS survey	Abundance and SIS diversity	Saptri,Sirha,Dhanusha, Mahottari,Sarlahi,Rautahat, Bara and Parsa	13 Feb. to June 15th, 2012
Part 2	**Title**	**Experiment site**	**Experiment duration**
Expt.1	Growth & production assesment from selected SIS spp by monoculture method.	Fisheries Development & Training Centre, Janakpur.	18th June to Oct. 17th, 2012.
Expt.2	Growth & production assesment from carp's combination with selected SIS spp.	Fisheries Development & Training Centre, Janakpur	15th March to 7th July, 2013.
Expt.3	Prod^{n} assesment to obtain best stocking ratio of carps & SIS spp.	Fisheries Development & Training Centre, Janakpur	21st March to 25th July 2014.

Table 3.2 Sampling sites and sampling stations of SIS survey

S N	Districts	Sampling stations	Sampling sites
1	Saptari	S1	Bhardah, Hanumannagar & Rajbiraj
2	Siraha	S2	Sirha, Lahan & Bandipur
3	Dhanusha	S3	Janakpur, Mahendranagar & khajuri
4	Mahottari	S4	Jaleshwar, Ramgopalpur & Gaushala
5	Sarlahi	S5	Malangwa, Lalbandi & Barhathwa
6	Rautahat	S6	Gaur, Gadura & Chapur
7	Bara	S7	Kalaiya, Nijgadh & Jitpur
8	Parsa	S8	Birgunj, Chapkuiyan & Bindbasini maisthan

3.1.1 Experimental design

All the three experiments were designed under CRD (Complete Randomized Design) method. Three treatments were randomly allocated into each experiment. Three replications were allocated for each treatment of all experiments. SIS species were collected in the early morning from nearby natural habitat for the experimental purpose. Experiments 1, 2 and 3 were conducted in 12 earthen ponds; the size of each pond was 12.5 x 8 m. They were located in the Fisheries Development and Training Centre, Janakpur.

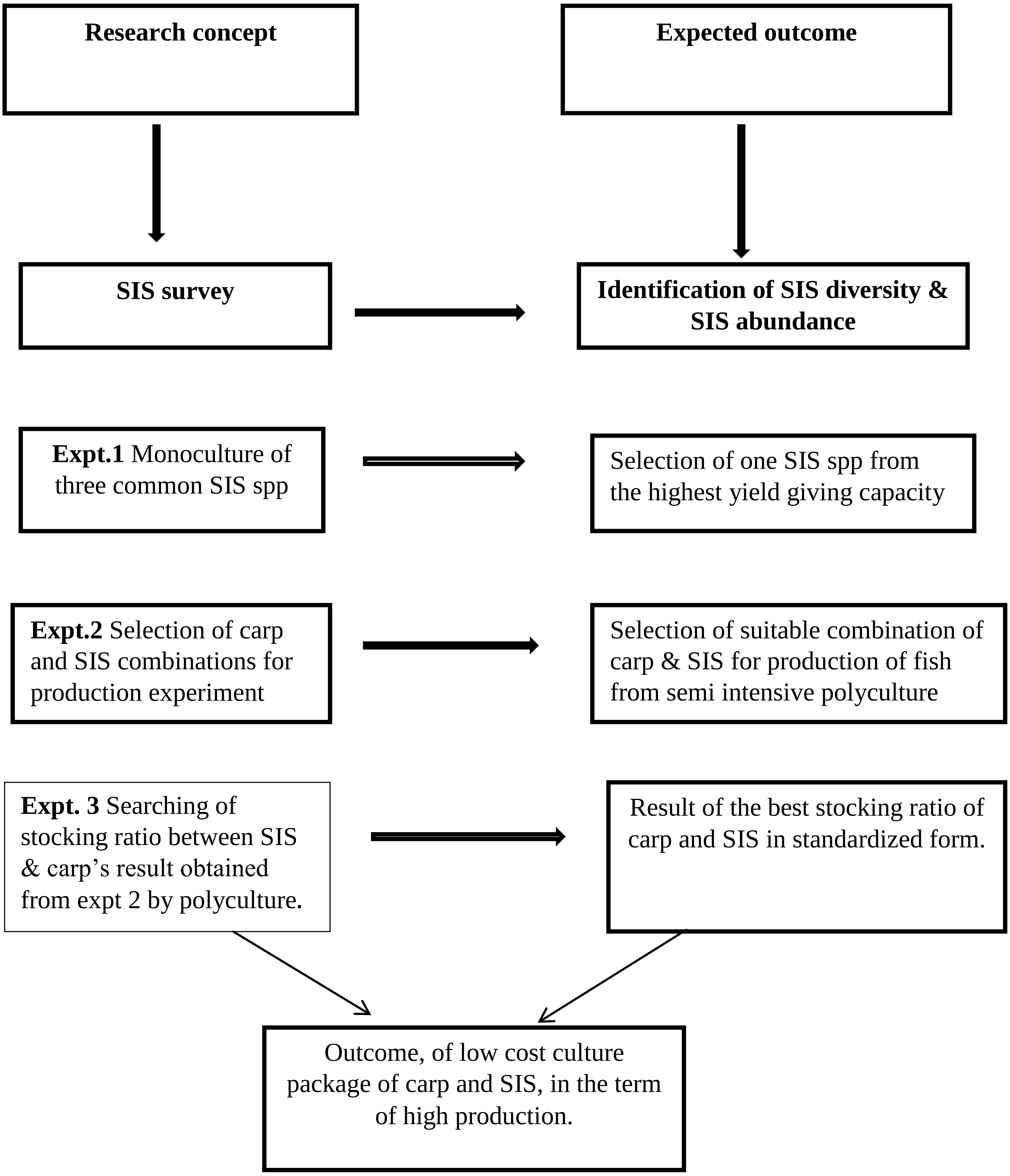


Figure 1 Conceptual Framework

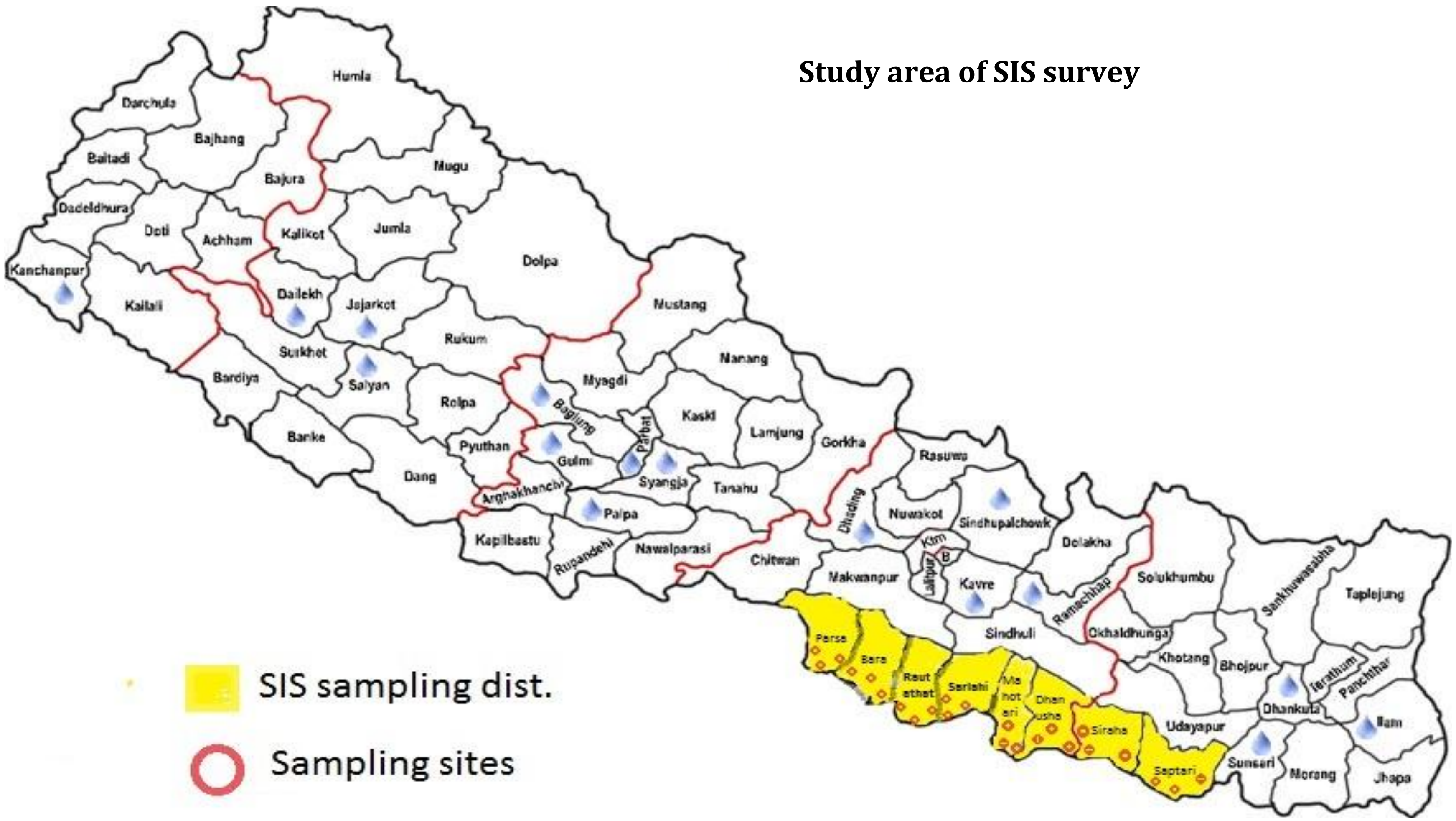


Figure 2 Study area of SIS survey map

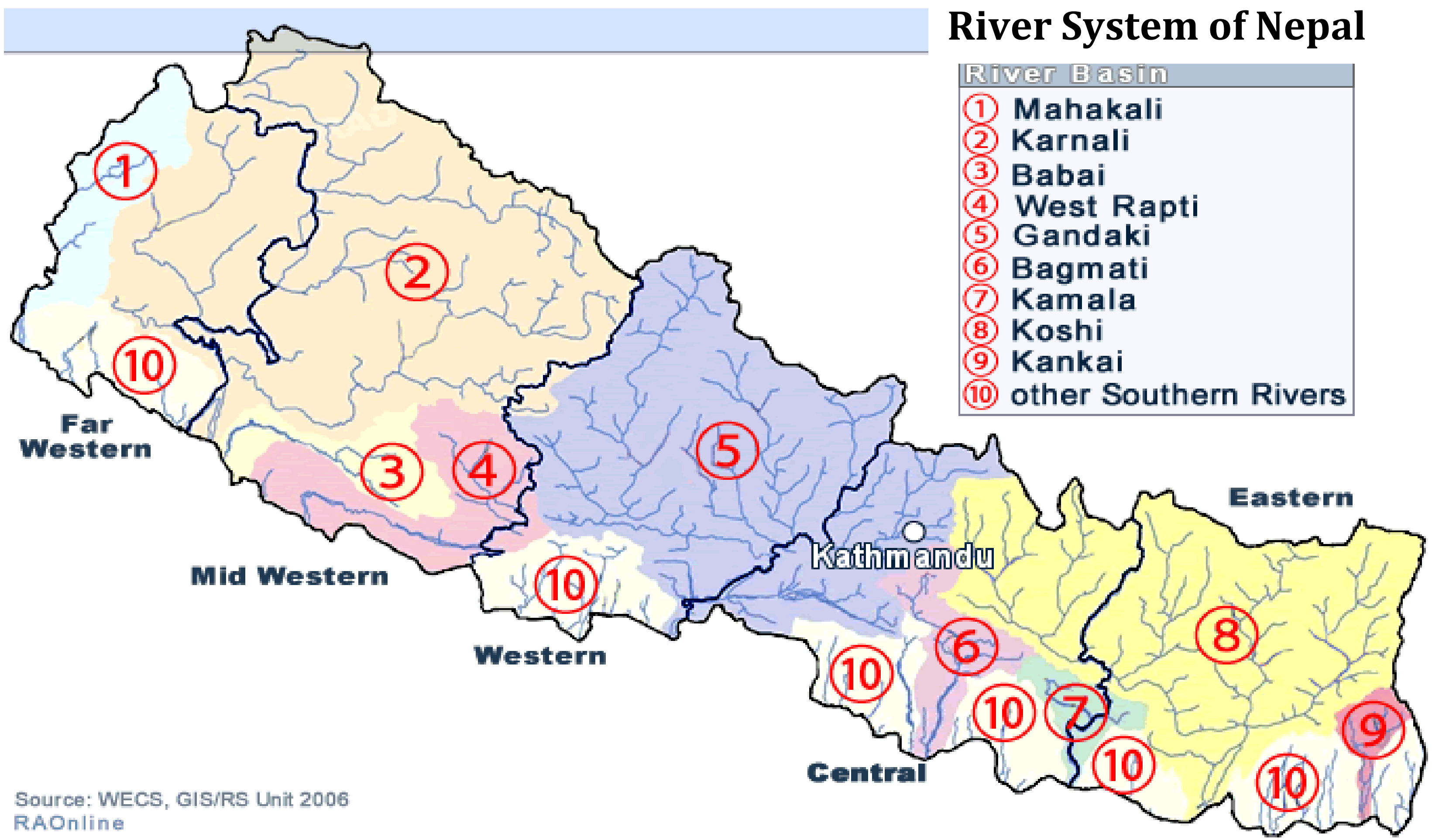


Figure 3 River system of Nepal

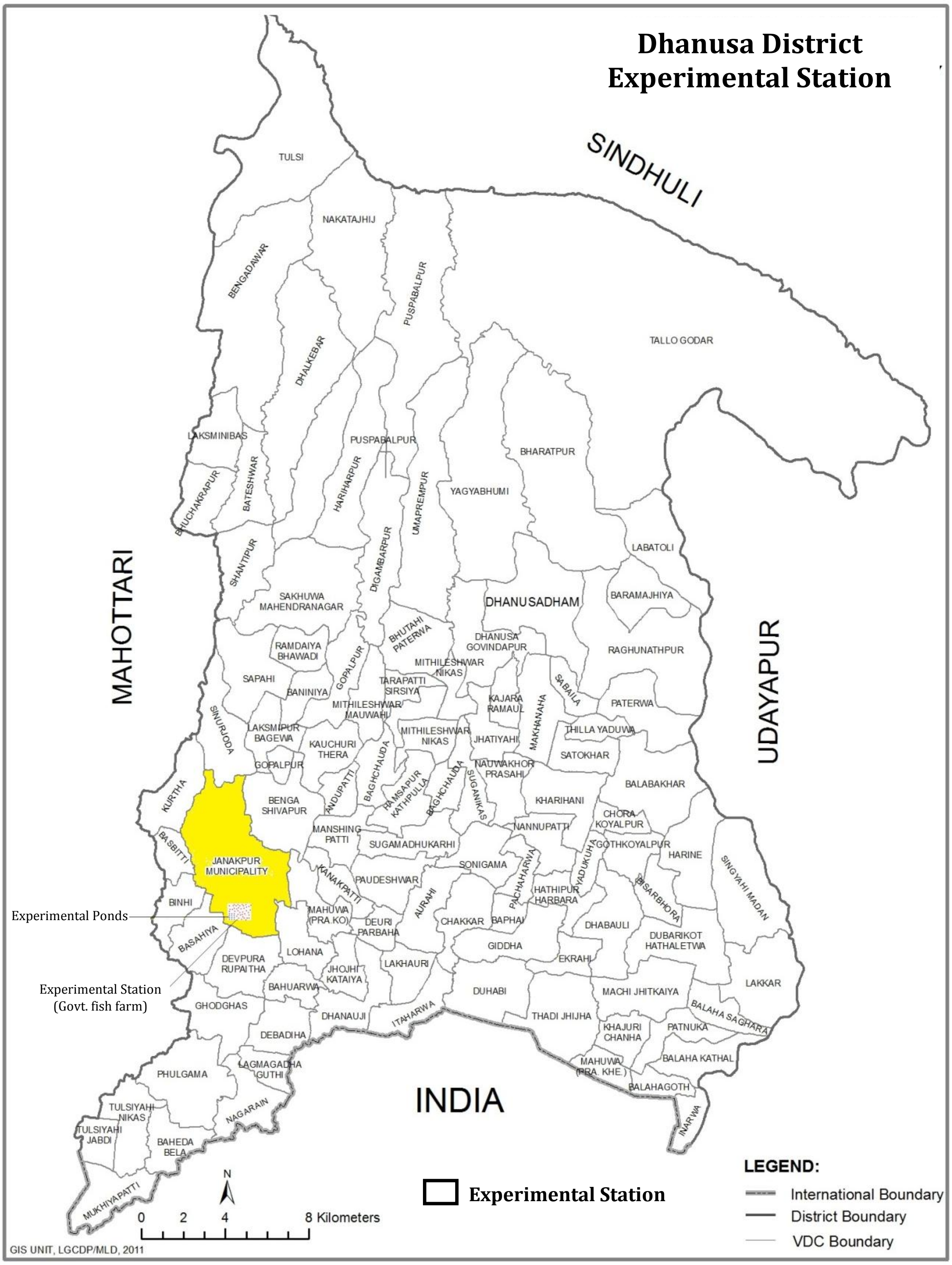


Figure 4 Experimental Stations ponds in Dhanusa District

3.2 Method for Diversity, Abundance and Identification of SIS

The SIS survey was conducted at three sites (fish market) of each eight districts (Table 3.2). The method applied was as follow:

1) SIS identification was done at the site. The measurement of weight and length of samples were recorded for SIS abundance analysis.
2) SIS species were counted according to the numbers in kg^{-1} weight of fish.
3) The unidentified SIS species (about 5–10 %) were preserved in 10 % formalin solution for identifying later on.
4) A set of semi structured questionnair was filled by discussion with fishermen groups and fish traders regarding source of SIS collection, variety, SIS sell. 5) The numerical data recorded from SIS survey was used for statistical analysis.

The diversity of small indigenous fish species (SIS) was calculated by following formula:

Shannon diversity index calculation (H) = $- p_i \sum \ln(p_i)$

Margalef index = (N-1)/LN (N) Simpson diversity index calculation = $\sum (p_i)^2$ (Magurran, 1988 ; McIntosh,1967 ; Rosenzweig, 1995).

3.3 General Method for Research Experiments 1, 2 & 3

3.3.1 Experimental fish species

The summary of experiments 1, 2 and 3 is shown in Table 3.1.

- For expt. 1: Three SIS species *Puntius ticto* (pothi), *Esomus denricus* (dedhuwa) and *Amblypharyngodon mola* (mara) were selected on the basis of high abundance catch obtained from SIS survey.

- For expt. 2: The carp species silver carp (*Hypophalmicthys molitrix*), bighead carp (*Aristichthys nobilis*), grass carp (*Ctenopharyngodon idella*), common carp (*Cyprinus carpio*), rohu (*Labeo rohita*) and naini (*Cirrhinus mrigala*) were selected on the basis of farmer's level cultivable carp species.

- For expt. 3: Silver carp (*Hypophalmicthys molitrix*), bighead carp (*Aristichthys nobilis*), rohu (*Labeo rohita*) and naini (*Cirrhinus mrigala*) were selected.

- SIS species *A. mola* (Mara) was used for experiments 2 and 3 both.

3.3.2 Preparation of Ponds

Prior to stocking all the ponds were drained, dried and limed with powdered CaCO3 at the rate of 500 kg ha^{-1}. Ponds were filled with water up to 1.0 m deep. Ponds were fertilized with semi-decomposed cattle dung at the rate of 1000 kg ha^{-1}, urea at the rate of 25 kg ha^{-1} and diammonium phosphate (DAP) at the rate of 25 kg ha^{-1} after one week of liming (Roy et al., 2002). Fish species were stocked after 7 days of the use of manure and fertilizer. The reuse fertilization in ponds was adjusted on the basis of sechi disc reading. (Roy et al., 2002).

3.3.3 Experimental fish stocking density and species ratio

- The stocking density of Pothi (*Puntius ticto*), Mara (*Amblypharyngodon mola*) and Dedhuwa (*Esomus denricus*) were 20, 0000 ha^{-1} in expt 1.

- The stocking density of carp species silver carp (*Hypophthalmicthys molitrix*), big head carp (*Aristichthys nobilis*), rohu (*Labeo rohita*), naini (*Cirrhinus mrigala*), grass carp (*Ctenopharyngodon idella*), and common carp (*Cyprinus carpio*) was 15, 000 fingerlings and fry of SIS 50, 000 ha^{-1} in experiment 2.

- The stocking density of carp species silver carp (*Hypophthalmicthys molitrix*), big head carp (*Aristichthys nobilis*), rohu (*Labeo rohita*), naini (*Cirrhinus mrigala*) in experiment 3 was 15, 000 fingerlings $ha^{-1}$and SIS in ratio 50, 000 ratio 10, 0000 and ratio 20, 0000.

The summary of stocking ratio in experiment wise form is shown in specific method of each experiment.

3.3.4 Post stocking management

Supplimentary food in the form of mustard oil cake and rice bran in 1:2 ratio were provided to standing fishes of pond according to 5 % of their body weight.

Fertilization with urea, DAP and cattle dung were used at the rate of 12.5 kg ha^{-1}, 12.5 kg ha^{-1} and 1000 kg ha^{-1} respectively to maintain natural food in the ponds, on the basis of sechi disc reading (Roy *et al.,* 2002). Fish culture period was 120 day.

3.3.5 Sampling carps and SIS

Carps and SIS were sampled at the interval of 30 days by using mesh size 12 to 25 mm seine net to assess their growth and health condition. At least 20% of all fish species were collected and weighed individually during each sampling for the growth check up in experiment 2 and 3 while growth assessment was not carried out in experiment 1 due to increased rate of mortality in mara (*Amblypharyngodon mola*). The calculation of daily food supply for future was adjusted on the basis of weight record obtained from monthly growth check up.

3.3.6 Harvesting of fishes

All experimental fishes were harvested by repeated netting and dewatering of the ponds using diesel pumps, the remained fishes were caught by hand picking to determine the yield of carp and SIS fish species. All the harvested fish species were washed, counted, weighed and measured separately to keep the record for accessing survival rate and production. Net fish yield was determined by deducting stocked experimental fishes from harvested fishes. The following parameters were used to evaluate the growth of fishes;

Total Weight gain (g) = Totalfinal weight (g) – Total initial weight (g)

$$\text{Survival rate (\%)} = \frac{\text{No. of fish harvested}}{\text{Initial no. of fishes stocked}} \times 100$$

3.3.7 Analytical method

Analytical methods were used to calculate the weight of total used foods, fertilizers, chemicals, financial investment and production of carps and SIS.

3.3.7.1 Water quality analysis

Essential activities like monitoring of water quality parameters such as water temperature, transparency, DO, pH, total alkalinity, CO_2 was performed every fortnight during the experimental period. Temperature and dissolved Oxygen (DO) were measured by a digital DO meter (YSI, model 58), transparency was measured by using a secchi disc and pH with a pH meter (Hanna microelectronics) and total alkalinity was measured by acid titration method following Stirling (1985). Temperature (^{0}C), pH, transparency (cm) and DO (mg L^{-1}) were measured directly from the experimental ponds between 0800 and 0900 hrs and other parameters were measured at Water Quality Laboratory of the Fisheries Development and Training Centre and RRMC Janakpur. The methods used in measurement of water quality parameters is shown in Table 3.3.

Table 3.3 Summary of water quality parameters and their analytical methods

Parameters	Analytical Methods
Water temperature	D O Meter YSI model 58
Secchi disc depth	Secchi disc
Dissolved Oxygen	D O Meter YSI model 58
pH	pH meter (HANNA microelectronics)
Total Alkalinity	Acid titration method (APHA 1980)
Free CO2	Titration Method (APHA 1980)

3.3.7.2 Plankton enumeration

Plankton samples were collected at monthly intervals by following Dewan *et al.*(1991) to enumerate plankton population. Ten liters of water samples were collected from four different places of each pond and passed through plankton net (mesh size 20 µm). The concentrated samples were transferred into a measuring cylinder and made it up to 50 ml with distilled water. Samples were preserved in small plastic bottles in 10% buffered formalin. Plankton numbers were estimated by using a Sedgewick-Rafter counting cell (S-R cell) under a binocular microscope (Olympus, M-4000D) following APHA, 1992. Identification of plankton to genus level was carried out by using the keys from Ward and Whipple (1959), Prescott (1962) and Bellinger (1992). The quantitative estimation was done after following the same procedure mentioned by Azim *et al.*(2001) and it was made by using the following formula:

$N = (P \times C \times 100)/L$

In which,

N= Number of plankton cells or units per liter of original water

P = Total number of plankton counted in 10 fields

C= Volume of final concentrated sample (ml)

L= Volume of original water (l)

3.3.7.3 Fish Growth Performance

Fish were counted and weighed individually at stocking and harvesting. The total weight gain (TWG) and survival rate were used to compare fish growth performance.

TWG (Kg $Pond^{-1}$) = Final Total wt. – Initial total wt.

Survival rate % = Number of fish harvested × 100 / Number of fish stocked

3.3.7.4 Economic Analysis

An economic analysis of different treatments was performed on the basis of the expenditure incurred and the total return from the selling price of freshwater carp fishes and SIS both. The economic analysis (benefit cost ratio) was carried out on the basis of record of inputs (Food, fertilizer, lime, manure, fingerlings of carps and SIS, labor cost, etc.) and outputs (fish sold, fish consumed, etc) were used during the treatments of experiments. All records of investment and return in rupees (Nepalese currency) were kept in the record for further analysis, although, the price of carps and SIS depended on their size in local market. The net benefit was calculated by using the following formula:

Net benefit = total income – total variable cost

3.3.8 Statistical analysis

The fish yield parameters, water quality parameters and plankton data were compared among treatment by one-way ANOVA. If main effects was found significantly different from one another in treatments, post hoc analysis were tested with Tukey's multiple comparision tests of means. The analysis was considered at 5% confidence level or α level. Mean were given with ± S.E.

3.4 Specific methods for experiment 1 for growth and production assessment of SIS spp: *A. mola, P. ticto* & *E. denricus*.

Three SIS species *P. ticto, A. mola and E. denricus* were reared in nine experimental ponds to determine the growth and production performance of SIS species. The experiment was conducted in completely randomized design from 18 th June to 17 th October 2012 for 120 days duration. There were three treatments T1, T2 and T3 for each type of SIS species. Treatments were allocated randomly in experiments. Each treatment had three replications. T1 treatment was allocated for *A. mola*, T2 treatment for *P. ticto* and T3 treatment for *E. denricus*. Ponds P2, P5 and P9 were used for replications of T1 treatment, P1, P4 and P8 for T2 treatment and P3, P6 and P7 for T3 treatment. SIS species were grown by monoculture method. Fish stocking in expt 1 is shown in Table 3.4.

Table 3.4 Species composition (ha^{-1}) in the treatments during stocking

Fish species	Treatments		
	T1	T2	T3
A.mola (Mara)	200000	0.0	0.0
P.ticto (Porhi)	0.0	200000	0.0
E.denricus (Dedhua)	0.0	0.0	200000

These SIS species were collected from different sources. Paddy fields and village ponds of Kowa-Rampur, Ganguly and Dhanauji Kataiya, which are located within 20 km area of experimental station, Janakpur. The special precaution was taken for the identification and transportation of *A. mola* by the help of fishermen. The repeated process of netting was done in the natural habitat of mara for about a week.

The live fries of mara were kept for the conditioning for about 6 to 12 hours in the hapa where reconfirmation for identification of *A. mola* carried out. The fries were brought up to the experimental ponds from the help of local fishermen using metallic pots on cycle. Transportation of SIS species was carried out in the early morning.

The pre-stocking and post-stocking management of experimental ponds were carried out on the basis of previously mentioned general method. The stocking density of SIS was 200000 ha^{-1} and for each pond 2000 fries. The average stocking size of mara (*A.mola*), pothi (*P. ticto*) and dedhuwa (*E. denricus*) were 1.33 ± 0.01 g, 1.46 ± 0.02 g and 1.05 ± 0.02 g. All ponds were subjected to the same regime of feed and fertilizers application in the post stocking management. The rice bran and mustard oil cake were used at the rate of 2:1 ratio for supplementary feed according to the biomass of 5% body weight. Water quality parameters of all experimental ponds were measured at every fornight according to the procedure mentioned in general method. Plankton samples were collected and analysed for plankton's enumeration from experimental ponds according to the procedure previously mentioned in general method. Fishes were harvested pond wise at the end of the experiment according to general method mentioned for experiments. The statistical analyis of water quality parameters, data of phytoplanktons, zooplanktons and the fish yield parameters were carried out according to the procedure previously mentioned in general method for experiment.

3.5.1 Benefit-cost (BCR) analysis in specific methods for experiment 1

An economical analysis of different treatments was performed on the basis of the expenditure incurred and the total estimated return from the selling price of SIS species mara (*A.mola*), pothi (*P. ticto*) and dedhuwa (*E. denricus*). All input costs were noted to keep the record. The local market prices of all inputs and outputs in Janakpur market were used for the economic analysis. Although the price of SIS species mara (*A.mola*), pothi (*P. ticto*) and dedhuwa (*E. denricus*) depends on their size but the average price in local market was 400 kg^{-1} NC (Nepalese currency). The net benefit was calculated by using the following formula,

Net benefit = total sale – total cost

$$\text{BCR} = \frac{Total\ revenue}{Total\ cost}$$

3.6 Specific method of experiment 2 to explore appropriate combinations of carps with *A. mola* (SIS)

Experiment 1 was conducted to determine the suitable combinations of carps with mara (*A. mola*) for their growth and production assesment from Feb 15 to 7th June 2013. Ponds, which were used for expt 1 were reused for expt. 2 after general process of repairing wherever required for maintinence. Experiment 2 was conducted in three treatments T2, T3, and T4 and a control (ctrl) T1 in CRD method. Three replications were allocated for each treatment of experiment 2. The ponds or replications for each treatment and control were allocated randomly as for treatment T1 P3. P6 and P8 ponds, P2, P9 and P12 for T2, P4, P5 and P11 for T3 and P1, P7 and P10 for T4 treatment. The pre-stocking and post-stocking management of experimental ponds were carried out on the basis of general method. Out of six different species of carps; silver carp (*Hypophthalmicthys molitrix*), big head carp (*Aristichthys nobilis*), rohu (*Labeo rohita*), naini (*Cirrhinus mrigala*), grass carp (*Ctenopharyngodon idella*), and common carp (*Cyprinus carpio*), only three different combinations of carp fishes were tested on the basis of knowledge of feeding habit of carps and use of natural foods produced in all regimes of ponds in the experiment as follows; treatment 1 or control (T1- silver carp, bighead carp, rohu, naini, grass carp and common carp), treatment 2 (T2- silver carp, bighead carp, rohu, naini and *A. mola*), treatment 3 (T3- silver carp, bighead carp, rohu, naini, grass carp and *A. mola*) and treatment 4 (T4 - silver carp, bighead carp, rohu, naini, grass carp common carp and *A. mola*). The stocking weight of fingerlings of silver carp was 9.2±0.48 g, 9.2±0.33 g , 9.2±0.48 g, 9.2 ± 0.24 g, bighead carp was 8.7 ± 0.21 g, 8.7 ± 0.33 g, 8.7 ± 0.16 g, 8.7 ± 0.16 g, rohu was 10 ± 0.16 g, 10 ± 0.29 g, 10 ± 0.16 g, 10 ± 0.16 g, naini was 9.0 ± 0.28 g, 9.0 ± 0.16 g, 9.0 ± 0.16 g, 9.0 ± 0.28 g, in T1, T2, T3, T4 grass carp was 8.5 ± 0.24 g, 8.5 ± 0.24 g, 8.5 ± 0.24 g, in T1, T3, T4 and common carp was 9.5 ± 0.16 g and 9.5 ± 0.16 g, in T1 and T4. The stocking weight of *A.mola* (SIS) species was 1.2 ± 0.09 g, 1.2 ± 0.12 g, 1.2 ± 0.09 g, and it was stocked with carp's combinations in T2, T3 and T4. The stocking ratio of carps was 15000 fingerlings ha^{-1} in the combination of following percentage (silver, bighead, rohu, naini, grass carp and common carp); 35%, 10%, 15%, 10%, 5% and 25% in ctrl or T1. The stocking ratio of carp species were 42.67: 17.34: 22.67: 17.33 after optimizing silver carp, bighead carp, rohu and naini in the T2 treatment. The *A. mola* was stocked at the rate of 50000 fish ha^{-1} in all treatments except T1. The fingerlings of carps and fries of *A.mola* stocked in experiment 2 are shown in table 3.5.

Table 3.5 Stocking density of carps and SIS (ha^{-1}) in expt 2

Fish species	Treatments			
	T1 (ctrl)	**T2**	**T3**	**T4**
H. molitrix	5200	6400	6000	5200
A. nobilis	1500	2600	2200	1500
L. rohita	2300	3400	3000	2300
C. mrigala	1500	2600	2300	1500
C. idella	700		1500	700
C. carpio	3800			3800
A. mola		50000	50000	50000

Water quality parameters, collection of plankton's samples, use of supplementary food, harvesting of carps and SIS, and economic analysis or benefit cost ratio were carried out according to previously mentioned general methods of experiment.

3.7 Specific method for experiment 1 to determine the best stocking ratio between carps and SIS

Experiment 1 was also conducted to determine the appropriate stocking ratio of carps and *A. mola* (SIS), in ponds which were already used for expt. 2. The ponds were repaired according to their need. Carps combination like silver carp (*Hypophthalmicthys molitrix*), big head carp (*Aristichthys nobilis*), rohu (*Labeo rohita*), naini (*Cirrhinus mrigala*), and *A. mola* were used in experiment 3. Experiment was conducted from 21 March to 25 August 2014 for 120 days time period. A control (ctrl) or T1 and three treatments T2, T3, T4 in CRD was used in experiment 3. Stocking density of carps was 15000 ha^{-1} in combinations of following percentage, silver carp 42.67 %, bighead carp 17.33 %, rohu 22.67 % and naini 17.33 %. All the treatments and control were stocked with fingerlings of silver carp (*Hypophthalmicthys molitrix*), big head carp (*Aristichthys nobilis*), rohu (*Labeo rohita*), naini (*Cirrhinus mrigala*) but *A. mola* was stocked in only treatments T2, T3, T4. *A. mola* was stocked at the rate of 50000 ha^{-1} in T2 treatment, 100000 ha^{-1} in T3 treatment and 200000 ha^{-1} T4 treatments. Treatments were settled on the basis of stocking density of *A. mola*. The ponds for each treatment and control were allocated randomly. Pond P6, P11 and P12 were allocated for T1 treatment, P1, P4 and P9 for T2 treatment, P3, P8 and P10 for T3 treatment and P4, P7 and P9 for T4 treatments. The stocking weight of fingerlings of silver carp was 6.5 ± 0.12 g, 6.5 ± 0.14 g , 6.5 ± 0.09 g, 6.5 ± 0.08 g, bighead carp was 7.0 ± 0.17 g, 7.0 ± 0.94 g, 7.0 ± 0.04 g, 7.0 ± 0.14 g, rohu was 8.0 ± 0.04 g, 8.0 ± 0.08 g, 8.0 ± 0.18 g, 8.0 ± 0.12 g, naini was 8.0 ± 0.09 g, 8.0 ± 0.18 g, 8.0 ± 0.04 g, 8.0 ± 0.16 g, in T1,T2, T3, T4. The stocking weight of *A.mola* (SIS) species was 1.5 ± 0.12 g, 1.5 ± 0.09 g, 1.5 ± 0.12 g. The stocking plan of experiment 3 is shown in Table no. 3.6.

The pre stocking and post stocking management of experimental ponds, use of supplimentary food, water quality parameters, collection of planktons and harvesting of fishes were performed according to previously mentioned general method. The benefit and cost of different treatments in experiment 3 were calculated on the basis of the expenditure incurred and the total return from the selling price of carps (silver carp, bighead carp, rohu and naini), and *A.mola*. The cost of fertilizer, fish seed price (including transport) and price of feed was noted down to keep the record for further analysis. At the end of the experiment, carp fishes and *A.mola* were sold in the local market Janakpur. The analysis was based on market prices in Janakpur for fish and all other items expressed in Nepalese currency (1 USD = 96.88 rupiya) However, the net benefit and benefit-cost ratio (BCR) were calculated using the following formula:

Net benefit = Total income – Total variable cost

$$\text{BCR} = \frac{Total\ revenue}{Total\ \cos t}$$

Table 3.6 Stocking density of Carps & SIS (ha^{-1}) in treatments of expt. 3

Fish species	Treatments			
	T1(ctrl)	**T2**	**T3**	**T4**
H. molitrix	6400	6400	6400	6400
A. nobilis	2600	2600	2600	2600
L. rohita	3400	3400	3400	3400
C. mrigala	2600	2600	2600	2600
A. mola	0	50000	100000	200000

CHAPTER 4

4. RESULTS AND DISCUSSION

4.1 SIS SURVEY

4.1.1 SIS identification, abundance and diversity

During the entire study period, a total of 55 species of SIS belonged to 16 families and 38 genera were recorded from the sampling stations of study area. Family Cyprinidae formed the largest dominant family, contributing 24 species from all eight sampling stations, family Cobitidae formed the sub dominant family contributing 5 species and the rest of families followed order of abundance. The percentage wise SIS species belonging from various families in taxonomical hierarchy is shown in Figure 5. Family Cyprinidae consisted 43 %, family Cobitidae 9 %, family Schelibidae, Nandiae and Ophiocephalidae 7 %. All the identified SIS species their abundance and diversity is summarized in Table 4.1.1 and 4.1.2. Among total SIS species identifed from the whole study period, all 55 SIS species were recorded from the sampling sites of only S1 sampling station (Bhardah, Hanumannagar and Rajbiraj), next 28 SIS species documented from S7 sampling station. The richness of SIS species varied greatly at spatial scale. Station SI showed highest species richness (55 species) in comparision to other sampling stations respectively. The SIS species richness was lowest in sampling station S4. SIS species reported from all sampling stations in present study is shown in Table 4.1.1. The abundance of SIS species from all sampling stations are shown in Table number 4.1.2.

4.1.2 Small indigenous fish species (SIS) abundance in sampling stations

Abundance of SIS fishes was assessed on the basis of SIS landed into the local market for sale. The relative landing of SIS in all sampling stations were not uniform throughout the study period. The highest landing of SIS species landed in sampling station one (S1) throughout the year. The SIS landed for sale was lying between 15 to more than 100 kg week $^{-1}$ of a year in S1 sampling station. The lowest landing of SIS species was recorded in S5 sampling station. It was about 1.5 to 5.0 kg week^{-1} of a year in S5 sampling station. The dominant SIS species of all sampling stations was *A.*

mola, *E. denricus* and *Puntius ticto*. It was found throughout of the study period. SIS species mara (*A. mola)*, and dedhuwa (*E. denricus)* were collected in the monsoon season from all sampling stations.The SIS landed in all sampling stations during study period are shown in Table 4.1.2. The riverine production has reduced drastically due to the cultivable carp species, so the fish landing centers have also moved from the riverside to the fish cultivated areas exceptionally in S1, S3 and S5 sampling stations. Some of the cheap small fishes of past (10 to 15 years ago) *M. tengra* (tengra), *A.morar* (maroar), *O. bacaila* (paunsi), *E.denricus* (dedhua), *A. mola* (mara) have now very much high rate for sell because of their low landing in market, delicious taste, high nutritional value and acceptability to high economic class of peoples. So, price of the smaller fishes tremendously increased in comparison to the cultivated fish now a day. The price of *Mastacembelus armatus* was 800 to1200 Rs kg^{-1}, bam was 800-1200 Rs kg^{-1}, *C.garua* (jalkapoor) was 1000-1500 Rs kg^{-1}, *A. mola* was 400 to 650 Rs kg^{-1} in large fish market situated near of high way. The variation in price of SIS was mainly due to the quantity of SIS landed into fish market, their size and preserved condition of SIS brought for sell and fish market's location close or away from high way.

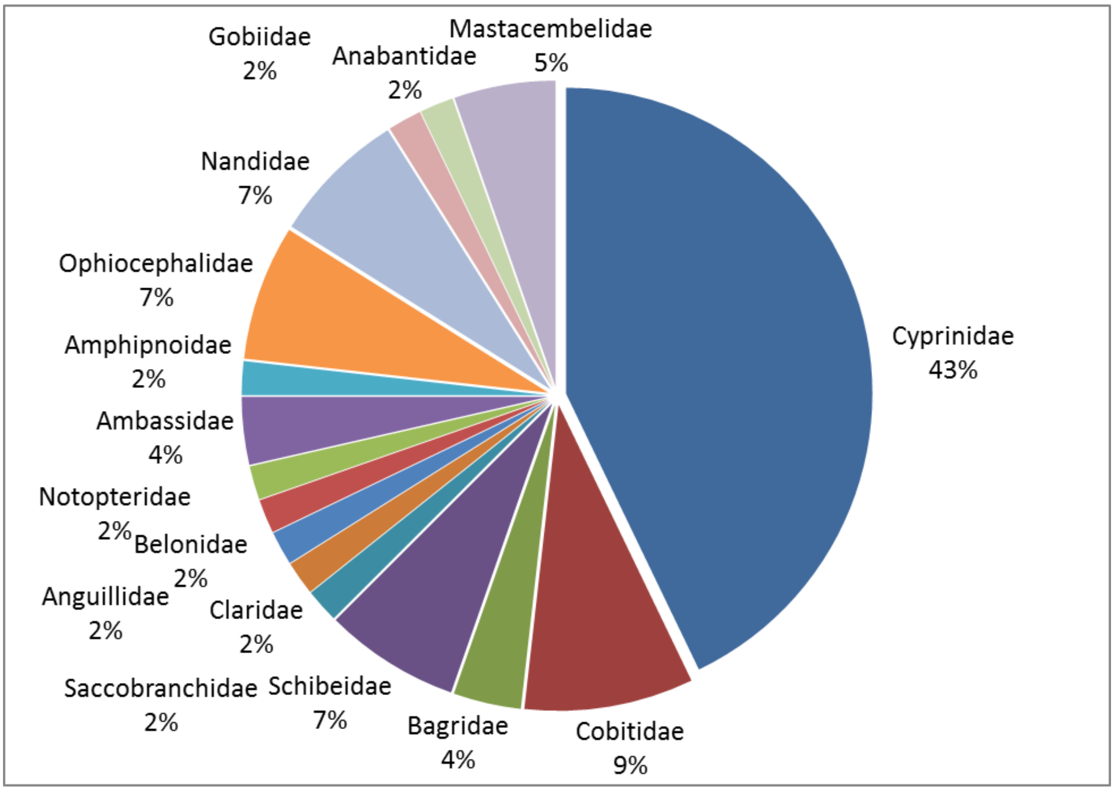


Figure 5 Distribution of SIS from study in taxonomic family

Table 4.1.1 Check list of SIS from sampling station

S/no	Family	Species	S1	S2	S3	S4	S5	S6	S7	S8
1	**Cyprinidae**	*Amblypharyngodon mola* (Ham.)	p	ppp	ppp	ppp	ppp	ppp	Pp	pp
2		*Esomus danricus* (Ham.)	pp	ppp	ppp	ppp	ppp	ppp	Ppp	ppp
3		*Puntius chola* (Ham.)	pp	ppp	ppp	ppp	ppp	ppp	Ppp	ppp
4		*Puntius sarana* (Ham.)	p	ppp	ppp	pp	pp	ppp	Pp	pp
5		*Puntius conchonius* (Ham.)	pp	ppp	ppp	pp	ppp	ppp	Pp	pp
6		*Puntius sophore* (Ham.)	pp	ppp	ppp	ppp	ppp	ppp	Ppp	ppp
7		*Puntius ticto* (Ham.)	ppp	ppp	ppp	ppp	ppp	ppp	Ppp	ppp
8		*Aspidoparia morar* (Ham.)	ppp	*	*	*	*	*	*	*
9		*Aspidoparia jaya* (Ham.)	pp	*	*	*	*	*	*	*
10		*Barilius barila* (Ham.)	pp	ppp	p	*	p	p	*	*
11		*Barilius bendelisis* (Ham.)	pp	ppp	p	*	ppp	p	*	P
12		*Barilius barana* (Ham.)	pp	p	p	*	pp	pp	*	P
13		*Barilius vagra* (Ham.)	pp	p	p	*	pp	pp	*	P
14		*Chela lubuca* (Ham.)	pp	p	p	p	p	p	p	P
15		*Danio devario* (Ham.)	pp	*	p	p	p	p	*	P
16		*Danio rerio* (Ham.)	pp	*		*	*	*	*	*
17		*Crossocheilus latius* (Ham.)	p	p	p	*	p	p	*	*
18		*Cirrhinus reba* (Ham.)	pp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
19		*Labeo dero* (Ham.)	pp	p	p	*	p	*	*	*
20		*Oxygaster bacaila* (Ham.)	pp	p	pp	p	pp	p	*	P
21		*Osteobrama cotio* (Ham.)	pp	*	*	*	*	*	*	P
22		*Rasbora daniconius* (Ham.)	pp	*	*	*	*	*	*	*
23		*Rasbora elanga* (Ham.)	p	*	*	*	*	*	*	*
24		*Semiplotus semiplotus* (McClell.)	p	*	*	*	*	*	*	*
25	**Cobitidae**	*Lepidocephalichthys guntea* (Ham.)	ppp	ppp	ppp	ppp	PPP	ppp	ppp	ppp
26		*Botia lochata* (Chaudhury)	pp	ppp	ppp	p	pp	*	*	P
27		*Semileptes gongota* (Ham.)	pp	*	*	*	*	*	*	*
28		*Noemacheilus bevani* (Gunther)	pp	p	pp	*	p	*	*	*
29		*Noemacheilus botia* (Ham.)	pp	ppp	ppp	*	p	*	*	*
30	**Bagridae**	*Mystus tengra* (Ham.)	pp	ppp	pp	ppp	ppp	ppp	ppp	ppp
31		*Mystus vittatus* (Bl.)	pp	p	p	p	p	p	P	P
32	**Schilbeidae**	*Alia colia* (Ham.)	pp	*	*	*	*	*	*	*
33		*Clupisoma garua* (Ham.)	pp	*	*	*	*	*	*	*
34		*Etropiichthys vacha* (Ham.)	pp	*	*	*	*	*	*	*
35		*Pseudeutropius murius* (Bl.)	pp	*	*	*	*	*	*	*
36	**Saccobranchidae**	*Heteropneustes fossilis* (B.)	ppp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
37	**Claridae**	*Clarius batrachus* (Linn.)	pp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
38	**Anguillidae**	*Anguilla bengalensis* (Gray&Hard)	p	p	*	*	*	p	*	P
39	**Belonidae**	*Xenentodon cancilla* (Ham.)	p	ppp	pp	*	*	*	*	P
40	**Notopteridae**	*Notopterus notopterus* (Pallas.)	p	P	ppp	pp	pp	pp	pp	ppp
41	**Ambassidae**	*Chanda nama* (Ham.)	pp	ppp	ppp	ppp	ppp	ppp	pp	ppp
42		*Chanda ranga* (Ham.)	ppp	ppp	ppp	ppp	pp	pp	Pp	ppp

43	**Amphipnoidae**	*Amphipnous chuchia* (Ham.)	pp	ppp	ppp	ppp	ppp	ppp	pp	pp
44	**Ophiocephalidae**	*Channa gachua* (Ham.)	ppp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
45		*Channa marulius* (Ham.)	ppp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
46		*Channa punctatus* (Bl.)	pp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
47		*Channa striatus* (Bl.)	p	ppp	pp	ppp	pp	pp	P	P
48	**Nandidae**	*Nandus nandus* (Ham.)	p	*	*	*	*	*	*	*
49	**Psilorhynchini**	*Psilorhynchus sucatio* (Ham.)	p	*	*	*	*	*	*	*
50	**Anabantidae**	*Colisa fasciatus* (Bl.Schn.)	ppp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
51	**Gobiidae**	*Glossogobius guiris* (Ham.)	pp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
52	**Anabantidae**	*Annabas testudineus* (Bl.)	ppp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
53	**Mastacembelidae**	*Mastacembelus armatus* (Bl.)	pp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
54		*Mastacembelus puncalus* (Ham.)	pp	ppp	ppp	ppp	ppp	ppp	pp	ppp
55		*Macrognathus aculeatus* (Bl.)	pp	ppp	ppp	ppp	ppp	ppp	pp	pp

Symbols of table signifies; p = few no., pp =high no., ppp =very high no., and * absent in SIS survey.

Table 4.1.2 SIS abundance (number) in different samplimg stations

S/no	Family	Species	S1	S2	S3	S4	S5	S6	S7	S8
1	**Cyprinidae**	*Amblypharyngodon mola* (Ham.)	750	525	450	315	375	450	600	525
2		*Esomus danricus* (Ham.)	900	600	450	300	300	300	750	300
3		*Puntius chola* (Ham.)	300	150	180	150	150	150	225	300
4		*Puntius sarana* (Ham.)	100	50	60	25	50	50	50	50
5		*Puntius conchonius* (Ham.)	300	150	150	75	75	75	150	225
6		*Puntius sophore* (Ham.)	600	375	180	375	75	150	375	300
7		*Puntius ticto* (Ham.)	800	500	400	400	400	400	500	400
8		*Aspidoparia morar* (Ham.)	2250	0	0	0	0	0	0	0
9		*Aspidoparia jaya* (Ham.)	750	0	0	0	0	0	0	0
10		*Barilius barila* (Ham.)	360	60	60	0	60	60	0	0
11		*Barilius bendelisis* (Ham.)	400	80	40	0	80	80	0	80
12		*Barilius barana* (Ham.)	350	50	50	0	50	100	0	50
13		*Barilius vagra* (Ham.)	420	50	100	0	100	50	0	100
14		*Chela lubuca* (Ham.)	480	240	180	120	120	180	240	180
15		*Danio devari* (Ham.)	375	0	150	75	150	75	0	75
16		*Danio rerio* (Ham.)	300	0	0	0	0	0	0	0
17		*Crossocheilus latius* (Ham.)	120	60	30	0	60	30	0	0
18		*Cirrhinus reba* (Ham.)	80	160	80	80	80	120	120	80
19		*Labeo dero* (Ham.)	90	15	30	0	15	0	0	0
20		*Oxygaster bacaila* (Ham.)	1170	65	65	65	130	130	260	130
21		*Osteobrama cotio* (Ham.)	250	0	0	0	0	0	0	0
22		*Rasbora daniconius* (Ham.)	210	0	0	0	0	0	0	0
23		*Rasbora elanga* (Ham.)	210	0	0	0	0	0	0	0
24		*Semiplotus semiplotus* (McClell.)	240	0	0	0	0	0	0	0
25	**Cobitidae**	*Lepidocephalichthys guntea* (Ham.)	640	160	240	160	240	240	320	320
26		*Botia lochata* (Chaudhury)	320	160	320	80	80	0	0	80
27		*Semileptes gongota* (Ham.)	324	0	0	0	0	0	0	0
28		*Noemacheilus bevani* (Gunther)	360	200	200	0	100	0	0	0

29		*Noemacheilus botia* (Ham.)	300	100	100	0	100	0	0	0
30	**Bagridae**	*Mystus tengra* (Ham.)	200	40	40	40	20	40	40	60
31		*Mystus vittatus* (Bl.)	315	45	45	45	45	23	68	67
32	**Schilbeidae**	*Alia colia* (Ham.)	100	0	0	0	0	0	0	0
33		*Clupisoma garua* (Ham.)	60	0	0	0	0	0	0	0
34		*Etropiichthys vacha* (Ham.)	105	0	0	0	0	0	0	0
35		*Pseudeutropius murius* (Bl.)	80	0	0	0	0	0	0	0
36	**Saccobranchidae**	*Heteropneustes fossilis* (B.)	108	18	27	18	9	18	27	18
37	**Claridae**	*Clarius batrachus* (Linn.)	54	18	18	9	10	20	19	18
38	**Anguillidae**	*Anguilla bengalensis* (Gray&Hard)	50	5	0	0	0	6	0	5
39	**Belonidae**	*Xenentodon cancilla* (Ham.)	180	45	23	0	0	0	0	45
40	**Notopteridae**	*Notopterus notopterus* (Pallas.)	18	3	3	4	3	4	6	6
41	**Ambassidae**	*Chanda nama* (Ham.)	400	100	150	100	50	100	200	200
42		*Chanda ranga* (Ham.)	220	110	165	55	55	110	55	55
43	**Amphipnoidae**	*Amphipnous chuchia* (Ham.)	18	6	4	3	3	2	6	6
44	**Ophiocephalidae**	*Channa gachua* (Ham.)	100	63	50	25	25	25	30	27
45		*Channa marulius* (Ham.)	40	12	8	4	4	4	12	16
46		*Channa punctatus* (Bl.)	40	15	10	5	7	12	11	15
47		*Channa striatus* (Bl.)	10	3	4	3	3	4	5	6
48	**Nandidae**	*Nandus nandus* (Ham.)	60	0	30	0	40	25	18	0
49	**Psilorhynchini**	*Psilorhynchus sucatio* (Ham.)	60	20	0	25	0	0	15	0
50	**Anabantidae**	*Colisa fasciatus* (Bl.Schn.)	480	240	180	120	120	80	240	120
51	**Gobiidae**	*Glossogobius guiris* (Ham.)	120	30	15	15	15	30	30	16
52	**Anabantidae**	*Annabas testudineus* (Bl.)	105	35	53	35	35	35	70	35
53	**Mastacembelidae**	*Mastacembelus armatus* (Bl.)	120	180	80	28	20	40	40	20
54		*Mastacembelus puncalus* (Bl.)	80	40	40	20	20	20	40	40
55		*Macrognathus aculeatus* (Bl.)	80	40	20	20	20	40	24	40

4.1.3 Biotic indices of SIS diversity

The Shannon diversity index values ranged from 2.85 to 3.53. The lowest value was for sampling site S4 and the highest value was for sampling site S1. The values of Simpson diversity index were from 0.04 to 0.08. The lowest value was also for sampling stations S7 and S4 while the highest value was for sampling station S1. The values of Margalef diversity index were from 8.74 to 13.48. The lowest Margalef diversity index value was for sampling station S7 and the highest value was for sampling station S1. The biotic indices values of sampling stations are shown in Table 4.1.3.

Table no 4.1.3 Numeric data of the SIS in sampling stations of study area

Variables	S1	S2	S3	S4	S5	S6	S7	S8
Taxa_S	55	41	41	32	40	37	31	36
Individuals	16702	4818	4480	2794	3294	3278	4546	4010
Shannon_H	3.53	3.14	3.22	2.86	3.17	3.06	2.77	3.04
Simpson_1-D	0.04	0.06	0.05	0.08	0.06	0.06	0.08	0.06
Margalef	13.48	10.77	10.77	8.94	10.57	9.97	8.74	9.77

4.2 GROWTH AND PRODUCTION ASSESMENT OF SIS *P. ticto, A. mola* AND *E. denricus* IN EXPT 1

4.2.1 Growth and production performance of SIS

Growth and production performance of three very common SIS species *P. ticto, A.mola* and *E.denricus* obtained from SIS survey during 2012-2013 was shown in Table 4.1.4 and 4.1.5. Mean individual weight of SIS species *A. mola* at harvest was 3.0 ± 0.0, in treatment T1 though the initial stocking weight was 1.3 ± 0.01 g. As *A. mola* breeds under pond condition, so the survival percentage was not carried out for the experiment's result purpose. The net yield of *A.mola* was 7.1 ± 0.29 kg in the ponds of the treatment T1. The net yeild of *A.mola* was 2162.6 ± 89.15 kg ha $^{-1}$ yr $^{-1}$. The mean individual harvesting weight of *P. ticto* was 2.7 ± 0.06 g in treatment T2. It was 1679 ± 60.43 kg ha $^{-1}$ yr $^{-1}$ in treatment T2. The survival percentage of *P. ticto* breeds under pond condition, so the survival percentage was not carried out of this species.

Table 4.1.4 Growth & production of SIS *A. mola*, *P. ticto* & *E. denricus* expt. 1

Parameters	Treatments		
	T1	T2	T3
Mara (*A. mola*)			
Initial mean stocking wt.(g $fish^{-1}$)	1.3 ± 0.0		
Initial total wt. (kg $pond^{-1}$)	3.0 ± 0.0		
Final harvesting wt.(g $fish^{-1}$)	3.2 ± 0.1		
Final total wt.(kg $pond^{-1}$)	7.1 ± 0.0		
Daily weight gain ($g^{-1}fish^{-1}day^{-1}$)	0.03 ± 0.0		
Net mean fish yield (kg $pond^{-1}$)	4.1 ± 0.08		
Net fish yeild (kg $ha^{-1}yr^{-1}$)	2162.6 ± 0.0^{a}		
Pothi (*P. ticto*)			
Initial mean stocking wt.(g $fish^{-1}$)		1.4 ± 0.0	
Initial total wt. (kg $pond^{-1}$)		2.9 ± 0.0	
Final harvesting wt.(g $fish^{-1}$)		2.7 ± 0.0	
Final total wt.(kg $pond^{-1}$)		5.5 ± 0.1	
Daily weight gain ($g^{-1}fish^{-1}day^{-1}$)		0.02 ± 0.0	
Net mean fish yield (kg $pond^{-1}$)		2.2 ± 0.04	
Net fish yeild (kg $ha^{-1}yr^{-1}$)		1679 ± 0.0^{b}	
Dedhua (*E. denricus*)			
Initial mean stocking wt.(g $fish^{-1}$)			1.0 ± 0.0
Initial total wt. (kg $pond^{-1}$)			2.1 ± 0.0
Final harvesting wt.(g $fish^{-1}$)			2.3 ± 0.1
Final total wt.(kg $pond^{-1}$)			5.1 ± 0.4
Daily weight gain ($g^{-1}fish^{-1}day^{-1}$)			0.02 ± 0.0
Net mean fish yield (kg $pond^{-1}$)			3.1 ± 0.1
Net fish yeild (kg $ha^{-1}yr^{-1}$)			1563.4 ± 0.1^{b}

Different superscript letters in the same row are significantly different ($P<0.05$) according to one way ANOVA and Tukey's test. (Mean±S.E)

Table 4.1.5 Net yeild (production) of SIS species in expt 1

(Figures in bracket shows the range)			
SIS species	Treatments	Final total wt. kg $pond^{-1}$	$Prod^{n}$ kg $ha^{-1}yr^{-1}$
A. mola	T1	7.1 ± 0.29^{a}	2162.6 ± 89.15^{a}
		(6.4-7.5)	(1949.7-2305.5)
P. ticto	T2	5.5 ± 0.19^{b}	1679 ± 60.43^{b}
		(5.2-6.0)	(1581.6-1825.0)
E. denricus	T3	5.1 ± 0.47^{b}	1563.4 ± 143.49^{b}
		(4.3-6.2)	(1327.0-1908.9)

Different superscript letters in the same row are significantly different (P<0.05) according to one way ANOVA and Tukey's test. (Mean±S.E)

The individual harvesting weight of *E. denricus* (dedhua) was 2.3 ± 0.12 g. The survival percentage of *E. denricus* was not carried out as the fish species breed into pond condition. The gross production of dedhuwa was the lowest among all three species of SIS. The mean value for net yield of *E. denricus* was 5.1 ± 0.47 kg. Net yield of *E. denricus* in treatment T3 was 1563.4 ± 143.4 kg ha^{-1} yr^{-1}. *A.mola* showed the best production performance 2162.6 ± 89.15 kg ha^{-1} yr^{-1} among all three SIS species.

4.2.2 Benefit cost analysis of expt 1

The economic feasibility of three treatments was analyzed on the basis of the locally purchased item's cost and total return from the sale of SIS species *A.mola*, *P. ticto* and *E. denricus* in the local market. The financial characteristics of all treatments of expt. 1 are presented in Tables 4.1.6, 4.1.7 and 4.1.8. The major and also variable input costs were mainly due to supplemental feeds and fish seeds of SIS. The net benefit was highest in treatment T1, followed by treatments T2 and T3. Net benefit rupees $pond^{-1}$ was 952.0 ± 6.89 but ha^{-1} yr^{-1} was 289587.9 ± 6.89 in treatment T1. It was rupees $pond^{-1}$ 373.4 ± 11.33 but ha^{-1} yr^{-1} was 113588 ± 11.33 in treatment T2. Net benefit was rupees $pond^{-1}$ 609.7 ± 19.79 but ha^{-1} yr^{-1} was 185471.7 ± 19.79 in treatment T3. However, when net benefit was compared with investment, the ratio was higher in treatment T1 (1:2.88) followed by treatments T3 (1: 2.72) and T2 (1:2.66).

Table 4.1.6 Variable costs of different treatments Rs (pond^{-1}) in expt 1

Variables	T1			T2			T3		
	P2	P5	P9	P1	P4	P8	P3	P7	P6
Feeding tray(12pcs)	100	100	100	100	100	100	100	100	100
Mara(kg)	1000	1000	1000	0	0	0	0	0	0
Pothi(kg)	0	0	0	600	600	600	0	0	0
Dedhuwa(kg)	0	0	0	0	0	0	600	600	600
Urea(kg)	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5
DAP(kg)	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5
Cow dung(kg)	60	60	60	60	60	60	60	60	60
Lime(kg)	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5
Oil cake(kg)	24	27.9	30	22.6	27.9	28.9	16.9	22	18.6
Rice bran(kg)	38	41.4	50	36.2	41.4	48.4	23.6	34.5	27.6
Total	1346.5	1353.8	1364.5	943.3	953.8	961.8	925	941	930.7

Table 4.1.7 Gross return (rupees pond^{-1}) treatments of expt 1

T1		T2		T3	
Ponds	Rupees(NC)	ponds	Rupees(NC)	ponds	Rupees(NC)
P2	2292.875	P1	1324.8	P3	1500
P5	2322.125	P4	1303.2	P7	1542
P9	2307.5	P8	1351.2	P6	1584
Mean ± SE	2307.5±6.89	Mean ± SE	1326.4±11.33	Mean ± SE	1542±19.79

Table 4.1.8 Gross margin analysis of treatments pond $^{-1}$& ha^{-1}yr $^{-1}$ in expt 1

Parameters	T1	T2	T3
Return Rs	2307.5±6.8^{a}	1326.4±11.3^{c}	1542±19.7^{b}
Variable cost Rs	1354.9±4.2	952.9±4.3	932.2±3.8
Gross margin Rs pond $^{-1}$	952.0±6.8	373.4±11.3	609.7±19.7
Gross margin Rs ha $^{-1}$ yr $^{-1}$	289587.9±6.8^{a}	113588±11.3^{c}	185471.7±19.7^{b}

Different superscript letters in the same row are significantly different (P<0.05) according to one Way ANOVA and Tukey's test. (Mean±S.E)

4.2.3 Water quality parameters of expt 1

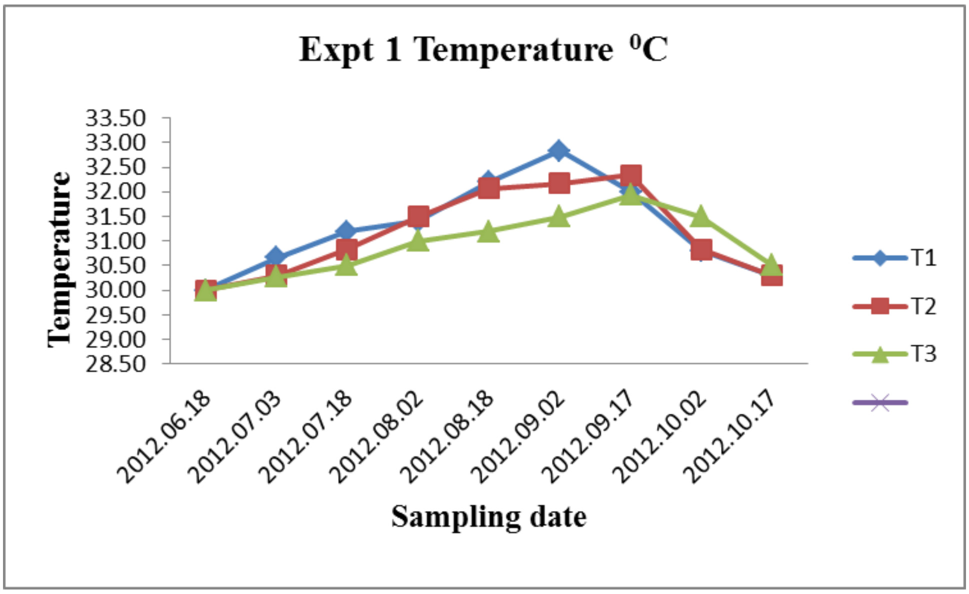
The fortnightly measured and analyzed results of some important water quality parameters; temperature, transparency, dissolved oxygen, pH, total alkalinity and CO_2 during the whole experimental period is shown in Table 4.1.9. Water temperature was lying between 30.0 ^{0}C to 32.5 ^{0}C during the study period. The mean water temperature was 31.1 ± 0.51 ^{0}C in T1 treatment, 31.2 ± 0.31 ^{0}C in T2 treatment and 30.9 ± 0.38 ^{0}C in T3 treatment. Water transparency recorded between 20.0 cm to 34.0 cm with significantly lower value in treatment T3 than in treatments T1 and T2. The mean value of transparency was recorded in all treatments; T1, 24.7 ± 0.25, T2, 25.9 ± 0.30 and T3, 24.7 ± 0.06 cm. Dissolved oxygen was recorded between 4.2 mg L^{-1} to 6.4 mg L^{-1} in whole experimental period and it did not vary among the treatments. The mean value of dissolved oxygen was recorded in all treatments as; T1, 5.5 ± 0.26, T2, 5.2 ± 0.32 and T3, 5.5 ± 0.29. The pH fluctuated between 7.4 and 8.2 without any significant difference among the treatments. The mean value of pH was recorded in all treatments as; T1, 7.5 ± 0.01, T2, 7.6 ± 0.13 and T3, 7.5 ± 0.12. Total alkalinity also showed similar patterns in between range of 82.8 to 130.5 mg L^{-1}. The mean total alkalinity was recorded in all treatments; T1, 93.3 ± 1.73, T2, 97.7 ± 0.41 and T3, 93.1 ± 0.06 mg L^{-1}.

Table 4. 1.9 Summary of water quality parameters (mean) during total experimental period in expt 1

Parameters	Treatments		
	T1	**T2**	**T3**
Temperature (^{0}C)	31.1±0.5	31.2 ± 0.3	30.9 ± 0.3
Transparency (cm)	24.7 ±0.2^b	25.9 ± 0.3^a	24.7 ± 0.0
DO (mg l^{-1})	5.5 ± 0.2	5.2± 0.32	5.5 ± 0.2
pH	7.5 ± 0.0	7.6 ± 0.1	7.5 ±0.1
Total Alkalinity (mg L^{-1})	93.30 ± 1.7^c	97.7 ± 0.4^a	93.1 ± 0.0
CO_2	12.2 ± 0.5	12.6 ± 0.5	12.3 ± 0.5

Different superscript letters in the same row are significantly different ($P<0.05$) according to one Way ANOVA and Tukey's test. (Mean±S.E)

The CO_2 of experimental ponds remained between 10.5 mg L^{-1} to 14.2 mg L^{-1} in whole experimental period and it did not vary among the treatments. The mean value of CO_2 was recorded in all treatments as; T1, 12.2 ± 0.52, T2, 12.6 ± 0.58 and T3, 12.3 ± 0.50 mg L^{-1}. All water quality parameters of experiment 1taken at an interval of fortnight are illustrated in Figure 6, 7 and Figure 8.



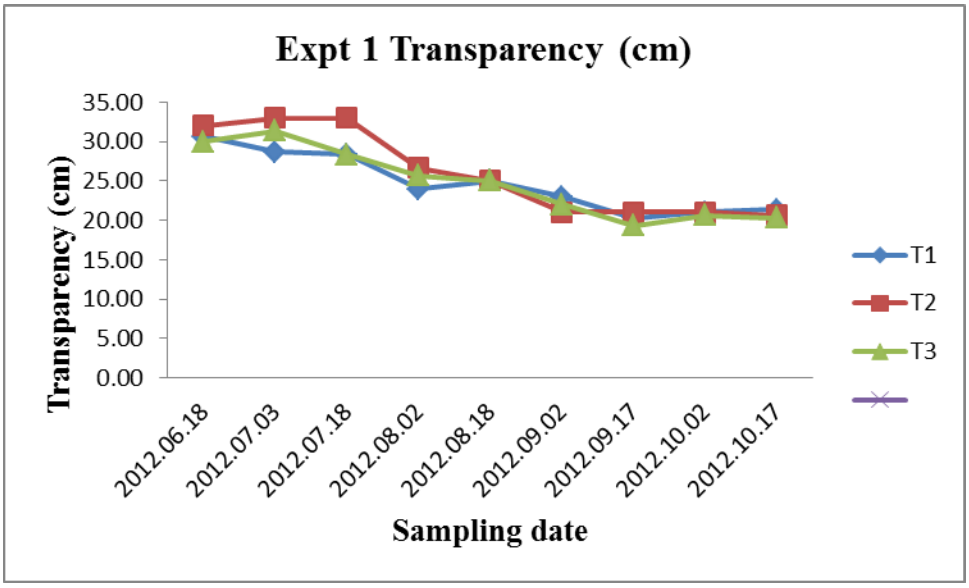
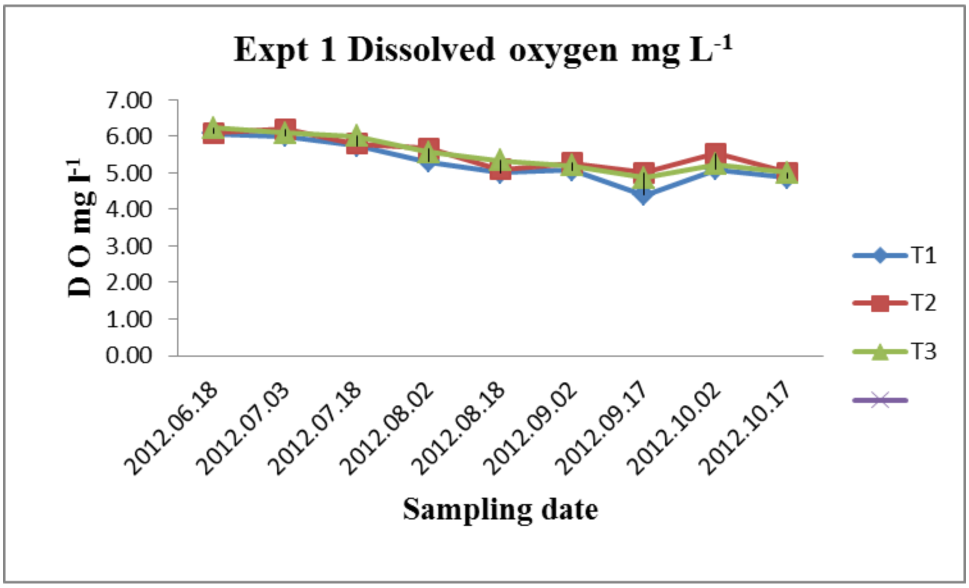
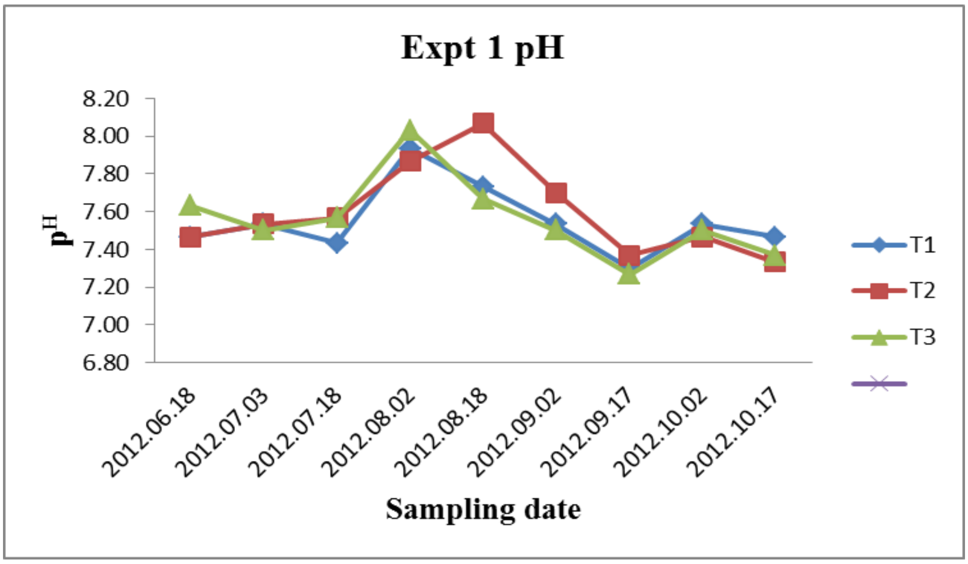


Figure 6 Fortnight variation in water temp & transparency of expt 1





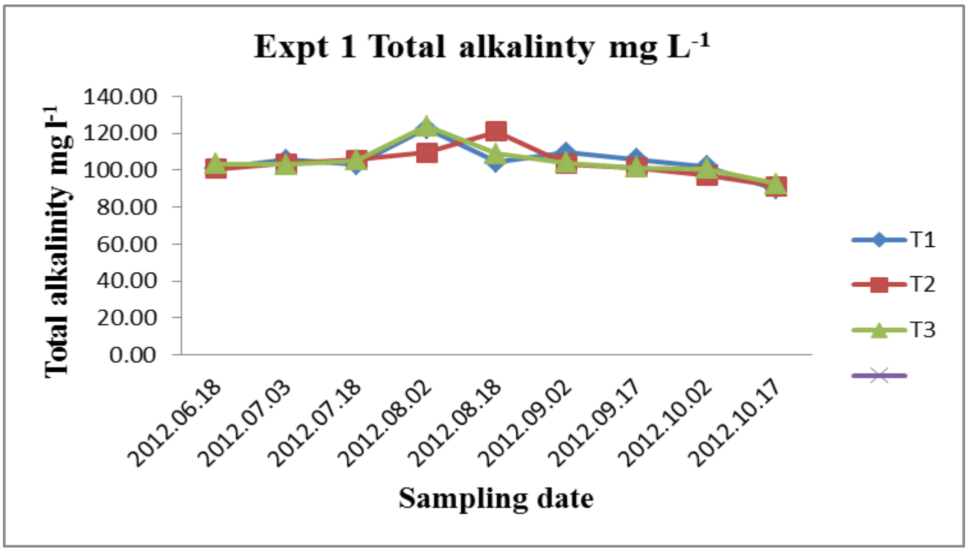


Figure 7 Fortnight variation in DO, P^H & total alkalinity of experiment 1

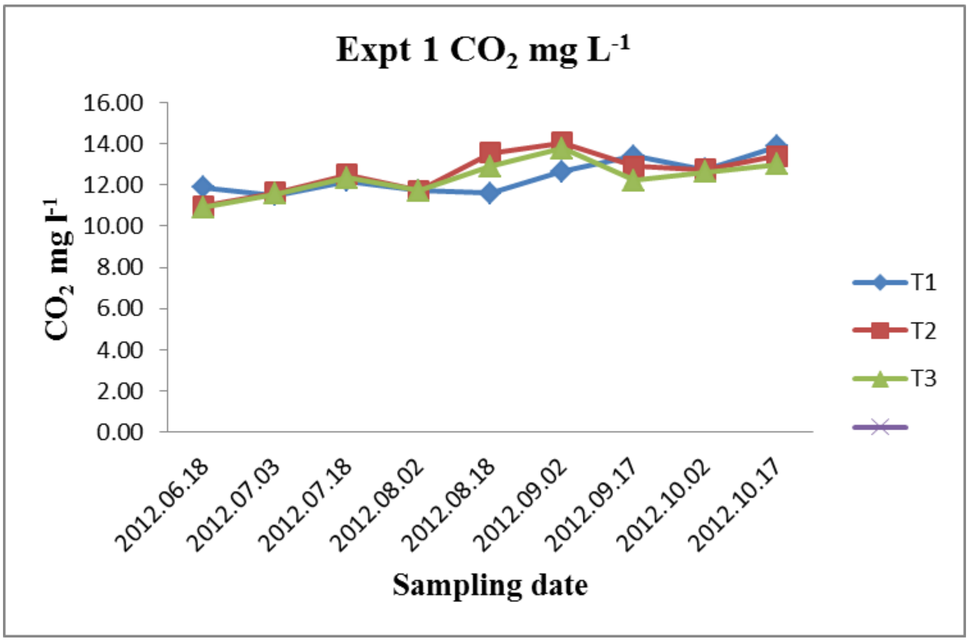


Figure 8 Fortnight variation in water quality parameters CO_2 of expt 1

4.2.3 Plankton composition and abundance in expt. 1

The group wise numerical data of planktons is shown in Tables 4.1.10 and 4.1.11. A total of 37 genera of planktons were recorded from the experimental ponds, in which 25 genera of planktons belonged to phytoplanktons and 16 genera belonged to zooplanktons. Altogether four groups of phytoplanktons were recorded from the experimental ponds. Phytoplankton groups were Chlorophyceae, Cyanophyceae, Euglinophyceae and Bacillariophyceae. The Chlorphyceae group contained 13 genera, Cyanophyceae 5 genera, Bacillariophyceae 4 genera and Euglinophyceae 2 genera. Chorophyceae group was dominant group of phytoplankton in the study. There were no significant differences in phytoplankton abundance among the treatments. *Chlorella* was the dominant genus in all the treatments followed by *Oscillatoria*. Zooplanktons belonged from three groups; Rotifera (6 genera), Protozoa (1 genus) and Crustacea (6 genera). Among zooplankton, rotifera was the dominant group. There were no significant differences in numbers of Rotifera, Protozoa and Crustacea group of zooplanktons among the treatments. *Brachiomus* spp was the dominant zooplankton in experiment 1.

Table 4.1.10 Phytoplankton's record (units L^{-1}) of experiment 1

		Treatment 1 (T1)	Treatment 2 (T2)	Treatment 3 (T3)
		units L^{-1} ± SE		
Group	Genus			
Chlorophyceae	*Chiorella*	203±6.60	112±5.99	175±8.18
	Closterium	7±0.55	17±0.93	15±1.2
	Zygnema	25±1.99	41±1.96	5±0.4
	Actinastrum	7900±301.96^{a}	1800±97.54^{b}	800±63.8^{c}
	Cladophora	71±5.66	90±5.38	41±3.27
	Chlamydomonas	3120±184.98	2830±152.8	1040±83.00
	Oedogonium	1300±72.13	2000±160.00	0.0±0.0
	Netrium	260±20.74	0.0±0.0	25±1.99
	Pediastrum	6500±340.85^{a}	800±63.8^{c}	1700±91.5^{b}
	Selenastrum	11500±444.65	5120±246.6	2300±130.00
	Spirogyra	800±63.83	0.0±0.0	200±16.00
	Tetraedron	4100±233.48	0.0±0.0	3300±189.00
	Tetraspora	9020±439.14^{a}	0.0±0.0^{b}	4280±190.00
	Subtotal	3446.6±1068.19	985.3±417.82	1067.7±379.67
Cynophyceae	*Volvox*	3150±164.69	0.0±0.0	0.0±0.0
	Ulothrix	980±60.39	6400±417.2	4500±334.00
	Anabaena	830±44.68	620±49.5	1100±87.8
	Microcystis	7710±320.05	2300±131.5	8400±366.00
	Oscillatoria	1480±85.30	0.0±0.0	1100±79.50
	Subtotal	2830±1151.76	1864±1081.91	3020±1380.30
Euglinophyceae	*Euglina*	8780±279.40	3800±205.00	13400±560.00
	Phacus	12040±375.14	7906±297.7	9760±391.00
	Subtotal	10410±1152.59	5853±1451.70	11580±1286.94
Bacillariophyceae	*Fragillaria*	4700±238.19	2900±138.00	6080±189
	Diatoma	16100±226.80^{a}	4400±264.40^{b}	13320±298.00^{ab}
	Synedra	2100±73.18	1860±64.40	0.0±0.0
	Cyclotella	5980±252.83	5710±164.40	6020±225.00
	Subtotal	7220±2657.02	3717.5±731.20	6355±2359.62
	Total phytoplankton	4527.3±905.30	2029.4±476.34	3231.7±840.81
	Unknown sps.	8.2±3.46	5.1±3.44	8.4±3.57
	No. of identified species	24	24	24

Different superscript letters in the same row are significantly different (P<0.05) according to one Way ANOVA and Tukey's test. (Mean±S.E)

Table 4.1.11 Zooplankton's record (units L^{-1}) of experiment 1

		Treatment 1 (T1)	Treatment 2 (T2)	Treatment 3 (T3)
		units L^{-1} ± SE		
Group	Genus			
Crustacea	*Cyclops* spp	811.7±405.87	475±433.34	475±368.19
	Daphnia spp	233.3±273.25	141.6±158.71	140.8±124.00
	Cerio spp	235.8±211.28	50.0±82.91	205±233.95
	Moina spp	106.6±133.14	144.1±161.72	402.5±395.04
	Nauplius spp	739.1±581.06	788.3±622.66	494.1±358.42
	Diaptomus spp	33.3±55.27	85±140.95	140.8±158.90
	Subtotal	2160.0±123.650	1684.1±108.66	1858.3±61.91
Protozoa	*Diffugia* spp	755±453.56	416.6±690.96	490±547.97
	Subtotal	755±453.56	416.6±690.96	490±547.97
Rotifera	*Brachionus* spp	924.1±462.71	516.6±319.50	1120.8±743.24
	Keratella spp	347.5±337.81	166.6±212.45	175±198.03
	Monostyla spp	136.6±153.66	0.0±0.0	146.6±166.44
	Trichocerca spp	540±551.83	438.3±350.05	316.6±303.33
	Filinia spp	355±287.46	121.6±201.76	216.6±193.46
	Asplanchna spp	355±287.46	121.6±201.76	216.6±193.46
	Subtotal	3413.3±184.35	1781.63±96.22	2682.4±144.88
	Total zooplankton	428.7±78.65	262.75±61.78	349.2±71.77
	Unknown sps.	2.4±0.66	1.25±0.48	0.7±0.39
	No. of identified species	13	13	13

Different super script letters in the same row are significantly different (P<0.05) according to one way ANOVA and Tukey's test. (Mean±S.E)

4.3 GROWTH AND PRODUCTION ASSESMENT IN CARP & *A. mola* COMBINATION IN EXPT 2

4.3.1 Growth and production assessment of carp combinations with SIS

The growth and production performance of carp species; silver carp (*Hypophthalmicthys molitrix*), big head carp (*Aristichthys nobilis*), rohu (*Labeo rohita*), naini (*Cirrhinus mrigala*), grass carp (*Ctenopharyngodon idella*), and common carp (*Cyprinus carpio*) in combination of SIS *A. mola* in all treatments except of T1 treatment of experiment 2 are shown in Table 4.2.1 and 4.2.2. The final harvesting weight of *H. molitrix* in all treatments T1 (ctrl), T2, T3 and T4 were 110 ± 2.35, 134.0 ± 0.81, 132.3 ± 1.18, 129 ± 1.69 g though the mean individual stocking weight of *H. molitrix* was 9.2 ± 0.48, 9.2 ± 0.33, 9.2 ± 0.48, 9.2 ± 0.23 g in all treatments. Net weight gained by *H. molitrix* in all treatments were 100.8 ± 2.22, 124.8 ± 0.61, 123.3 ± 1.10, 119.8 ± 1.83 g. The daily weight gain and survival percentage of *H. molitrix* is shown in Table 4.2.1. Net fish yield of silver carp in treatments T1, T2, T3 and T4 was 4.7 ± 0.11, 7.2 ± 0.01, 6.4 ± 0.05, 5.6 ± 0.08 kg. Net production of *H. molitrix* was the highest 2198.2 ± 0.01 kg $ha^{-1}yr^{-1}$ in T2 and the lowest 1438.1 ± 0.11 kg $ha^{-1}yr^{-1}$ in treatment T1. The mean individual stocking weight of *A. nobilis* in all treatments were 8.7 ± 0.21, 8.7 ± 0.33, 8.7 ± 0.16, 8.7 ± 0.21 g and the final harvesting weight in treatments T1, T2, T3 and T4 were 86.0 ± 0.81, 89.0 ± 1.69, 85.6 ± 1.9 and 85.0 ± 1.41 g. Net weight gain by *A. nobilis* in all treatments were 77.3 ± 0.9, 79.8 ± 2.03, 76.9 ± 1.99 and 76.4 ± 1.24 g from treatments ponds. Net yield of *A. nobilis* in treatments (T1, T2, T3 and T4) were 0.959 ± 0.03, 1.6 ± 0.06, 1.3 ± 0.01 and 0.804 ± 0.01 kg. Net production of *A. nobilis* was the highest 514.0 ± 0.06 kg ha^{-1} yr^{-1} in T2 and the lowest 244.5 ± 0.1kg $ha^{-1}yr^{-1}$in treatment T4. The mean individual stocking weight of *L. rohita* in all treatments was 8.0 ± 0.62, 10.0 ± 0.62, 10.0 ± 0.23 and 8.0 ± 0.62 g and the final harvesting weight in treatments T1, T2, T3 and T4 were 71.6 ± 1.36, 86.6 ± 1.9, 76.6 ± 1.36 and 76.0 ± 0.81 g. Net weight gain by rohu in all treatments (T1, T2, T3 and T4) were 61.6 ± 1.44, 76.6 ± 1.46, 66.6 ± 1.36 and 66.0 ± 0.73 g. Net yield of rohu (*L. rohita*) in treatments (T1, T2, T3 and T4) was 1.2 ± 0.04, 2.2 ± 0.05, 1.5 ± 0.04, and 1.1 ± 0.00 kg. Net production of *L. rohita* was the highest 702.6 ± 0.05 kg $ha^{-1}yr^{-1}$ in T2 and the lowest 338.2 ± 0.0 kg $ha^{-1}yr^{-1}$ in treatment T4. The survival percentage of *L. rohita* was between 78.25 ± 4.09 to 86.65 ± 2.05. The mean individual stocking weight of naini (*C. mrigla*) in all treatments was 9.0 ± 0.28, 9.0 ± 0.16, 9.0 ± 0.16 and 9.0 ± 0.28 g. The final harvesting weight of *C. mrigla* in treatments T1, T2, T3 and T4 were 72.3 ± 1.18, 86.6 ± 1.36, 82.3 ± 1.18 and 77.0 ± 1.24 g. Net weight gain by *C. mrigla* in all treatments were 63.3 ± 1.05, 77.6 ± 1.28, 73.3 ± 1.24 and 68.0 ± 1.14 g. The daily weight gain and survival percentage of naini is shown in table 4.3.1. The survival percentage of naini at harvesting was from 89.2 to 84.3. Net yield of *C. mrigla* in treatments were 0.709 ± 0.2, 1.7 ± 0.00, 1.3 ± 0.01and 0.789 ± 0.01 kg. Net production of *C. mrigla* was the highest 525.9 ± 0.00 kg $ha^{-1}yr^{-1}$ in T2 and the lowest 215.6 ± 0.2 kg $ha^{-1}yr^{-1}$ in treatment T1. The mean individual stocking weight of grass carp (*C. idella*) in all treatments was 8.5 ± 0.24 g and the final harvesting weight in treatments were 77.6 ± 1.18, 77.6 ± 1.36 and 77.6 ± 1.8 g. The survival percentage of *C. idella* was 80.9 ± 3.88, 84.2 ± 1.72 and 73.3 ± 5.44 in T1, T3 and T4 treatments. Net weight gain by *C. idella* in treatments T1, T3 and T4 were 69.1 ± 1.32, 68.1 ± 1.48 and 69.1 ± 1.32, g. Net yield of grass carp in treatments (T1, T3 and T4) was 0.381 ± 0.04, 0.844 ± 0.03 and 0.355 ± 0.02, kg. Net production of *C. idella* was the highest 256.7 ± 0.03 kg $ha^{-1}yr^{-1}$ in T3 and the lowest 107.979 ± 0.02 kg $ha^{-1}yr^{-1}$ in treatment T4. The mean individual stocking weight of common carp (*C. carpio*) in treatments T1 and T4 was 9.5 ± 0.16 and 9.5 ± 0.14 g. The final harvesting weight of *C. carpio* in treatments T1, and T4 were 87.3 ± 1.18 and 100.6 ± 0.54 g. The survival percentage of *C. carpio* at harvesting was 86.8 ± 3.72 and 86.8.71 ± 1.42. Net weight gain by *C. carpio* in treatments T1 and T4 were 77.8 ± 1.29 and 91.1 ± 0.42 g. Net yield of *C. carpio* was 2.4 ± 0.04 and 2.7 ± 0.01 kg in the treatments T1 and T4. Net production of *C. carpio* was the highest 828.8 ± 0.01 kg $ha^{-1}yr^{-1}$ in T4 and the lowest 757.6 ± 0.04 kg $ha^{-1}yr^{-1}$ in treatment T1. The mean individual stocking weight of *A. mola* in treatments T2, T3 and T4 were 1.2 ± 0.09, 1.2 ± 0.12 and 1.2 ± 0.09 g. The final harvesting weight of *A. mola* were 3.06 ± 0.05, 3.0 ± 0.0 and 3.0 ± 0.0 g. *A. mola* breeds in the pond condition so the survival percentage was not carried out. Net weight gain of *A. mola* in treatments was 1.8 ± 0.04, 1.8 ± 0.02 and 1.8 ± 0.09. Net production of *A. mola* was the highest 618.6 ± 0.0 kg $ha^{-1}yr^{-1}$ in T2 and the lowest 566.6 ± 0.09 kg $ha^{-1}yr^{-1}$ in T4. Net fish (carp and *A. mola*) production $ha^{-1}yr^{-1}$ of experiment 2 is shown in Figure 9. Species wise silver carp (*H. molitrix*) contributed in the highest quantity of the experiment 2. Species wise contribution of carp and *A. mola* in the experiment 2 is shown in Figure 10. A combination of carp species silver carp, bighead carp, rohu, naini and *A. mola* proved the best combination from experiment. The net production performance of carp's combination along with *A. mola* kg $ha^{-1}yr^{-1}$ of experiment 2 is shown in Table 4.2.2

Table 4.2.1 Growth & production of carps & SIS in expt. 2

Parameters	Treatments			
	T1	T2	T3	T4
H. molitrix				
Initial mean wt.(g $fish^{-1}$)	9.2 ± 0.48	9.2 ± 0.33	9.2 ± 0.48	9.2 ± 0.24
Initial total wt. (kg $pond^{-1}$)	0.588 ± 0.01	0.588 ± 0.02	0.552 ± 0.01	0.478 ± 0.01
Final harvesting wt.(g $fish^{-1}$)	110±2.35	134 ± 0.81	132.3 ± 1.18	129 ± 1.69
Final total wt.(kg $pond^{-1}$)	5.2±0.11	7.8 ± 0.01	7.0 ± 0.06	6.1 ± 0.08
Daily weight gain ($g^{-1}fish^{-1}day^{-1}$)	0.8 ± 0.01	1.0 ± 0	1.0 ± 0	0.9 ± 0.01
Net mean fish yield (kg $pond^{-1}$)	4.7 ± 0.11	7.2 ± 0.01	6.4 ± 0.05	5.6 ± 0.08
Survival (%)	91.0 ± 1.04	93.0 ± 1.42	88.3 ± 0.05	91.6 ± 0.52
Net fish yeild (kg $ha^{-1}yr^{-1}$)	1438.1± 0.11[b]	2198.2 ±0.01[a]	1965.2 ± 0.05[ab]	1724.6± 0.08[ab]
A. nobilis				
Initial mean wt.(g $fish^{-1}$)	8.7 ± 0.21	8.7 ± 0.33	8.7 ± 0.16	8.7 ± 0.21
Initial total wt. (kg $pond^{-1}$)	0.13 ± 0.01	0.23 ± 0.01	0.19 ± 0.01	0.13 ± 0.01
Final harvesting wt.(g $fish^{-1}$)	86 ± 0.81	89 ± 1.69	85.6 ± 1.9	85 ± 1.41
Final total wt.(kg $pond^{-1}$)	1.1± 0.02	1.9 ± 0.05	1.5 ± 0.01	0.935 ± 0.01
Daily weight gain ($g^{-1}fish^{-1}day^{-1}$)	0.64 ± 0.0	0.66 ± 0.01	0.64 ± 0.01	0.63 ± 0.01
Net mean fish yield (kg $pond^{-1}$)	0.959 ± 0.03	1.6 ± 0.06	1.3 ± 0.01	0.8 ± 0.01
Survival (%)	84.4 ± 1.81	84.3 ± 1.99	80.3 ± 1.50	73.3 ± 3.14
Net fish yield (kg $ha^{-1}yr^{-1}$)	291.6 ± 0.03	514.1 ± 0.06	389.3 ± 0.01	244.5 ± 0.01
L. rohita				
Initial mean wt.(g $fish^{-1}$)	8.0 ± 0.62	10 ± 0.62	10.0 ± 0.23	8.0 ± 0.62
Initial total wt. (kg $pond^{-1}$)	0.23 ± 0.00	0.34 ± 0.00	0.30 ± 0.02	0.23 ± 0.05
Final harvesting wt.(g $fish^{-1}$)	71.6±1.36	86.6±1.9	76.6±1.36	76±0.81
Final total wt.(kg $pond^{-1}$)	1.4±0.04	2.5±0.05	1.8±0.04	1.3±0
Daily weight gain ($g^{-1}fish^{-1}day^{-1}$)	0.51±0.01	0.63±0.01	0.55±0.01	0.54±0
Net mean fish yield (kg $pond^{-1}$)	1.2±0.04	2.2±0.05	1.5±0.04	1.1±0
Survival (%)	86.9 ± 2.05	84.8 ± 1.42	82.6 ± 1.08	78.2 ± 4.09
Net fish yield (kg $ha^{-1}yr^{-1}$)	365.9±0.04[b]	702.6±0.05[a]	483.9±0.04[ab]	338.2±0[b]
C. mrigala				
Initial mean wt.(g $fish^{-1}$)	9.0 ± 0.28	9.0 ± 0.16	9.0 ± 0.16	9.0 ± 0.28
Initial total wt. (kg $pond^{-1}$)	0.135±0.00	0.542±0.08	0.207±0.00	0.135±0.00
Final harvesting wt.(g $fish^{-1}$)	72.3±1.18	86.6±1.36	82.3±1.18	77±1.24
Final total wt.(kg $pond^{-1}$)	0.844±0.03	1.9±0	1.5±0.01	0.924±0.01
Daily weight gain ($g^{-1}fish^{-1}day^{-1}$)	0.52±0	0.64±0.01	0.61±0.01	0.56±0
Net mean fish yield (kg $pond^{-1}$)	0.709±0.02	1.7±0	1.3±0.01	0.789±0.01
Survival (%)	79.2 ± 1.92	79.2 ± 1.92	84.3 ± 1.16	80 ±1.54
Net fish yield (kg $ha^{-1}yr^{-1}$)	215.6±0.02[b]	525.9±0[a]	420.9±0.01[ab]	239.9±0.01
C. idella				
Initial mean wt.(g $fish^{-1}$)	8.5 ± 0.24		8.5 ± 0.24	8.5 ± 0.24
Initial total wt. (kg $pond^{-1}$)	0.059±0.00		0.294±0.04	0.14±0.02
Final harvesting wt.(g $fish^{-1}$)	77.6±1.18		76.6±1.36	77.6±1.18
Final total wt.(kg $pond^{-1}$)	0.441±0.02		0.971±0.03	0.415±0.02

Daily weight gain ($g^{-1}fish^{-1}day^{-1}$)	0.57±0.01		0.56±0.02	0.57±0.01
Net mean fish yield (kg $pond^{-1}$)	0.381±0.01		0.844±0.03	0.355±0.02
Survival (%)	80.9 ± 3.8		84.2 ± 1.72	73.3 ± 5.4
Net fish yeild (kg $ha^{-1}yr^{-1}$)	115.8±0.01		256.7±0.03	107.9±0.02
C. carpio				
Initial mean wt.(g $fish^{-1}$)	9.5 ±0.16			9.5 ±0.14
Initial total wt. (kg $pond^{-1}$)	0.361±0.00			0.834±0.13
Final harvesting wt.(g $fish^{-1}$)	87.3±1.18			100.6±0.54
Final total wt.(kg $pond^{-1}$)	2.8±0.04			3.0±0.01
Daily weight gain ($g^{-1}fish^{-1}day^{-1}$)	0.64±0.01			0.75±0.01
Net mean fish yield (kg $pond^{-1}$)	2.4±0.04			2.7±0.01
Survival (%)	86.8 ± 3.72			80.7 ± 1.42
Net fish yeild (kg $ha^{-1}yr^{-1}$)	757.6±0.04			828.8±0.01
A. mola				
Initial mean wt.(g $fish^{-1}$)		1.2±0.09	1.2±0.12	1.2±0.09
Initial total wt. (kg $pond^{-1}$)		1.3±0.21	1.3±0.22	1.3±0.21
Final harvesting wt.(g $fish^{-1}$)		3.0±0.05	3.0±0.0	3.0±0
Final total wt.(kg $pond^{-1}$)		2.6±0.06	2.4±0.05	2.4±0.01
Daily weight gain ($g^{-1}fish^{-1}day^{-1}$)		0.01±0	0.01±0	0.01±0
Net mean fish yield (kg $pond^{-1}$)		2.0±0	1.9±0.1	1.8±0.09
Net fish yeild (kg $ha^{-1}yr^{-1}$)		618.6±0	606.2±0.1	566.6±0.09

Different superscript letters in the same row are significantly different (P<0.05) according to one way ANOVAandTukey's test. (Mean±S.E)

Table 4.2.2 Treatment wise net fish production kg ha^{-1} yr^{-1} in expt 2

Fish sps.	T1	T2	T3	T4
H. molitrix	1438.1±0.11	2198.2±0.01	1965.2±0.05	1724.6±0.08
A. nobilis	291.6±0.03	514.0±0.06	389.3±0.01	244.5±0.01
L. rohita	365.9±0.04	702.6±0.05	483.9±0.04	338.2±0
C. mrigala	215.6±0.02	525.9±0	420.9±0.01	239.9±0.01
C. idella	115.8±0.01	0.0±0	256.7±0.03	107.9±0.02
C. carpio	757.6±0.04	0.0±0	0.0±0	828.8±0.01
A. mola	0.0±0	618.6±0	606.2±0.1	566.6±0.09
Net total $prod^{n}$	3184.9	4559.4	4122.4	4050.8

Different superscript letters in the same row are significantly different (P<0.05) according to one way ANOVA and Tukey's test. (Mean±S.E)

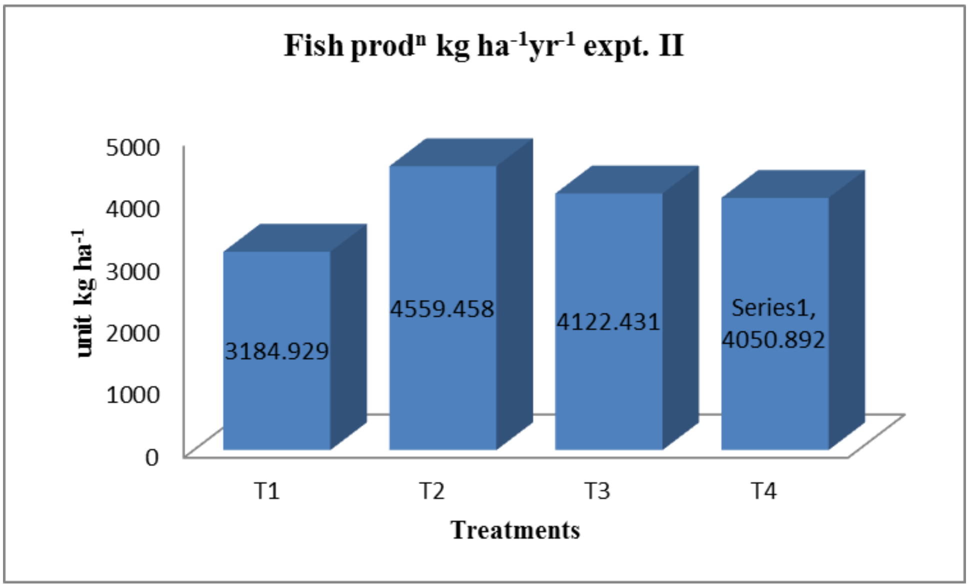


Figure 9 Fish production per year and per hectar in expt 2

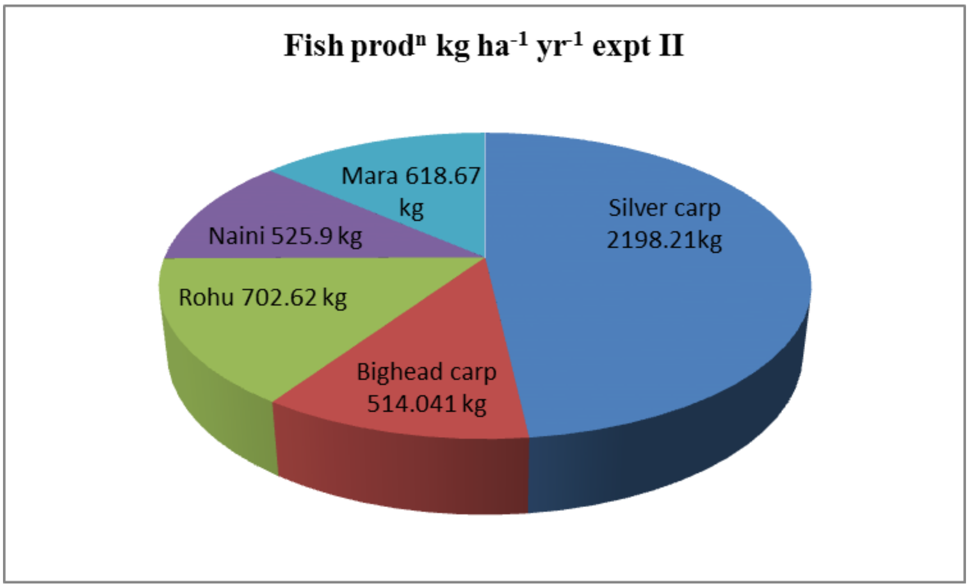


Figure 10 Species wise fish production kg ha^{-1} yr^{-1} in T2 treatment expt 2

4.3.2 Benefit-cost analysis of experiment 2

The benefit cost analysis of all treatments was analyzed on the basis of the locally purchased item's cost and total return from the sale of carp fishes and SIS species mara, in the local market. The return from sale of carp fishes depends upon their size. The financial characteristics of different treatments are presented in Tables 4.2.3, 4.2.4 and 4.2.5. The major and also variable input costs were mainly due to experimental carp's fingerling, supplemental feeds, lime and inorganic fertilizers. The net benefit was highest in treatment T2. It was followed by treatments T3, T4 and T1. Net benefit was 3473.5 ± 1229.1 rupees pond $^{-1}$ in T2. It was 2950.8 ± 1043.28 in T3, 2828.9 ± 1000.18 in T4 and 1212.8 ± 428.80 rupees pond $^{-1}$in T1. Net benefit was the highest 347658.0 ± 1229.17 rupees ha^{-1}yr^{-1}in treatment T2. However net benefit was compared among treatments control (T1) gave the lowest production. It suggests that (*A. mola*) can be reared with the carp species; silver carp (*Hypophthalmycthys molitrix*), bighead carp (*Aristichthys nobilis*), rohu (*Labeo rohita*) and naini (*Cirrhinus mrigala*).

Table 4.2.3 Variable cost (Nepalese currency) pond $^{-1}$ of different treatments in expt 2

	Treatments											
Variables	T1			T2			T3			T4		
	P1	P7	P10	P3	P6	P8	P2	P9	P12	P4	P5	P11
Feeding tray	100	100	100	100	100	100	100	100	100	100	100	100
H. molitrix	260	260	260	320	320	320	300	300	300	260	260	260
A. nobalis	75	75	75	130	130	130	110	110	110	75	75	75
L. rohita	161	161	161	238	238	238	210	210	210	161	161	161
C. mrigala	105	105	105	182	182	182	161	161	161	105	105	105
C. idella	35	35	35				75	75	75	35	35	35
C.carpio	304	304	304							304	304	304
A. mola	0	0	0	250	250	250	250	250	250	250	250	250
Urea	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5
DAP	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5
Cow dung	60	60	60	60	60	60	60	60	60	60	60	60
Lime	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5
Oil cake	6.5	6.28	6.15	8.85	8.77	8.68	8.12	7.97	7.78	7.85	7.88	8.22
Rice bran	8.97	9.32	9.5	13	12.9	12.88	12.5	11.82	11.55	11.52	11.55	12.25
Total	1255.9	1256.1	1256.1	1442.3	1442.1	1442.0	1427.1	1426.2	1425.8	1509.8	1509.9	1510.9

Table 4.2.4 Gross return value pond $^{-1}$ of different treatments in expt 2

Treatments							
T1		T2		T3		T4	
Ponds	Rupees(NC)	ponds	Rupees(NC)	ponds	Rupees(NC)	ponds	Rupees(NC)
P1	1642.3	P3	2672.872	P2	2470.272	P4	2362.22
P7	1703.6	P6	2588.484	P9	2324.892	P5	2446.372
P10	1635.07	P8	2541.81	P12	2434.898	P11	2551.112
Mean ± SE	1660.34±17.75	Mean ± SE	2601.05±31.31	Mean ± SE	2410.02±35.74	Mean ± SE	2453.23±44.61

Table 4.2.5 Gross margin analysis pond $^{-1}$& ha^{-1}yr $^{-1}$ of all treatments in expt 2

Parameters	Treatments			
	T1	T2	T3	T4
Outputs	1660.34±17.75	2601.05±31.31	2410.02±35.74	2453.23±44.61
Inputs	1256.07±0.04	1442.19±0.06	1426.41±0.30	1510.25±0.29
Gross margin pond $^{-1}$	404.27±17.75	1158.86±31.31	983.61±35.74	942.98±44.61
Gross margin ha $^{-1}$ yr $^{-1}$	122965.5±17.75^{b}	352486.6±31.31^{a}	299181.4±35.74^{ab}	286823.1±44.61^{ab}

Different superscript letters in the same row are significantly different (P<0.05) according to one way ANOVA and Tukey's test. (Mean±S.E)

4.3.3 Water quality parameter of expt 2

The fortnightly measured and analyzed results of some important water quality parameters are shown in Table 4.2.6. The water temperature was recorded from 27.1 ^{0}C to 33.5 ^{0}C in treatments of experiment. The mean temperature recorded in treatments (T1, T2, T3 and T4) were 28.2 ± 0.41, 28.4 ± 0.37, 28.5 ± 0.41, and 28.5 ± 0.43 ^{0}C. Water transparency ranged from 16.0 to 40.0 cm. Transparency increased in rainy seson of June. The mean value of transparency in treatments (T1, T2, T3 and T4) of experiment 2 was 21.3 ± 1.21 cm, 22.7 ± 1.19 cm , 20.3 ± 1.40 cm and 25.9 ± 1.72 cm. Dissolved oxygen of pond water ranged from 4.1 mg L^{-1} to 10.1 mg L^{-1} during experimental period and did not vary among the treatments. The mean value of dissolved oxygen in treatments (T1, T2, T3 and T4) of experiment 2 was 5.5 ± 0.22 mg L^{-1}, 5.4 ± 0.21 mg L^{-1}, 5.4 ± 0.24 mg L^{-1} and 5.4 ± 0.23 mg L^{-1}. The pH of experimental ponds varied from 7.7 to 8.5 without any significant difference among the treatments. The high pH was in April before of monsoon arrival. The mean value of pH in treatments (T1, T2, T3 and T4) were 7.4 ± 2.73, 7.4 ± 0.11, 7.4 ± 0.07 & 7.4 ± 0.89. Total alkalinity ranged from 76.0 and 150.0 mg L^{-1}. The mean value of total alkalinity in treatments (T1, T2, T3 and T4) were 92.2 ± 4.19 mg L^{-1}, 95.4 ± 4.71 mg L^{-1}, 91.1 ± 3.66 mg L^{-1} and 90.0 ± 3.46 mg L^{-1}. The CO_2 of experimental ponds varied between 10.5 to 16.4 mg L^{-1}. The mean value of CO_2 in treatments (T1, T2, T3 and T4) of experiment 2 was 12.2 ± 0.30 mg L^{-1}, 12.7 ± 0.35 mg L^{-1}, 13.0 ± 0.35 mg L^{-1} and 12.2 ± 0.28 mg L^{-1}. The fortnight water quality parameters of experiment are illustrated in Fig 11, 12 and 13.

Table4.2.6 Summary of water quality parameters (mean) during total experimental period in expt 2

parameters	Treatments			
	T1	T2	T3	T4
Temperature (^{0}C)	28.4 ± 0.37	28.5 ± 0.41	28.5 ± 0.43	28.2 ± 0.41
Transparency (cm)	22.7 ± 1.19^{ab}	20.3 ± 1.40^{ab}	25.9 ± 1.72^{b}	21.3 ± 1.21^{a}
DO (mg L^{-1})	5.4 ± 0.21	5.4 ± 0.24	5.4 ± 0.23	5.5 ± 0.22
pH	7.4 ± 0.11	7.4 ± 0.07	7.4 ± 0.89	7.4 ± 2.73
Total Alkalinity mg L^{-1}	95.4 ± 4.71^{a}	91.1 ± 3.66^{ab}	90.0 ± 3.46^{b}	92.2 ± 4.19^{ab}
CO_2 mg L^{-1}	12.7 ± 0.35	13.0 ± 0.35	12.2 ± 0.28	12.2 ± 0.30

Different superscript letters in the same row are significantly different (P<0.05) according to one way ANOVA and Tukey's test. (Mean±S.E)

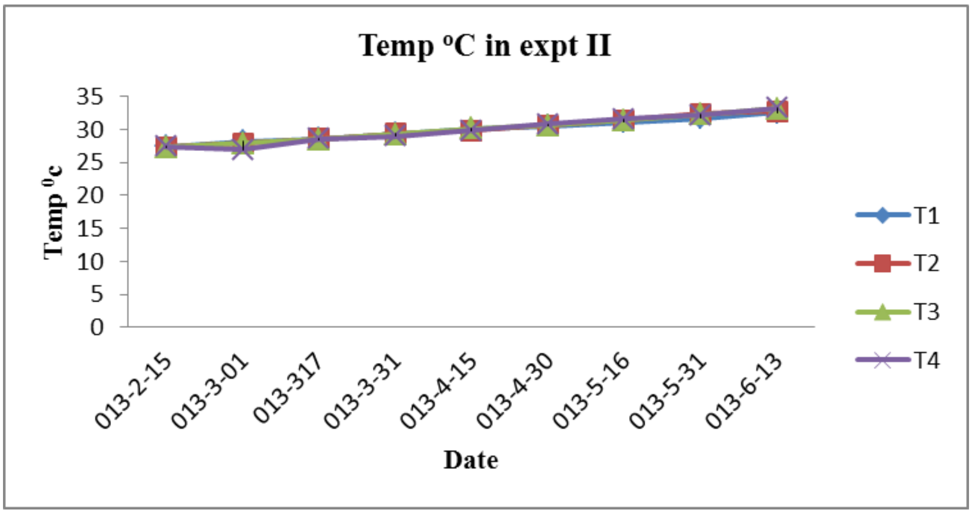


Figure 11 Fortnight variation in water temperature parameters of experiment 2

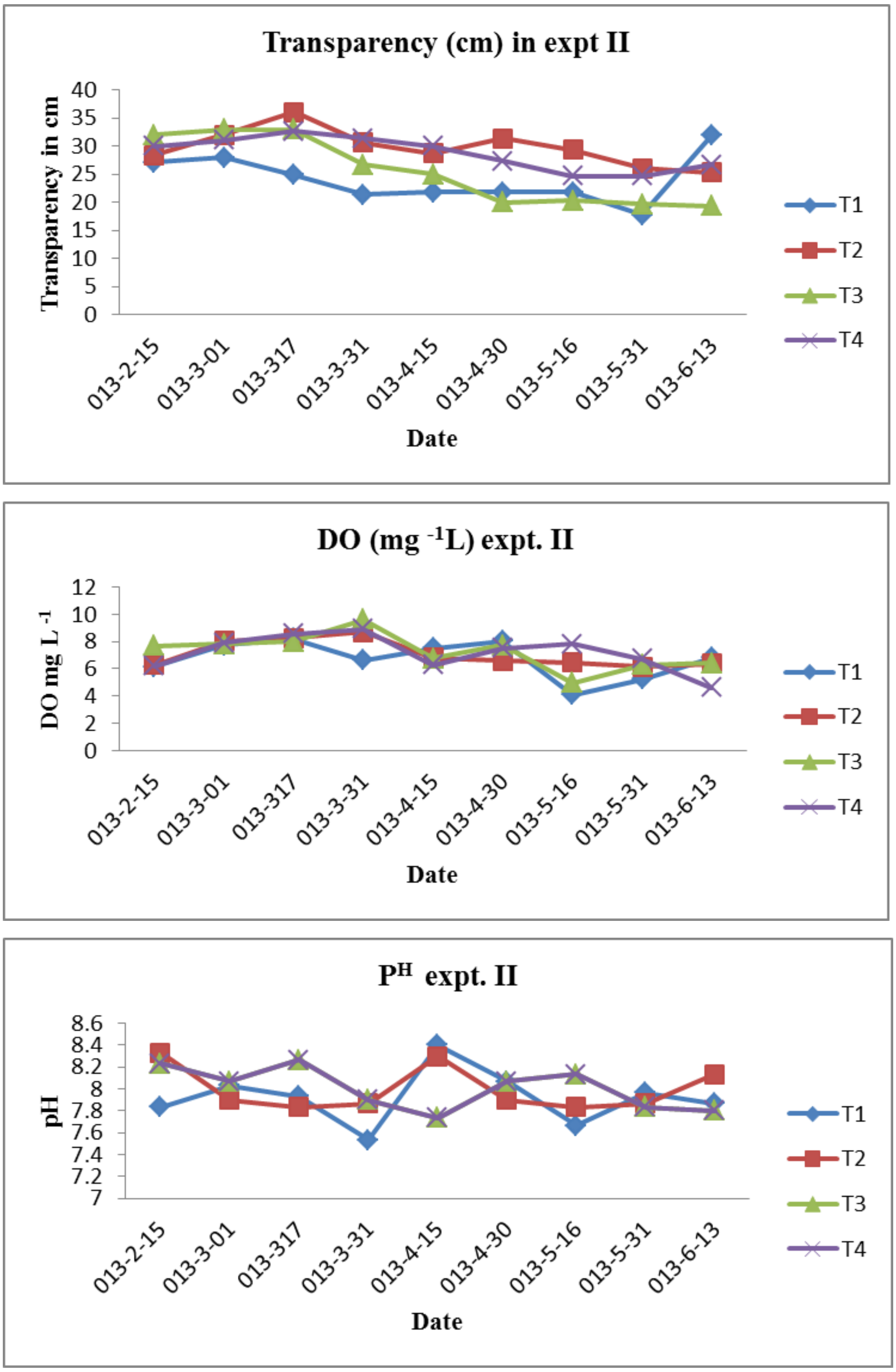
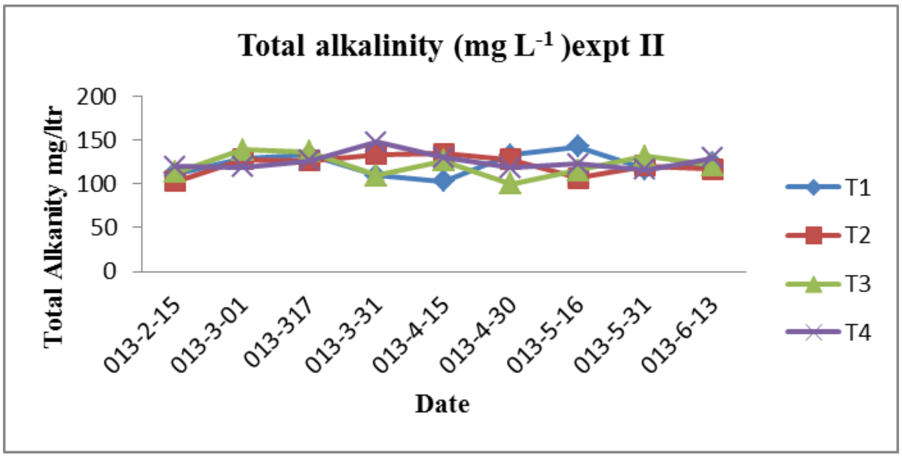


Figure 12 Fortnight variation in transparency, DO and P^H of experiment 2



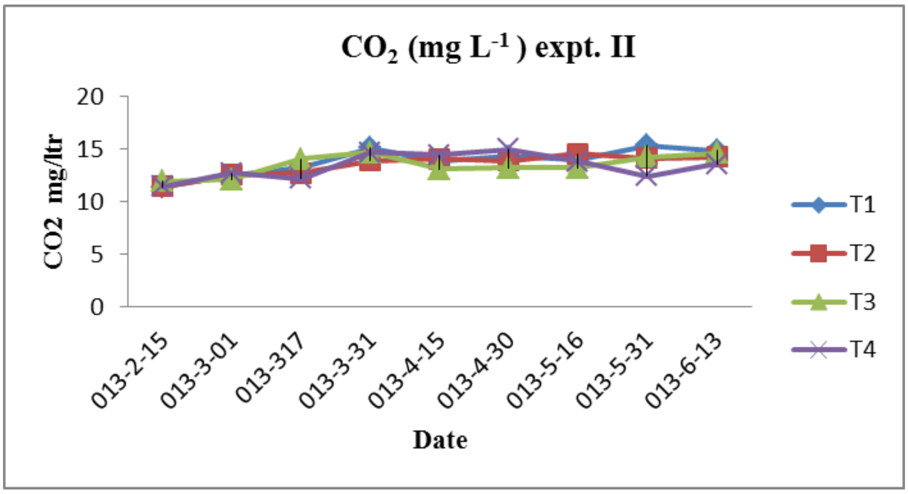


Figure 13 Fortnight variation in total alkalinity & CO_2 of experiment 2

4.3.4 Plankton biomass and composition in expt 2

The group-wise numerical data of phytoplanktons and zooplanktons are shown in Tables 4.2.7and 4.2.8. A total of 39 genera of planktons were recorded from the experimental ponds, in which 26 genera were from phytoplanktons and 13 genera were from zooplanktons. Altogether four groups of phytoplanktons were recorded from the experimental ponds. Phytoplanktons group were chlorophyceae, cyanophyceae, euglinophyceae and bacillariophyceae. The chlorphyceae group contained 13 genera, cyanophyceae 7 genera, bacillariophyceae 4 genera and euglinophyceae 2 genera. Chorophyceae was the dominant group in experiment 2. *Chlorella* was the dominant genus in all treatments. Genus *Chlorella* was followed by Phytoplankton genus *Cyclotella*. Zooplanktons were belonged from groups rotifera (6 genera), protozoa (1 genus) and crustacea (6 genera). Among zooplankton groups, rotifera and crustacea were the dominant group.

Table 4.2.7 Phytoplankton's record (units L^{-1}) in experiment 2

		T1	T2	T3	T4
		(units L^{-1} ± SE)			
Group	Genus				
Chlorophyceae	*Chiorella*	18660±271.51^{b}	29400±429.56	27620±498.27	33200±436.59^{a}
	Closterium	4800±319.73	7300±367.52	1560±72.40	6350±299.62
	characium	0.0±0.0^{b}	5421±256.74^{a}	0.0±0.0^{b}	1800±99.65
	Actinastrum	2000±159.57	3140±131.47	1100±87.76	1000±64.37
	Cladophora	730±30.51	1190±53.26	1550±77.15	1440±82.52
	Chlamydomonas	3960±270.89	5040±180.75	5220±284.53	4000±319.15
	Oedogonium	0.0±0.0^{b}	0.0±0.0^{b}	2850±167.61^{a}	2240±120.86^{ab}
	Netrium	560±30.21	440±35.10	1200±55.67	0.0±0.0
	Pediastrum	12010±295.49	9180±360.62	12180±370.99	13160±366.95
	Selenastrum	2700±146.31	5200±337.34	7820±284.04	300±181.24
	Spirogyra	0.0±0.0^{b}	2150±102.67^{a}	0.0±0.0^{b}	1130±66.79^{ab}
	Tetraedron	3800±212.73	2170±117.15	5660±250.51	3600±199.31
	Tetraspora	2100±167.55	4470±204.76	1600±127.66	1600±127.66
	Subtotal	53520±1360.35	79101±1882.00	69260±1901.42	71420±2257.71
Cynophyceae	*Volvox*	2200±175.53^{ab}	4000±182.30^{a}	900±71.80^{b}	1600±127.66
	Ulothrix	3600±199.31	5040±335.71	3000±171.80	0.0±0.0
	Anabaena	0.0±0.0^{b}	1100±72.13	1600±86.87	1900±103.72^{a}
	Microcystis	1200±95.74	2330±99.01	870±69.41	3120±110.50
	Oscillatoria	0.0±0.0	5040±255.77	3120±177.11	1860±101.22
	Gloeocapsa	1680±134.04	3770±175.56	2300±127.18	1700±91.63
	Chroococcus	6500±349.79	3700±240.79	2400±137.44	6850±379.63
	Subtotal	18500±915.54	23500±511.3	13290±400.86	25230±1210.17
Euglinophyceae	*Euglina*	5520±234.04	2520±145.99	0.0±0.0	9800±294.59
	Phacus	3200±178.47	3580±155.59	11050±257.70	4900±204.39
	Subtotal	6840±155.58	16820±3415.8	14380±2729.84	11520±608.20
Bacillariophyceae	*Fragillaria*	3640±195.80^{b}	13240±301.72^{a}	3330±99.44^{b}	6620±248.84^{ab}
	Diatoma	11480±229.70	9410±311.51	8760±272.84	8490±203.99
	Synedra	6400±108.70	4040±229.10	2600±281.53	6040±335.71
	Cyclotella	3880±178.29	10860±221.26	7350±266.87	6100±152.83
	Subtotal	122380±20270.90	168041±29396.	134350±23719.	149430±26406.
	Total phytoplankton	3870±841.61	5528.1±1120.4	4447.6±1114.8	4953.8±1276
	Unknown sps.	16.8±5.1	8.7±5.14	5.8±2.65	13.7±5.74
	No. of identified species	26	26	26	26

Different superscript letters in the same row are significantly different (P<0.05) according to one way ANOVA and Tukey's test. (Mean±S.E)

Table 4.2.8 Zooplankton's record (units L^{-1}) in experiment 2

		(T1)	(T2)	(T3)	(T4)
		(unit L^{-1} ± SE)			
Group	Genus				
Crustacea	*Cyclops*	4560 ± 137.97	5150 ± 223.00	5350 ± 190.35	4740 ± 258.35
	Daphnia	2200 ± 95.11	900 ± 71.80	2320 ± 97.53	1800 ± 143.61
	Ceriodaphnia	550 ± 43.88	2100 ±114.34	2700 ± 114.55	800 ± 63.83
	Moina	2870 ±161.94	1524 ± 82.30	840± 67.02	6190 ± 220.96
	Nauplius	494 ± 198.90	9540 ± 189.45	16720 ± 384.01	26730 ± 345.65
	Diaptomus	4110 ± 143.93	0.0 ± 0.0	1700 ± 91.63	0.0 ± 0.0
	Subtotal	14784 ± 643.06^{c}	19214 ± 1328.87^{b}	29630 ± 2224.84^{ab}	40260 ± 3760.96^{a}
Protozoa	*Diffugia*	9700 ± 474.42	4200 ± 249.59	8270 ± 283.82	9840 ± 209.18
	Subtotal	9700 ±474.42	4200 ± 249.59	8270 ± 283.82	9840 ± 209.18
Rotifera	*Brachionus*	3900 ± 185.53^{b}	6410 ± 246.37	22740 ± 461.77^{a}	10910 ± 210.02^{ab}
	Keratella	1910 ± 118.15	4050 ± 188.49	3560 ± 157.67	4640 ± 200.19
	Monostyla	850 ± 67.81	740 ± 59.04	1120 ± 89.36	920 ±73.40
	Trichocerca	1920 ± 103.52	540 ± 43.08	3920 ± 243.90	11250 ± 351.51
	Filinia	3250 ± 192.07^{ab}	0.0 ± 0.0^{b}	14360 ± 78.96^{a}	3000 ± 239.36^{ab}
	Asplanchna	1460 ± 83.08^{c}	5160 ± 189.47^{a}	1980 ± 111.85^{b}	4050 ± 228.57^{ab}
	Subtotal	13390 ± 396.81	16900 ± 945.08	47680 ± 3003.78	34770 ± 1484.17
	Total zooplankton	2905.6 ± 650.91	3101.0 ± 779.38	6583.0 ± 1862.12	6528 ± 1908.09
	Unknown sps.	0.3 ± 0.24	0.3 ± 0.24	1.2 ± 0..33	1.4 ± 0.32
	No. of identified species	13	13	13	13

Different superscript letters in the same row are significantly different (P<0.05) according to one way ANOVA and Tukey's test. (Mean±S.E)

4.4 DETERMINATION OF THE BEST STOCKING RATIO BETWEEN CARP AND SIS IN EXPT 3

4.4.1 Production of carp species with SIS in different ratio

The result of growth, survival and production performance of carp species silver carp (*Hypophthalmicthys molitrix*), big head carp (*Aristichthys nobilis*), rohu (*Labeo rohita*), naini (*Cirrhinus mrigala*) along and SIS species *A. mola* in all treatments T1 (ctrl), T2, T3 and T4 of experiment 3 are shown in Table 4.3.1 and Fig 4.3.1. The final harvesting weight of *H. molitrix* was 120.6 ± 0.54, 128.3 ± 1.36, 134.0 ± 0.89

and 126.0 ± 0.81 g but net weight gain or growth of *H. molitrix* was 114.1 ± 0.51, 121.8 ± 1.24, 127.5 ± 0.82 and 119.5 ± 0.86 g in treatments T1, T2, T3, T4. The mean individual stocking weight, daily weight gain and survival percentage of *H. molitrix* is shown in Table 4.3.1. The survival percentage of *H. molitrix* was never less than 82 percent but it was the highest in T3 treatment (90.0±1.14). Net fish yield of *H. molitrix* was 6.1 ± 0.32, 6.6 ± 0.15, 7.3 ± 0.20 and 6.3 ± 0.03 kg in treatments (T1, T2, T3 and T4) of the ponds. It was the highest 2223.4 ± 0.20 kg $ha^{-1}yr^{-1}$ in T3 and the lowest 1858.4 ± 0.32 kg $ha^{-1}yr^{-1}$ in treatment T1. The final harvesting weights of *A. nobilis* in all treatments were 80.6 ± 0.54, 80.6 ± 0.54, and 90.0 ± 0.0 and 81.3 ± 0.54 g though the mean individual stocking weight were 7.0 ± 0.17, 7.0 ± 0.94, 7.0 ± 0.04 and 7.0 ± 0.14 g. The survival percentage of *A. nobilis* was 83.3 ± 3.78, 82.0 ± 2.77, 87.1 ± 1.03 and 85.8 ± 1.03 in T1, T2, T3, T4 treatments. Net weight gain of *A. nobilis* in treatments (T1, T2, T3 and T4) of the ponds were 74.1 ± 0.62, 73.4 ± 0.73, 83.0 ± 0.04 and 74.3 ± 0.67 g. Net fish yield of *A. nobilis* was 1.5 ± 0.09, 1.5 ± 0.07, 1.8 ± 0.02, and 1.6 ± 0.03 kg in the ponds of all treatments. Net production of bighead carp (*A. nobilis*) was the highest 565.7 ± 0.02 kg $ha^{-1}yr^{-1}$ in T3 and the lowest 480.5 ± 0.09 kg $ha^{-1}yr^{-1}$in treatment T1. The mean individual stocking weight of rohu (*L. rohita*) were 8.0 ± 0.04, 8.0 ± 0.08, 8.0 ± 0.18 and 8.0 ± 0.12 g in treatments T1, T2, T3, T4 and the final harvesting weight were 71.6 ± 1.36, 74.3 ± 1.9, 76.6 ± 1.36 and 72.6 ± 2.77 g. The survival percentage of *L. rohita* was 84.2 ± 1.61, 82.3 ± 2.78, 88.2 ± 0.00 and 81.3 ± 0.78 in T1, T2, T3, T4 treatments. Net weight gain by *L. rohita* in all treatments were 63.6 ± 1.23, 66.3 ± 1.82, 68.6 ± 1.52 and 64.6 ± 2.22 g. Net fish yield of *L. rohita* was 1.7 ± 0.03, 1.8 ± 0.10, 2.0 ± 0.04, and 1.7 ± 0.07 kg in the ponds of all treatments. Net production of rohu (*L. rohita*) was the highest 614.4 ± 0.04 kg $ha^{-1}yr^{-1}$ in T3 and the lowest 529.2 ± 0.07 kg $ha^{-1}yr^{-1}$ in treatment T4. The final harvesting weight of naini (*C. mrigala*) in treatments T1, T2, T3 and T4 were 72.3 ± 1.18, 75.0 ± 2.35, 85.6 ± 1.9 and 73.6 ± 1.51 g although mean individual stocking weight of *C. mrigala* in all treatments were 8.0 ± 0.09, 8.0 ± 0.18, 8.0 ± 0.4 and 8.0 ± 0.16 g. Net weight gain by naini in all treatments (T1, T2, T3, T4) were 64.3 ± 1.13, 67.0 ± 2.54, 77.6 ± 1.93 and 65.6 ± 1.65 g. The daily weight gain and survival percentage of *C. mrigala* is shown in Table 4.3.1. The survival percentage of *C. mrigala* at harvesting was from 85.8 to 91.0. Net fish yield of *C. mrigala* pond $^{-1}$ was 1.4 ± 0.01, 1.4 ± 0.10, 1.8 ± 0.05 and 1.4 ± 0.06 kg in the ponds of all treatments (T1, T2, T3, and T4). Net production of naini (*C. mrigala*) were 434.9 ± 0.01, 447.1 ± 0.10, 553.8 ± 0.05 and 444.0 ± 0.06 kg $ha^{-1}yr^{-1}$ in all treatments (T1, T2, T3, and T4). The highest production of *C. mrigla* $ha^{-1}yr^{-1}$ was in treatment T3 and the lowest production was in the treatment T1. The mean individual stocking weight of *A.mola* in treatments T2, T3, T4 were 1.5 ± 0.12, 1.5 ± 0.09 and 1.5 ± 0.12 g but the final harvesting weight were 3.6 ± 0.13, 3.5 ± 0.19 and 3.2 ± 0.11 g. Survival percentage of *A. mola* was not find out because *A. mola* bred repeatedly after stocking, therefore harvesting number was higher than stocking. A sudden decrease of growth of *A. mola* was observed in the last fish sampling due to smaller in the size of *A. mola* which indicated that it had bred in the previous month. Net weight gains of *A. mola* in treatments T2, T3, and T4 were 2.1 ± 0.01, 2.2 ± 0.09 and 2.0 ± 0.09. Net production of the *A. mola* $ha^{-1}yr^{-1}$ was the highest 1034.1 ± 0.21 kg $ha^{-1}yr^{-1}$in T3 and the lowest 839.5 ± 0.14 kg $ha^{-1}yr^{-1}$ in T4. The production of carps and SIS from experiment 3 in total per hectar per year is shown in Figure 14. The Species wise fish production $ha^{-1}yr^{-1}$ of expt 3 is shown in Figure 15.

Table 4.3.1 Growth & production of carps & SIS fish in expt. 2

Parameters	Treatments			
	T1	**T2**	**T3**	**T4**
***H. molitrix* (silver carp)**				
Initial mean wt.(g $fish^{-1}$)	6.5±0.12	6.5±0.14	6.5±0.09	6.5±0.08
Initial total wt. (kg $pond^{-1}$)	0.416±0.00	0.416±0.00	0.416±0.00	0.416±0.00
Final harvesting wt.(g $fish^{-1}$)	120.6±0.54	128.3±1.36	134±0.81	126±0.81
Final total wt. gain(kg $pond^{-1}$)	6.3±0.20	7.0±0.16	7.7±0.20	6.7±0.10
Daily weight gain ($g^{-1}fish^{-1}day^{-1}$)	0.94±0.00	1.01±0	1.05±0.00	0.99±0.00
Net mean fish yield (kg $pond^{-1}$)	6.1±0.32	6.6±0.15	7.3±0.20	6.3±0.03
Survival (%)	82.2±2.25	85.4±1.12	90.0±1.84	83.8±1.11
Net fish yeild (kg $ha^{-1}yr^{-1}$)	1858.4±0.32[b]	2010.5±0.15	2223.4±0.20[a]	1928.4±0.03
***A. nobalis* (bighead carp)**				
Initial mean wt.(g $fish^{-1}$)	7.0±0.17	7.0±0.94	7.0±0.04	7.0±0.14
Initial total wt. (kg $pond^{-1}$)	0.169±0.0	0.182±0.00	0.182±0.00	0.182±0.00
Final harvesting wt.(g $fish^{-1}$)	80.6±0.54	80.6±0.54	90±0	81.3±0.54
Final total wt. gain(kg $pond^{-1}$)	1.7±0.09	1.7±0.06	2.0±0.02	1.8±0.03
Daily weight gain ($g^{-1}fish^{-1}day^{-1}$)	0.61±0.00	0.6±0	0.69±0.00	0.61±0.00
Net mean fish yield (kg $pond^{-1}$)	1.5±0.09	1.5±0.07	1.8±0.02	1.6±0.03
Survival (%)	83.3±3.78	82.0±2.77	87.1±1.03	85.8±1.03
Net fish yeild (kg $ha^{-1}yr^{-1}$)	480.5±0.09	468.4±0.07	565.7±0.02	495.7±0.03
***L. rohita* (rohu)**				
Initial mean wt.(g $fish^{-1}$)	8.0±0.04	8.0±0.08	8.0±0.18	8.0±0.12
Initial total wt. (kg $pond^{-1}$)	0.272±0.00	0.272±0.00	0.272±0.00	0.272±0.00
Final harvesting wt.(g $fish^{-1}$)	71.6±1.36	74.3±1.9	76.6±1.36	72.6±2.17
Final total wt. gain(kg $pond^{-1}$)	2.0±0.03	2.0±0.10	2.3±0.04	2.0±0.07
Daily weight gain ($g^{-1}fish^{-1}day^{-1}$)	0.52±0.01	0.54±0.01	0.56±0.01	0.53±0.01

Net mean fish yield (kg pond^{-1})	1.7±0.03	1.8±0.10	2.0±0.04	1.7±0.07
Survival (%)	84.2±1.61	82.3±2.78	88.2±0.00	81.3±0.78
Net fish yeild (kg ha^{-1}yr^{-1})	541.4±0.03	550.5±0.10	614.4±0.04	529.2±0.07
***C. mrigala* (naini)**				
Initial mean wt.(g fish^{-1})	8.0±0.09	8.0±0.18	8.0±0.04	8.0±0.16
Initial total wt. (kg pond^{-1})	0.208±0.00	0.208±0.00	0.208±0.00	0.208±0.00
Final harvesting wt.(g fish^{-1})	72.3±1.18	75±2.35	85.6±1.9	73.6±1.51
Final total wt. gain(kg pond^{-1})	1.6±0.01	1.6±0.10	2.0±0.05	1.6±0.06
Daily weight gain (g^{-1}fish^{-1}day^{-1})	0.53±0.00	0.55±0.02	0.64±0.01	0.54±0.01
Net mean fish yield (kg pond^{-1})	1.4±0.01	1.4±0.10	1.8±0.05	1.4±0.06
Survival (%)	85.8±2.09	85.8±2.78	91.0±1.06	87.1±2.78
Net fish yeild (kg ha^{-1}yr^{-1})	434.9±0.01	447.1±0.10	553.5±0.05	444.0±0.06
***A. mola* (mara)**				
Initial mean wt.(g fish^{-1})	0	1.5±0.12	1.5±0.09	1.5±0.12
Initial total wt. (kg pond^{-1})	0	0.750±0.06	1.5±0.09	3.0±0.02
Final harvesting wt.(g fish^{-1})	0	3.6±0.13	3.5±0.19	3.2±0.11
Final total wt. gain(kg pond^{-1})	0	3.8±0.20	6.4±0.38	5.7±0.11
Daily weight gain (g^{-1}fish^{-1}day^{-1})	0	0.01±0	0.01±0.00	0.01±0.00
Net mean fish yield (kg pond^{-1})	0	3.1±0.16	3.4±0.21	2.7±0.14
Net fish yeild (kg ha^{-1}yr^{-1})	0	955.0±0.16	1034.1±0.21	839.5±0.14

Different superscript letters in the same row are significantly different (P<0.05) according to one way ANOVA and Tukey's test. (Mean±S.E)

Net production of carps and *A. mola* kg ha^{-1}yr^{-1} of experiment 3 is shown in Table 4.3.2

Table 4.3.2 Gross fish production (kg ha^{-1} yr^{-1}) in treatments of expt 3

Fish sps.	T1	T2	T3	T4
silver carp (*H, molitrix*)	1858.4±0.32^{c}	2010.5±0.15^{ab}	2223.4±0.20^{a}	1928.4±0.03^{b}
bighead carp (*A. nobilis*)	480.5±0.09	468.4±0.07	565.7±0.02	495.7±0.03
Rohu (*L. rohita*)	541.4±0.03	550.5±0.10	614.4±0.04	529.2±0.07
Naini (*C. mrigila*)	434.9±0.01	447.1±0.10	553.5±0.05	444.0±0.06
A. mola	0.0±0	955.0±0.16^{ab}	1034.1±0.21^{a}	839.5±0.14^{b}
Net total prod ^{n}	3315.4^{b}	4431.7^{ab}	4991.3^{a}	4237.0^{ab}

Different superscript letters in the same row are significantly different (P<0.05) according to one way ANOVA and Tukey's test. (Mean±S.E)

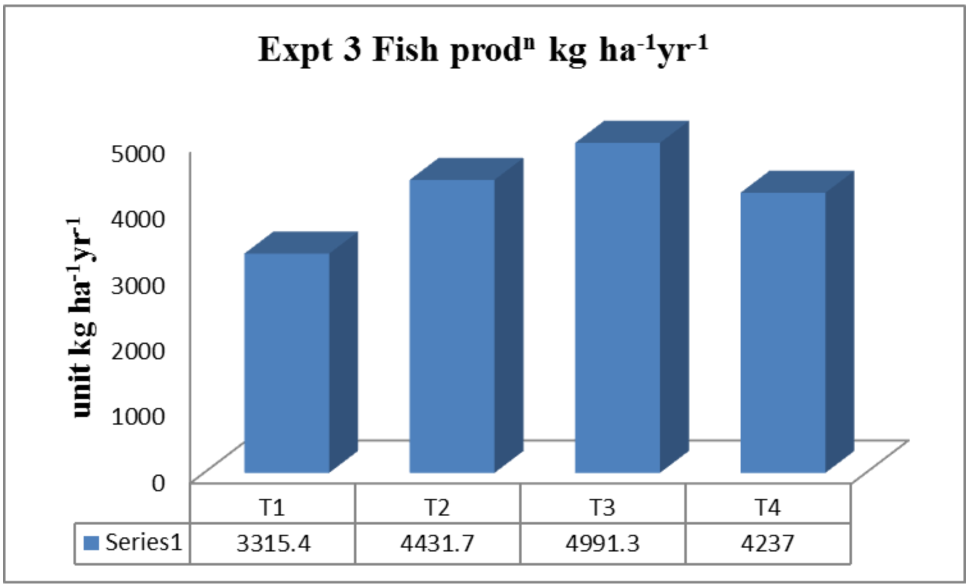


Figure 14 Fish production (kg $ha^{-1}yr^{-1}$) in treatments of experiment 3

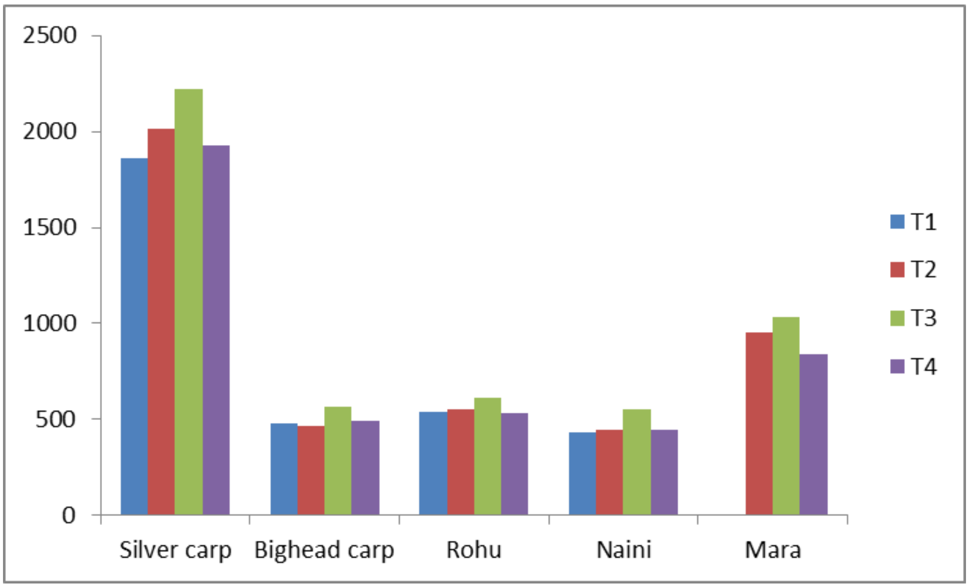


Figure 15 Species wise fish prod ^{n} (kg $ha^{-1}yr^{-1}$) in treatments of expt 3

4.4.2 Benefit-cost analysis result in expt 3

The financial characteristics of experiment 3 i.e the locally purchased item's costs and total return from the sale fish of all treatments are presented in Tables 4.3.3, 4.3.4, 4.3.5 and 4.3.6. The major and also variable input costs were mainly due to experimental fishes's fry, supplemental feeds and fertilizers. The highest net benefit was calculated in treatment T3 and it was followed by treatments T2, T4 and T1. The net highest benefit was 1786.9 ± 64.20 rupees pond^{-1} in T3. It was 1689.6 ± 66.42 in T2, 761.4 ± 70.31 in T4 and 769.1 ± 40.08 rupees pond $^{-1}$ in T1. Net benefit rupees ha^{-1}yr^{-1} was the highest 43533.7 ± 64.20 in treatment T3 and the lowest 231598.0 ± 70.31 in treatment T4. However net benefit was compared among treatments control (T1) gave the poor production but the lowest production was in the highest stocking rate of *A. mola* of treatment T4, it suggests that appropriate stocking ratio of *A. mola* with the carp species *H. molitrix*, *A. nobilis*, *L. rohita* and *C. mrigla* for carp SIS polyculture may be 10,0000 ha^{-1}.

Table 4.3.3 Pond based variable costs in Nepalese currency of different treatments in expt 3

Variables	Treatments											
	T1			T2			T3			T4		
	P4	P7	P9	P6	P11	P12	P1	P2	P5	P3	P8	P10
Feeding tray	100	100	100	100	100	100	100	100	100	100	100	100
silver carp	192	192	192	192	192	192	192	192	192	192	192	192
bighead carp	130	130	130	130	130	130	130	130	130	130	130	130
rohu	170	170	170	170	170	170	170	170	170	170	170	170
naini	130	130	130	130	130	130	130	130	130	130	130	130
mara	0	0	0	250	250	250	500	500	500	1000	1000	1000
Urea	45	45	45	45	45	45	45	45	45	45	45	45
DAP	65	65	65	65	65	65	65	65	65	65	65	65
Cow dung	60	60	60	60	60	60	60	60	60	60	60	60
Lime	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5
Oil cake	10.5	10.3	10.1	12.6	12.4	12.8	14.5	14.7	14.7	15.2	15.5	15.7
Rice bran	12.3	12.5	12.6	15.2	15.8	15.5	16.5	18.7	16.8	17.5	17.3	17.2
Total	952.3	952.3	952.3	1207.4	1207.7	1207.8	1460.5	1462.9	1461.0	1962.2	1962.3	1962.5

Table 4.3.4 Gross return in Nepalese currency from treatments of expt 3

Treatments							
T1		T2		T3		T4	
Ponds	Rupees	ponds	Rupees	ponds	Rupees	ponds	Rupees
P4	1672.6	P6	2839.9	P1	3332.8	P3	2890.7
P7	1672.1	P11	2794.0	P	3090.3	P58	2604.1
P9	1819.6	P12	3057.9	P5	3322.2	P10	2676.4
Mean ± SE	1721.4±40.08	Mean ± SE	2897.2±66.46	Mean ± SE	3248.4±64.60	Mean ± SE	2723.7±70.27

Table 4.3.5 Gross margin value in Nepalese currency from treatments of expt 3

Treatments							
T1		T2		T3		T4	
Ponds	Rupees	Ponds	Rupees	Ponds	Rupees	Ponds	Rupees
P4	720.3	P6	1632.5	P1	1872.3	P3	928.5
P7	719.8	P11	1586.2	P	1627.3	P58	641.7
P9	867.3	P12	1850.1	P5	1861.1	P10	713.9
Mean ± SE	769.1±40.08	Mean ± SE	1689.6±66.42	Mean ± SE	1786.9±65.20	Mean ± SE	761.4±70.31

Table 4.3.6 Gross margin analysis (Rs pond $^{-1}$& ha^{-1}yr^{-1}) in Nepalese currency expt3

Parameters	Treatments			
	T1	T2	T3	T4
Outputs	1721.4±40.08	2897.2±66.46	3248.4±64.60	2723.7±70.27
Inputs	952.3±0.00	1207.6±0.10	1461.5±0.60	1962.3±0.05
Gross margin Rspond $^{-1}$	769.1±40.08	1689.6±66.42	1786.9±64.20	761.4±70.31
Gross margin Rs ha $^{-1}$ yr $^{-1}$	233941±40.08^{b}	513926.1±66.42^{ab}	543533.7±64.20^{a}	231598.0±70.31^{b}

Different superscript letters in the same row are significantly different (P<0.05) according to one way ANOVA and Tukey's test. (Mean±S.E)

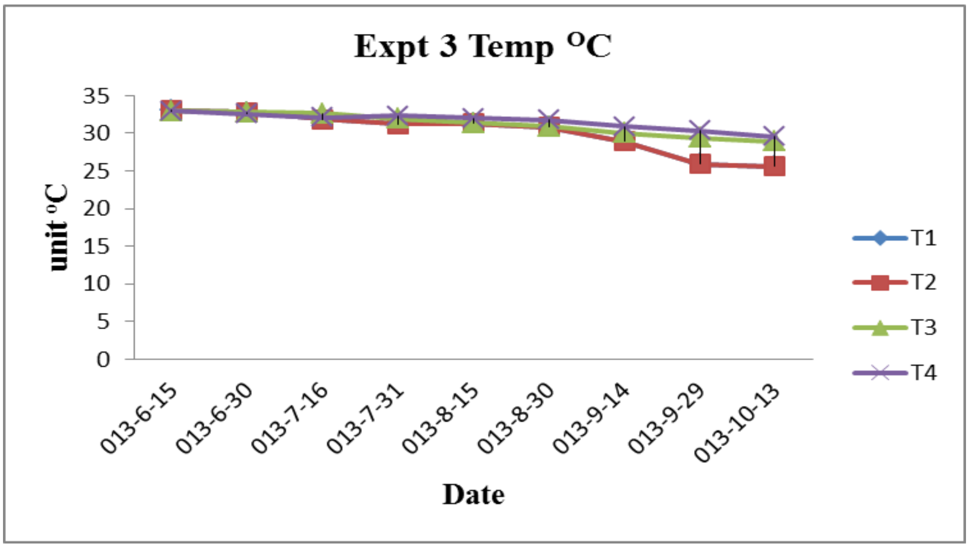
4.4.3 Summary of water quality parameters of experiment 3

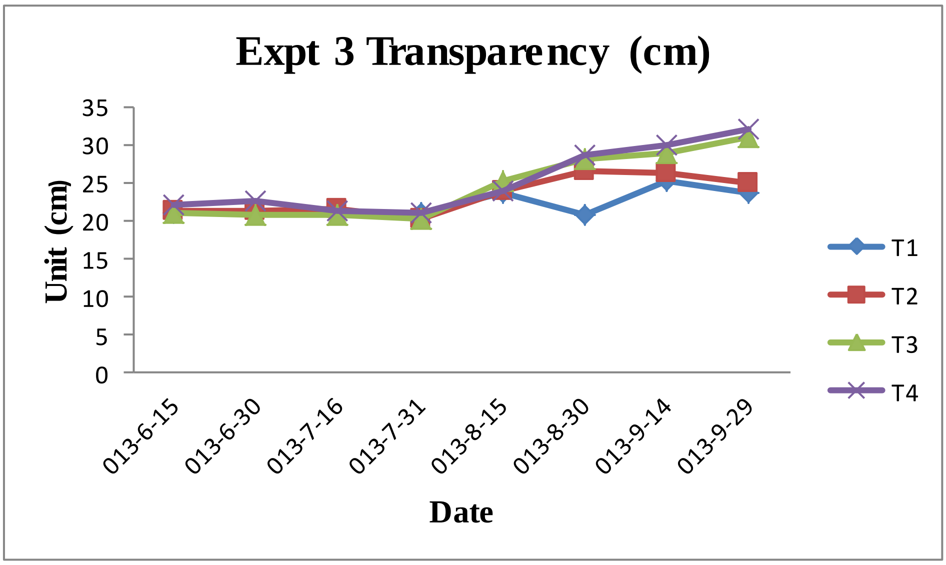
The water quality parameters of experiment 3, water temperature, transparency, DO, pH, total alkalinity and CO_2 are shown in Table 4.3.7. The water temperature was recorded from 28.2^{0}C to 33.1^{0}C among the all treatments of experiment. The mean water temperature was 34 ± 1.18 ^{0}C in treatment T1, 29.1 ± 1.14 ^{0}C in treatment T2, 29.1 ± 1.07 ^{0}C in treatment T3 and 28.6 ± 0.98 ^{0}C in treatmentsT4. The mean transparency was 21.9 ± 0.59 cm in treatment T1, 22.9 ± 0.85 cm in treatment T2, 24.1 ± 1.43 cm in treatment T3 and 24.7 ± 1.44 cm in treatment T4. The transparency remained from 18.0 cm to 32.0 cm. It was significantly lower in treatment T2 than the treatments T1, T3 and T4. Dissolved oxygen of pond water remained from 3.5 mg L^{-1} to 9.6 mg L^{-1} during experimental period and it did not vary among the treatments. The mean value of dissolved oxygen was 6.2 ± 0.53 in treatment T1, 6.1 ± 0.54 in treatment T2, 56.8 ± 0.63 in treatment T3 and 7.0 ± 0.63 mg L^{-1} in treatment T4. The mean value of pH was 7.8 ± 0.06, 7.8 ± 0.08, 7.6 ± 0.06 and 7.8 ± 0.06 in T1, T2, T3 and T4. The pH varied from 7.4 to 8.5 during experimental period. Total alkalinity of treatments varied from 80.0 to 142.0 mg L^{-1} during experimental period. The mean value of total alkalinity was 93.3 ± 4.81 mg L^{-1} in treatment T1, 111.8 ± 3.5 mg L^{-1} in treatment T2, 113.0 ± 2.38 mg L^{-1} in treatment T3, and 112.6 ± 3.22 mg L^{-1} in treatment T4. The CO_2 varied from 10.0 to 14.5 mg L^{-1}. The mean value of CO_2 was 12.3 ± 3.85 mg L^{-1} in T1, 9.3 ± 1.06 mg L^{-1} in T2, 9.3 ± 1.12 mg L^{-1} in T3 and 8.7 ± 1.00 mg L^{-1} in T4. Fortnightly recorded water quality parameters, water temperature, transparency, DO, pH, total alkalinity and CO_2 of experiment are shown in Figure 16 and 17.

Table 4. 3.7 Water quality parameter's summary of whole experimental period expt 3

parameters	Treatments			
	T1	T2	T3	T4
Temperature (^{0}C)	29.3 ± 1.1	29.1 ± 1.1	29.1 ± 1.0	28.6 ± 0.9
Transparency (cm)	21.9 ± 0.5	22.9 ± 0.8	24.1 ± 1.4	24.7 ± 1.4
DO (mg L^{-1})	5.2 ± 0.5	6.1 ± 0.5	5.8 ± 0.6	5.0 ± 0.6
pH	7.8 ± 0.0	7.8 ± 0.0	7.6 ± 0.0	7.8 ± 0.07
Total Alkalinity (mg L^{-1})	93.3 ± 4.8	111.8 ± 3.5	113.0 ± 2.3	112.6 ± 3.2
CO_2 mg L^{-1}	12.3 ± 3.8	9.3 ± 1.0	9.3 ± 1.1	8.7 ± 1.0

Different superscript letters in the same row are significantly different (P<0.05) according to one way ANOVA and Tukey's test. (Mean±S.E)





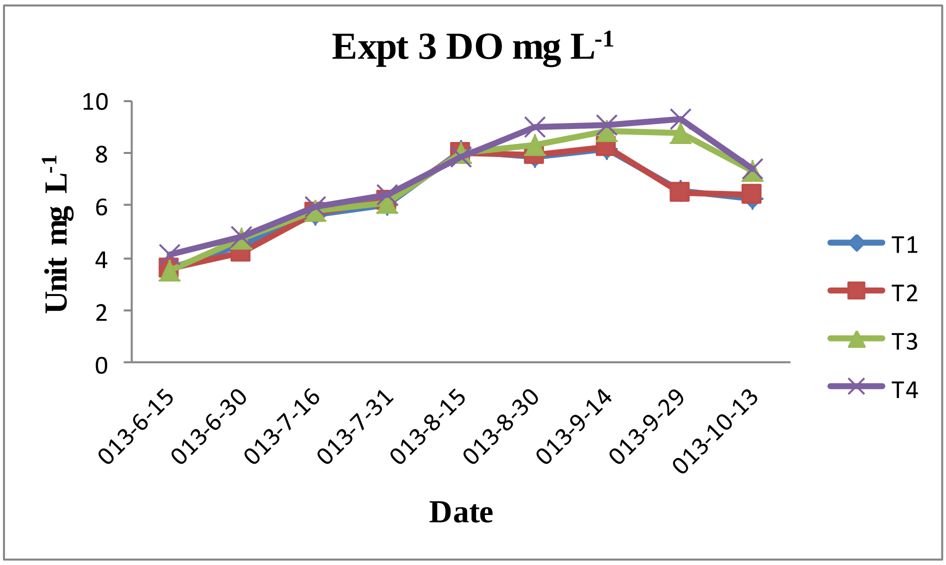


Figure 16 Fortnight variation water temp, transparency & DO of experiment 3

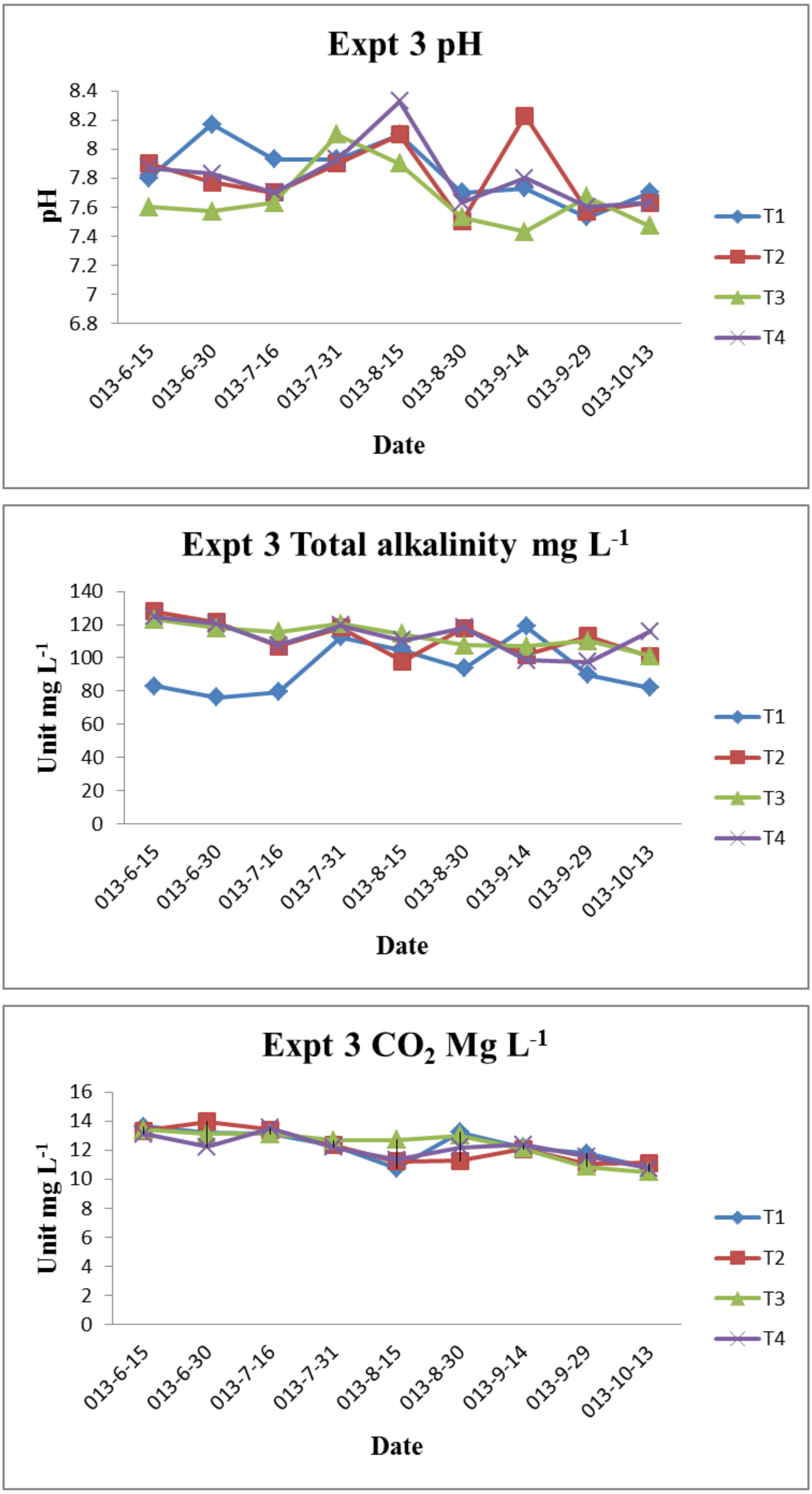


Figure 17 Fortnight variation in P^H, total alkalinity & CO_2 of experiment 3

4.4.4 Plankton composition and biomass of experiment 3

Mean (±SE) abundance of plankton's record in all treatments of expt.3 is shown in Table 4.3.8 and Table 4.3.9. Four group of phytoplankton and three group of zooplankton were investigated during the experimental period. A total of 39 genera of planktons were recorded from the experimental ponds, but among them phytoplanktons were 26 genera and zooplanktons were 13 genera. Among all phytoplanktons 4 genera were from group bacillariophyceae, 13 genera were from group chlorophyceae, 7 genera were from group cyanophyceae and 2 genera were from group euglenophyceae. Among the zooplanktons 6 genera were from group crustacea, 6 genera were from group rotifera and 1 genus was from protozoa group. There were 2 unidentified zooplanktons. Genus *Chlorella* showed the highest abundance among the phytoplankton and it was followed by *pediastrum.* Genus *Brachiomus* showed the highest abundance among the zooplanktons and it was followed by *Nauplius*. Mean abundance of phytoplankton was too much higher 5626.1 ± 1136.03 in the treatment T3 than other three treatments. The mean abundance of zooplankton was too much high in the treatment T3.

Table 4.3.8 Phytoplankton's record (units L^{-1}) of experiment 3

		T1	T2	T3	T4
		(units L^{-1} ± SE)			
Group	Genus				
Chlorophyceae	*Chlorella*	23560±194	34740±562	30100±403	24180±395
	Closterium	2480±167^{ab}	0.0±0.0^{b}	10590±333^{a}	6340±297^{ab}
	Characium	5440±298^{a}	0.0±0.0^{b}	2921±179^{ab}	1440±78^{ab}
	Actinastrum	2100±113	6000±343	3100±185	6840±259
	Cladophora	0.0±0.0	1420±83	1120±63	2140±91
	Chlamydomonas	4420±197	3000±239	2120±114	2200±125
	Oedogonium	3120±175^{a}	0.0±0.0^{b}	820±65^{ab}	3100±174^{ab}
	Netrium	640±51	0.0±0.0	2140±92	0.0±0.0
	Pediastrum	10800±307	13460±258	11850±288	9010±275
	Selenastrum	8490±250	6060±353	6000±216	2840±226
	Spirogyra	1180±65	1980±107	1160±62	1460±81
	Tetraedron	3260±185	3920±178	3080±130	3660±202
	Tetraspora	0.0±0.0	5800±212	4280±206	3100±170
	Subtotal	65490±1680	76380±2476	79281±2094	66310±1635
Cynophyceae	*Volvox*	5720±217^{a}	0.0±0.0^{b}	4640±179^{ab}	920±73^{ab}
	Ulothrix	3380±193	3220±256	2480±137	3150±176
	Anabaena	2500±358	1680±317	2400±317	0.0±0.0
	Microcystis	5090±582	1420±397	4620±894	1120±313
	Oscillatoria	2820±789	3920±616	3340±540	940±263
	Gloeocapsa	3540±710	2640±495	3360±527	920±257
	Chroococcus	3360±666	3300±924	4780±682	4840±919

	Subtotal	26410±388	16180±443	25620±335	11890±550
Euglinophyceae	*Euglina*	1420±397	1720±481	3180±355	10140±729
	Phacus	5880±562	4460±691	4400±623	8580±838
	Subtotal	7300±1577	6180±968	7580±431	18720±551
Bacillariophyceae	*Fragillaria*	4940±575	3320±695	10740±705	9100±706
	Diatoma	4900±595	9640±954	9620±1293	8260±641
	Synedra	2640±484	10940±1717	4000±466	9940±957
	Cyclotella	10460±1369	3700±567	9440±797	6540±805
	Subtotal	22940±1441	27600±1711	33800±1308	33840±628
	Total phytoplankton	4697.6±911.2	4859.2±1343.0	5626.1±1136	5029.2±984
	Unknown sps.	26.7±20.4	22.6±9.4	32.9±9.8	11.7±6.8
	No. of identified species	26	26	26	26

Different superscript letters in the same row are significantly different (P<0.05) according to one way ANOVA and Tukey's test, (Mean±S.E).

Table 4.3.9 Zooplankton's record (units L^{-1}) in treatments of expt. 3

		Treatment 1 (T1)	Treatment 2 (T2) units L^{-1} ± SE	Treatment 3 (T3)	Treatment 4 (T4)
Group	**Genus**				
Crustacea	*Cyclops*	8030±633	4590±377	5830±448	1560±138
	Daphnia	1620±142	1800±187	1700±149	450±46
	Ceriodaphnia	2650±215	650±67	1845±161	1700±149
	Moina	2870±255	1524±133	840±87	6190±486
	Nauplius	6000±487	1580±138	16510±1227	8350±652
	Diaptomus	2960±241^{a}	0.0±0.0^{b}	800±83^{ab}	1700±149^{ab}
	Subtotal	24130±3023	10144±1355	27525±3929	19950±2637
protozoa	*Diffugia*	3795.0±308	4785.0±432	15100±1174	4440±394
	Subtotal	3795.0±308	4785.0±432	15100±1174	4440±394
rotifera	*Brachionus*	3750.0±318^{c}	5880±455^{b}	24660±1808^{a}	13400.0±974^{ab}
	Keratella	2000.0±184	5830.0±460	2890±255	3970.0±328
	Monostyla	1790.0±157	930±96	0.0±0.0	1660.0±145
	Trichocerca	1780.0±155	660±68	5560±459	9020.0±720
	Filinia	3100±323	920±95	2700±247	780±81
	Asplanchna	1000±104	5085±414	800±83	5740±478
	Subtotal	13420±1651	19305±2492	258610±46397	34570±4473
	Total zooplankton	3180.3±516	2633.3±590	6095±2056	4535.3±1037
	Unknown sps.	0.3±0.2	0.4±0.2	0.5±0.2	0.5±0.1
	No. of identified species	3	5	2	13

Different superscript letters in the same row are significantly different (P<0.05) according to one way ANOVA and Tukey's test, (Mean±S.E).

DISCUSSION

4.5 Discussion on SIS diversity and abundance

The diversity of indigenous fish species of Nepal has been studied time to time (Hora, 1949; Menon, 1949, Shrestha, 1981, 1995, 2007, 2008). Menon found the diversity of 26 genera and 52 fish species from Koshi River belonging to 11 families. Shrestha (1981) obtained the diversity of 120 fresh water fish species from the rivers, ponds, lakes etc of Nepal. The diversity of fresh water fishes enriched time to time from the various studies conducted in Nepal. A total of fish diversity 206 species (Shresth, 2011), 227 species and 202 species (Shresth, 2007, 2008) was restricted to only the taxonomic diversty of fresh water fishes but it was unexplored about the richness of fish species, distribution of fishes, present status of fishes, dominant species of fishes. Though the documentation of Nepalese fish fauna is available but small indigenous fishes or SIS remained unexplored in the past. Small indigenous fishes (SIS) are the fresh water fish fauna of Nepal which attain the maximum length of about 25 cm even in fully grown stage. They are captured from fresh water bodies and quickly brought to sell in local markets. Altogether 55 species of SIS was investigated from present study Karn (2014) which is less in diversity than Bangladesh and India Mazid and Kohinoor (2003) and Sarkar and Lakra (2010). The less number of SIS diversity and their abundance in present study may be due to unexplored area of mountainous region and western Terai Nepal. The species richness of SIS in India and Bangladesh is related with flood occupied large area of country because flooded water is ideal habitat, feeding and breeding ground of SIS species.The SIS diversity was high in station S1 or Saptari district (55 sps) most probably it contained SIS landing from the large river and flooded area, more tributaries, ponds and tanks, lakes, streams, lowland areas, wetlands etc of country. The species richness of SIS is related with flooded plains, beels etc in Bangladesh, (Akhteruzzaman & Kuiya, 2003) and in India (Sarkar & Lakra, 2010). The high species richness of SIS in sampling station S1 or Saptari district seemed to be similar with the reports of Bangladesh and India (Akhteruzzaman & Kuiya, 2003 and Sarkar & Lakra, 2010). The SIS diversity was lesser in sampling stations S2, S3, S4, S5, S6, S7 and S8 than S1 throughout the study period may be due to the less abundant water bodies such as permanent rivers, large rivers, marshy land and increased activities of aquaculture in thsese areas. The checklist of recent trend on pattern, and abundance of small indigenous fish species of the Ganga basin and associated protected areas have been prepared by Sarkar and Lakra (2010). The checklist included minnows (*Chela* spp, *Rasbora* spp, *Amblypharyngodon* spp and *Salmophasia* spp), barbs (*Puntius* spp), scheilbids (*A. coila* and *Eutropichthys* spp), clupeids (*G. chapra*) and bagrids (*H. menoda* and *Mystus* spp) etc as the dominating groups of fishes. The checklist report obtained from this study resembles with the species composition of the Ganga river basin. Present study report includes the *Amblypharyngodon mola*, *Chela* spp and *Rasbora* spp (Minnows), *A. coila* and *Eutropichthys* spp (Scheilbids), *Mystus* spp (Bagrids), *Puntius* spp (Barbs) *Lepidocephalichthys guntea, Botia lochata, Semileptes gongota, Noemacheilus* spp (Cobitids), *Channa* spp (Snakeheads) etc. The gravid females of many SIS species such as *Colisa fasciatus, A. mola, Anabas testidunus, P.sophore, P. ticto, C. maurilius, H. fossilis, M. tengra, C. batrachus, C. nama, N. notopterus, X. cancila* etc were collected during May and June months of study period which suggests the breeding season of SIS species. Similar finding was reported by Akhteruzzaman and Kuiya (2003) from Bangladesh. Majority of SIS landing was very high in rainy season probably due to frequent movement from flooded water of river into ponds, ditches, paddy fields etc. A total of 91 species of minor carps (30 cm in length) were reported from the lakes of Pokhara valley in Nepal (Wagle et al., 2008). These numbers are similar to the previous reports on fish species of Nepal (Shrestha, 1981; Rajbanshi, 1981; Rajbanshi, 2002; Gurung et al., 2003). Mazid and Kohinoor (2003) reported 143 species of SIS from Bangladesh, among total of 260 species of fresh water fish fauna of country. Altogether 765 species of fresh water fishes has been reported from Ganga river basin India and among them 450 species are small indigenous fish species (Sarkar & Lakra, 2010).

One of the most complicated aspects of biodiversity is to find out the quantity of biological species (Gaston & Spicer, 1998). Many biodiversity indices have been created in an attempt to capture the diversity of biological species of an area. These indices attempt to define biodiversity in many different ways though most indices use a combination of number of species and the degree of difference between those species (Gaston & Spicer, 1998). Three diversity indices Shannon index, Simpson index and Margalef index were used to find out the diversity and species richness of small indigenous fish species (SIS) because it is said that the best way to characterize biodiversity is through the use of numerous biodiversity indices.

Shannon index as 3.53 was highest at S1 sampling station and it indicates good icthyobiodiversity. The sampling stations S2, S3, S5, S6 and S8 have also Shannon index (H) value more than 3 while two other sampling stations S4 and S7 have less Shannon index (H) value than 3. According to Wilhm and Dorris (1966) Shannon index (H) value ranged from >3 indicates good diversity, 1.00 to 3.00 indicates moderate diversity and <1.00 indicates poor diversity.

Simpson's diversity is used to measure diversity in account of the number of species present as well as the relative abundance of each species. The Simpson index represents the probability that two randomly selected individuals in the habitat will belong to the same species. In this form, Simpson index ranges from 0 to 1, in which 0 representing infinite diversity and 1 representing no diversity. A low Simpson index value signifies high diversity, whereas a high value correlates to a low diversity. The highest Simpson index value 0.08 was recorded at S4 and S7 while lowest value 0.04 was recorded in S1 sampling station during the study. The Simpson index value was 0.05 in S3 and 0.06 in S2, S5, S6 and S8 sampling station. It indicates that highest diversity was found in S1station, moderate diversity was in S2, S5, S6 and S8 station and the lowest diversity was in in S4.

Margelef index has no limit value and it shows a variation depending upon the number of species. Thus, it is used for comparing the sites (Kocataş, 1992). In present study the high margelef index value explains high diversity of species like that of the Shannon index value. The high margelef index value was present at the S1 sampling station and lowest values was present at the S7 and S4 sampling stations while moderate margelef index value were at other stations S2, S3, S5,S6 and S8 respectively. It indicated that highest diversity was found at S1 station may be due to large area covered from water, more flooded plains and large rivers. The sampling station S7 and S4 have low diversity that may be due to absence of permanent rivers flowing into this sampling area, less flood occupied plain, swampy lands for the SIS collection and sell into market.

4.6 Determination of production performance of SIS spp *P. ticto, A. mola* and *E. denricus* in expt 1

4.6.1 Discussion on production performance of SIS spp *P. ticto, A. mola, E. denricus* in expt 1

The production and growth of SIS species *P. ticto, A. mola* and *E. denricus* showed that the highest yield of SIS species was obtained in T1 treatment which included monoculture of *A. mola*. Individual weight of *A. mola* at harvesting in treatment T1 was significantly higher (P<0.05) than *P. ticto* and *E. denricus* in T2 and T3 treatments. The highest mean weight gained by *A. mola* was 3.2 g in P9 pond of T1 treatment and the lowest weight gain was 2.9 g in P2 pond of T1 treatment. Mondal (2001) reported that the average final weight of *A. mola* was 2.7 g and Ameen et al., (2008) obtained the growth rate of *A. mola*, 3.12 g, 3.16 g, 3.67 g and 3.57 g in treatments (T1, T2, T3 and T4) of experiment, "Inclusion of mola and prawn effects in water quality and rice production in prawn- fish-rice culture system". So the growth rate of *A. mola* of present experiment resembles with Ameen et al.(2008). The survival rate of *P. ticto, A. mola* and *E.denricus* was not being recorded because they had spawned after stocking. Therefore harvesting number was too much higher than stocking number in experiment. The breeding season of *A. mola* started from May and continued till October in Bangladesh (Afroze & Hossain, 1990). *A. mola* bred three times during three months of the culture period in the study of Rahmatullah *et al.*(1994). Piska and Waghray (1986) obtained similar type of result. These results are similar to the result of present study. The significant lower growth rate of SIS fish species of T2 treatment and T3 in comparision to T1 treatment may be due to variation in growth rate of individual type of fish species used in aquaculture.

The net yield of *Amblypharyngodon mola* was 7.1 ± 0.29 kg in the T1 treatment during study duration but it was 592.5 kg yr^{-1} ha^{-1}. The net yield of fish species *P. ticto* was 5.5 ± 0.19 kg in the T2 treatment during study duration but it was 460 kg $yr^{-1}ha^{-1}$. The net yield of *E. denricus* was 5.1 ± 0.04 kg in the T2 treatment during study duration but it was 428.3 kg $ha^{-1}yr^{-1}$. There was significant (P<0.05) higher production of SIS species *A. mola* in treatment T1 (592.5 kg $ha^{-1}yr^{-1}$) than SIS species *P. ticto* in treatments T2 (460 kg $ha^{-1}yr^{-1}$) and SIS species *E.denricus* in treatment T3 (428.3 kg $ha^{-1}yr^{-1}$). No significant difference in production of *P.ticto* and *E. denricus* was noticed between treatment T2 and T3. A similar variation was reported by Rahmatullah et al.(1994) in the case of *A. mola* and chapila (*G. chapra*) culture in pond condition. Kohinoor et al.(2001) obtained a production of 505 kg, 1,120 kg and 509 kg ha^{-1} in 6 per month for *A. mola*, *Puntius sarana* and *Chela lubaca* respectively under monoculture system. Mustafa (1991) obtained a production of 4 to 5 tons ha^{-1} yr^{-1} of *A. mola*, *P. chola* and *Colisa fasciatus*. The production of *A. mola, P. ticto* and *E denricus* is lower in present study than the finding of Mustafa (1991) may be due to selection of different experimental fish species, soil and water condition of the ponds.

4.6.2 Discussion on gross margin analysis of expt 1

The analysis of economic feasibility for three treatments and three fish species in present experiment showed higher significant gross margin in the treatment T1 ($P<0.05$) but no significant gross margin difference between T2 and T3. The variable costs for inputs in all treatments were similar with one another but the gross return was higher in treatment T1 due to high price of mola and consumer's high preference for the *A. mola* in local market.

4.6.3 Discussion on water quality parameters of expt 1

All the water quality parameters were within the suitable range for the growth, production and breeding of SIS species. Average water temperature was recorded from 30.0^{O}C to 32.5 ^{O}C without much marked variations in these experimental ponds. SIS species has wide range of temperature tolerance and they prefer to live in shallow water where water temperature remains high (Akhteruzzaman & Kuiya, 2003). Kohinoor (2000) recorded water temperature 26-33.7 ^{O}C respectively in the ponds of Bangladesh used for fish culture. The water transparency was recorded from 20.0 to 34.0 cm with significant lower reading in treatment T3 than in treatments T1 and T2. The variation in transparency was due to abundance of planktons. The transparency ranged from 15-40 cm is considered as appropriate for fish's growth and production (Boyd, 1982). The dissolved oxygen was recorded between 4.2 mg L^{-1} and 6.4 mg L^{-1} during experimental period. Relatively high DO in ponds was probably due to recording of DO in late morning. The dissolved oxygen did not vary significantly among the treatments. The planktonic density might be responsible for accelerated rate of photosynthesis in the experimental ponds of all treatments. Wahab et al.(1995)

recorded similar result of dissolved oxygen 2.2-7.1 mg L^{-1} in experimental ponds of Bangladesh. The dissolved oxygen lying between 5.0 to 10.0 PPM in fish ponds is considered as the ideal for fish production (Banarjee et.al., 1990). The pH of pond water was always around 7.5 throughout the experimental period. Swingle (1967) recommended, pH value ranging from 7.0 to 9.2 as the suitable for fish culture. The total alkalinity of pond water recorded from 82.8 to 130.5 mg L^{-1}. Similar finding of total alkalinity was recorded by Oppenheinmer et al.(1978). The free CO_2 of pond water was recorded from 10.5 mg L^{-1} to 14.2 mg L^{-1} during experimental period and it did not vary among the treatments. The upper limit of free carbon dioxide has been recommended as 25 mg L^{-1} for the safeguard of fish culture (Hynes, 1970).

4.6.4 Discussion on plankton abundance and density of expt 1

The plankton biomass varied significantly among the sampling dates but did not vary among the treatments ($P<0.05$). A total of 41 genera of planktons were recorded from the experimental ponds, out of them 25 genera were phytoplanktons and 16 genera were zooplanktons. Abundance of Phytoplanktons and zooplanktons per litre water of the ponds is interrelated with the growth and production of fishes by assuring the natural fish foods available in the ponds (Jhingran, 1982). Phytoplanktons belonged to four groups: Chlorophyceae, Cyanophyceae, Euglinophyceae and Bacillariophyceae. The Chlorphyceae group contained 13 genera, Cyanophyceae 5 genera, Bacillariophyceae 4 genera and Euglinophyceae 2 genera with the Chorophyceae as dominant group in the study. There were no significant differences in phytoplankton abundance among the treatments. Wahab et al.(1994) reported 25 genera of phytoplankton belonging to Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae group and 5 genera of zooplanktons belonging to Crustacea and Rotifera group. In the present study the zooplanktons belonged to three groups: Rotifera (6 genera), Protozoa (1 genus) and Crustacea (6 genera). There were no significant differences in numbers of Rotifera, Protozoa and Crustacea among the treatments. Among zooplankton group Rotifera was the dominant group. Kohinoor et al.(1998) recorded only two groups of zooplanktons viz. Crustacea (4 sps) and Rotifera (4 sps) from Bangladesh. The finding of phytoplanktons and zooplanktons in present study resembles with the result of Wahab et al.(1994) but planktons were found more than Kohinoor et al.(1998), probably due to the chemical nature of soil and annual rain pattern.

4.7 Determination of stocking combination between carp and SIS of expt 2

4.7.1 Discussion on growth and production performance of carp and SIS

Three different combinations of carp species with A. mola was taken in the experiment. Silver carp (*H. molitrix*), bighead carp (*A. nobilis*), rohu (*L. rohita*) and naini (*C. mrigala*) in treatment T2, silver carp (*H. molitrix*), bighead carp (*A. nobilis*), rohu (*L. rohita*), naini (*C. mrigala*) and grass carp (*C. idella*) in treatment T3, and silver carp (*H. molitrix*), bighead carp, rohu (*L. rohita*), naini (*C. mrigala*) grass carp (*C. idella*) and common carp (*C. carpio*) in treatment T4 stocked with *A.mola* showed variation in growth and production of individual type of carp species in experiment 2.

Growth of silver carp was the high in T2 treatment among all. The competition for food did not occur between *H. molitrix* and *A. mola*, most probably sharing food in different feeding niche. The addition of *A. mola* and/or *Puntius sarana* fish ponds did not affect the growth of *H. molitrix* and common carps (Kadir et al., 2007). There were no significant differences (p >0.05) in individual harvesting weight of *H. molitrix*, indicating that *H. molitrix* production was not affected by *A.mola*. Roy (2004) also reported that *H. molitrix* production was not affected by the presence or absence of mola in carp – mola polyculture system.

Growth of *A.nobilis* (zooplankton feeder) was the high in T2 treatment in comparision of other treatments though it was lower than the growth of silver carp in all treatments. It may be due to the interspecific food competition among *A.nobilis*, *A. mola* and *H. molitrix*. Roy (2004) reported that production of *Catla catla* (zooplankton feeder) was higher in presence of grass carp and in absence of silver carp in his study on carp-SIS polyculture system. The addition of *A.mola* or *puntius sarana* in fish ponds affected rohu (*L. rohita*) and catla (*C. catla*) growth but did not affect the growth of common carp and silver carp. The addition of *A. mola* reduced catla's production performance by 20-24% (Kadir et al., 2007). There were no significant differences (p>0.05) in harvesting weight survival, total yield and net yield of *A. nobilis* among treatments.

Production of rohu (*L. rohita*) was lower in present study in presence of both higher stocking densities of silver carp and *A.mola* respectively. This might be due to the interspecific competition between rohu (*L. rohita*) and these two species. Roy (2004) reported lower growth of rohu (*L. rohita*) in higher stocking densities of *A. mola*. Kohinoor *et al.*(1998) also found that *A. mola* competes for food and space with *L. rohita*. The growth of naini (*C. mrigala*) and *L. rohita* in all treatments were less than silver carp perhaps due to the low stocking density and the slow growth rate of these fishes than the *H. molitrix*. Production of *C. mrigala* in this study was high in presence of *A. mola.* Presence of silver carp showed increased production of *C. mrigala* (Roy, 2004). Milstein (1992) reported such synergistic effect between *H. molitrix* and *C. carpo*. Grass carp (*C. idella*) growth was high at high stocking density of both silver carp (*H. molitrix*) and *A. mola*. Survival was the highest where both silver carp (*H. molitrix*) and *A. mola* were stocked in the treatment. This species have antagonistic effect on more than one species in carp polyculture system. Roy (2004) found that *C. idella* production was not affected by the presence or absence of silver carp, but it performed better growth and production in presence of *A. mola.*

The growth and production of common carp (*C. carpio*) was high in combination with *A. mola* in T4 treatment of this experiment. Alim (2005) reported that presence of *A. mola* had increased the growth parameter of *C. carpio*. These effects are explained and discussed considering fish interactions through the food web (Kadir et al., 2007). Roy (2004) stated that growth of *A.mola* was better with grass carp combination along with other carps reared together than the silver carp combination with other carps. Kohinoor et al.(1998) stated that the antagonisms between silver carp and *A.mola* were shown in their experiment. The highest net yield of carps (4559.4 kg $ha^{-1}yr^{-1}$) was found in T2, it may be due to of pond's food proper utilization, suitable water quality condition, and high abundance of planktons in pond water, consumption and conversion of artificial feed and fish interactions through the food web.

Paul (1998) and Hossain (2006) recorded high yield of silver carp with the low production of zooplankton feeder species. The present finding of high yield of silver carp in carp SIS culture experiment satisfy with Paul (1998) and Hossain (2006). The gross production of fishes (4559.4 kg $ha^{-1}yr^{-1}$) of present study is higher than that reported by Miah et al.(1992), Mazid et al.(1997), Rehman et al.(2006), Sahabuddin et al.(1994). The gross production of carp fishes of present experiment was lower (6767 kg $ha^{-1}yr^{-1}$) than those reported by Wahab et al.(1995). Lakshmanan et al.(1971) obtained the production of carp fishes 4209 kg $ha^{-1}yr^{-1}$ from semi intensive fish culture method which is more or less similar to the gross production of carp fishes in present study. The present finding is similar with the result obtained by Kunda et al.(2011). The gross yield of carps species under the combination of; silver carp, bighead carp, rohu and mrigala gave the better production with *A.mola* in the treatment T2 which was significantly higher than T3 and T4.. It was the indication of suitable combination of carp species silver carp (*H. molitrix*), bighead carp (*A.nobilis*), rohu (*L. rohita*) and naini (*C. mrigala*) in spite of silver carp, bighead carp, rohu, mrigala, grass carp and common carp for the rearing with SIS species *A. mola* in semi intensive pond aquaculture. *A.mola* didn't affect the growth of carp species silver carp (*H. molitrix*), bighead carp (*A.nobilis*), rohu (*L. rohita*) and naini (*C. mrigala*) in treatment T2 because food efficiency of all niches of pond was properly utilized by the carps and *A. mola* species and there were also no overlapping of food niches among them.

4.7.2 Discussion on gross margin analysis of expt 2

Gross margin analysis showed that all treatments were profitable. Gross margin was higher in combination of silver carp (*H. molitrix*), bighead carp (*A.nobilis*), rohu (*L. rohita*) and naini (*C. mrigala*) with *A. mola* in treatment T2 than that in the silver carp, bighead carp, rohu, mrigala, grass carp and common carp of treatment T4 due to probably low return value from the selling of grass carp, common carp and less quantity of *A.mola* for the sale. Based on fish production and economic return, the silver carp (*H. molitrix*), bighead carp (*A.nobilis*), rohu (*L. rohita*) and naini (*C. mrigala*) with *A. mola* treatment seemed better for the resource-poor farmers since the *A.mola* is self recruiting species so it's partial harvesting in the ponds with supplemental feed gave high fish production as high as in the only carps treatment. Using on-farm by-products like rice bran and mustard oil cake not only enhances the fish production but also makes venture cost effective.

The high financial return from the sale of craps and mola was in T2. The financial return was Rs 11, 5886 Nepalese currency ha^{-1} in 120 days, which is similar with the net benefit, reported by Roy (2004) 94,925, 88,330 and 68,270 Tk (taka) per hectare per 7 months for only carps, carps plus *A. mola* and carps plus *Chela chacius* polyculture systems respectively. The net financial return of present experiment was higher than the finding of Roy (2004) probably due to inclusion of silver carp and bighead carp as they are fastly growing fish species in polyculture of carps and *A.mola* species and the price value of total variable cost revenue in local market.

4.7.3 Discussion on water quality parameters of expt 2

All water quality parameters remained in the normal range for carp *A.mola* culture in experiment 2. There were no significant effects on addition of fishes, artificial feed and fertilizer on water quality. The water temperature remained from 27.1^{0}C to 33.5 ^{0}C in the experimental ponds which was suitable for fish culture. It agreed with the findings of Paul (1998) who recorded water temperature between 26.7-33.7 ^{O}C of carp polyculture with silver carp and *A.mola* fish rearing ponds from Bangladesh Agricultural University Campus, Mymensingh. Wahab et al.(1996) recorded water temperature between 28.5 to 31.0 ^{O}C in the ponds used for fertilization experiment. Kohinoor (2000) also recorded water temperature between 18.5 to 32.9 ^{O}C in the experimental ponds.

The water transparency is generally expressed as the level of productivity of water body and it also indicates the presence or absence of natural fish food organisms. The transparency of pond water was recorded from 16.0 to 40.0 cm in the present study indicated that the ponds were productive but water was slightly turbid. Boyd (1982) recommended the transparency ranged from 15 to 40 cm is appropriate for fish culture. The less transparent or increased turbidity of pond water that appeared might be due to planktonic organisms and stocking of common carp which is reported to be the most common natural reason for turbidity. Wahab et al.(2002) reported that common carp damages pond embankments by searching for food or burrowing to build nests which results reduced transparency. The transparency observed in experiment signifies that the culture ponds were suitable for fish culture though it exceeded the preferred range due to biological interaction of common carp.

The concentration of dissolved oxygen (DO) in the experimental ponds had generally varied from the range of 4.1 mg L^{-1} to 10.1 mg L^{-1}. Banerjea (1967) reported that dissolved oxygen ranging from 5 to 7 mg L^{-1} was good for fish culture. Ophenheimer et al.(1978) and Wahab et al.(1995) recorded the dissolved oxygen from 3.1 to 7.5 and 2.2 to 7.1 mg L^{-1} respectively. Roy (2004) recorded 3.6 to 7.6 mg L^{-1} dissolved oxygen in carp-mola polyculture ponds in rural farmer's ponds. The upper limit of dissolved oxygen reading was more than Ophenheimer et al.(1978) and Wahab et al.(1995) in present study that might be due to the increased activity of phytoplanktons in pond water.

The pH is an important factor in a fish pond and also called as the productivity index of a water body. An acidic pH of water reduces the growth, metabolism and other physiological activities of fishes (Swingle, 1967). The pH of pond water was from 7.7 to 8.5. It was suitable for fish culture according to Swingle (1967) who suggested the suitable pH of pond water for fish culture lied between 6.5 to 9.0. Kohinoor et al.(1998) recorded the pH between 7.1 to 7.2 in carp-mola polyculture ponds. The pH reading in treatments of present experiment is more or less similar to Kohinoor et al.(1998). Total alkalinity ranged from 76.0 and 150.0 mg L^{-1} in this experiment. Moyle (1946) stated that water bodies having total alkalinity more than 200.0 mg L^{-1}were highly productive. Bhowmic and Tripathi (1985) recorded the total alkalinity from 91.4 to 92.6 mg L^{-1} in research experiment's ponds of India. Total alkalinity record seems to be similar with the finding of Bhowmic and Tripathi (1985) in present study. Free CO_2 of pond water ranged from 10.5 mg L^{-1} to 16.4 mg L^{-1} during experimental period and it did not vary among the treatments.The upper limit of free carbon dioxide has been recommended as 25 mg L^{-1} for the safeguard of fish culture (Hynes, 1970). Present finding of free CO_2 seems to be suitable for fish culture according to Hynes (1970).

4.7.4 Discussion on plankton abundance and density expt 2

The numerical data of phytoplanktons and zooplanktons of present experiment showed 39 genera of planktons in which there were 26 genera of phytoplanktons and 13 genera of zooplanktons. The high planktonic diversity, a total of 47 genera in which 35 genera of phytoplanktons and 25 genera of zooplanktons was observed by Azim et al.(2002) in the periphyton based aquaculture experiment. The phytoplankton's groups were four; which included Chlorophyceae, Cyanophyceae, Euglinophyceae and Bacillariophyceae and the zooplankton's groups were Rotifera, Protozoa and Crustacea. Wahab et al.(1994) recorded four group of phytoplanktons Chlorophyceac, Cyanophyceac, Euglinophyceace and Bacillariophycea. *Kohinoor* et al.(1998) recorded zooplankton population from only two groups viz. 4 genera from Crustacea group and 4 genera from Rotifer group in the carp- sis culture experiment. The present finding of plankton groups and genus are similar with the plankton's result of Wahab et al.(1994) and Kohinoor et al.(1998). High diversity of planktons is related with over fertile water of ponds, the climatic condition, geographic condition, location of ponds etc. The quantitative and qualitative planktonic species of present study provided good indices of water quality and good capacity of natural food production in pond water to sustain heterotrophic communities of fishes. High abundance of planktons in T2 treatment supports the best gross production of carp fishes in this treatment. Plankton's abundance of treatments showed the fertile state of the experimental ponds.

4.8 Determination of stocking ratio of SIS and carps in expt 3

4.8.1 Discussion on production of SIS and carps in different stocking ratio

Optimum stocking density of a fish pond is that amount of fish released into the pond at the beginning of the production period, which guarantees for high possible harvesting number of fishes and the rapid growth of fishes from the stocked quantity. The assessment of fish pond stocking is one of the most important parameter for making success in the gross production of fish from low investment. Compared to all carp's species and *A. mola* used in experiment 3, the growth and production performance was high in T3 treatment. The productions of carps and *A. mola* in all treatments and control were varying from one another due to intraspecific and interspecific food competetion between the members of same species and among the member of many species so that they could consume the natural food available into different ecological niches and proper utilize of the supplemental foods. Gross production of carps and *A. mola* was the highest (4991.3 kg ha^{-1}) in treatment T3 at the stocking density of *A. mola* 100000 ha^{-1}. The high gross yield of fishes in treatment T3 may be due to high performance of food utilization in all ecological niches by the carps, low competition for food and suitable space to live in pond condition and good water quality. Gross production of carps was comparatively lower in treatment T4 (*A. mola* stocked at the rate of 200000 ha^{-1}) than the treatment T3 though the stocking density of *A. mola* was high in treatment T4. It may be due to the over competition for planktonic organisms food among the members of *A. mola* itself and with the carps and *A. mola* both. Overcrowding of *A. mola* within the ponds of treatment T4 might have reduced the space required for movement of fishes and it might have increased the rate of mortality of carp's fingerlings. Hepher et al.(1989) reported positive effects at the low density of silver carp and negative effects at the high density of silver carp production on its own and other fish species performances, including of the common carp. Fish production in a year of culture was 4824 kg ha^{-1} when carps and *A. mola* were stocked together at the rate of 10,000 and 25,000 fish ha^{-1} respectively (Roy et al., 2002). Gross production of carps and *Amblypharyngodon mola* 4991.3 kg ha^{-1} of treatment T3 in the present study is similar with the result obtained by Roy et al.(2002). Roy et al.(2003) used the stocking density of *A. mola* at 100000 ha^{-1} along with *Labeo bata* and *C. reba* in an experiment and they obtained the production of 417 to 560 kg *A. mola* in 240 days. The stocking density of *Amblypharyngodon mola* at 100000 ha^{-1}along with the silver carp (*H. molitrix*), bighead carp (*A. nobilis*), rohu (*L. rohita*) and naini (*C. mrigala*) in T3 treatment of present study gave the production of *A. mola* 339.9 kg in 120 days. The gross production of *A. mola* in present study was more than the result of fish production obtained by Roy et al.(2003). This might be due to different type of combinations of carp fishes reared in this study, decreased food competition for the support of high production.

Various experiments have been done on the past to find out the stocking density of SIS with carps. Kohinoor et al.(1998) obtained the production of 2,128 kg ha^{-1} when Indian major carps and punti was stocked at the rate of 7,500 carps and 50,000 SIS ha^{-1}. Kadir et al.(2007) used the stocking density of *A. mola* and *P. sophore* 25000 ha^{-1} in the carp- SIS polyculture experiment with the silver carp (*H. molitix*), rohu (*Labeo rohita*), catla (*Catla catla*) and common carp (*Cyprinus carpio*). The result obtained from experiment signified addition of *A. mola* and *P. sophore* affected rohu (*Labeo rohita*) and catla's (*Catla catla*) growth but did not affect common carp (*Cyprinus carpio*) and silver carp's (*H. molitix*) growth production. The production of silver carp was not affected by the presence or absence of *A. mola* in carp-mola polyculture system (Roy, 2004).

When fish density is high, competition for food becomes important. The high density of common carp decreased standing crop of *Lepomismacrochirus rafinesque* (bluegill) through food competition into such of the high level that the bluegill were forced to eat their own eggs (Forester & Lawrence, 1978). The production of carps in all three treatments stocked with *A. mola* was higher than carps stocked without *A. mola* (control). It suggested firstly that *A. mola* does not compete for food with the silver carp, bighead carp, rohu and naini so, *A. mola* can be reared with carps and secondly the optimum but suitable stocking density of *A. mola* along with the silver carp (*H. molitrix*), bighead carp (*A. nobilis*), rohu (*L. rohita*) and naini (*C. mrigala*) may be 100000 ha^{-1} as good solution for high rate of fish production in short time financial return.

4.8.2 Discussion on gross margin analysis of expt 3

Gross margin analysis was profitable in all treatments of experiment 3. Gross margin was more in treatment T3 where the stocking ratio of SIS was 100000 ha^{-1} than the treatments T2 stocking ratio 50000 ha^{-1}, T4 stocking ratio 200000 ha^{-1} and T1 (control). The gross margin was significantly higher in the treatment T3 ($P<0.05$) and there was no significant gross margin difference between T2 and T4 treatments. High gross margin return obtained from treatment T3 was due to high financial return from the selling of carps and *A.mola* and low financial investment for the fish production. The partial harvesting of *A. mola* applied earlierly than harvesting of carps to maintain the initial stocking density during the whole fishculture period when sold increased the economic return from T3 treatment. The financial return was 1, 78,696 Nepalese currency ha^{-1} in 120 days from the T3 treatment of experiment. It was more than net benefit 94925, 88330 and 68270 Tk ha^{-1} per 7 months for only carps, carps plus mola and carps plus chela polyculture systems obtained by Roy (2004). The high financial return from present experiment may be due to achievement of appropriately standerdised stocking density between mola and suitable combination of carps (IMC and CMC).

4.8.3 Discussion on water quality parameters of expt 3

All the water quality parameters of experiment were recorded within normal range. There was no significant difference among the water quality parameters of treatments. Water temperature was recorded from 28.2^0C to 33.1^0C with no significant difference among the treatments. Water temperature regulates growth, metabolism, reproduction feeding intensity, movement etc of fishes (Jhingran, 1982). Wahab et al.(1996) recorded water temperature from 28.5 to 31.3 ^OC in the ponds used for fertilization experiment. Kohinoor (2000) recorded water temperature from 18.5 to 32.9 ^OC in the carp SIS polyculture experiment. Temperature varied from 20.8 to 30.1 ^OC in experiment on the polyculture of large carps with small indigenous fish species (SIS) mola (*Amblypharyngodon mola*) and chela (C*hela cachius*) (Roy et al., 2002). The transparency of pond water recorded from 16.0 to 40.0 cm. The transparency reading varied with sampling date, which may be due to differences in abundance of planktons. Dissolved oxygen (DO) varied from 3.5 mg L^{-1} to 6.6 mg L^{-1}. Wahab et al.(1995) recorded the dissolved oxygen reading from 2.2 to 7.1 mg L^{-1}. So the temperature, tranceparency and dissolved oxygen of experiment 3 are similar with the findings of Kohinoor (2000) and Wahab et al.(1995). Roy (2004) recorded 3.6 to 7.6 mg L^{-1} dissolved oxygen in carp-mola polyculture rural farmer's ponds. The upper limit of dissolved oxygen reading in present study was more than Wahab et al. (1995) and Roy (2004) which might be due to the increased photosynthetic activity by phytoplanktons.The fish ponds were alkaline with pH values ranged between 7.4 to 8.5 in experiment. Kohinoor et al.(1998) recorded the pH between 7.18 to 7.24 in the research ponds of the Field Laboratory of Bangladesh Agricultural University, Mymensingh. The pH of fish ponds were recorded from 7.0 to 9.0 (Roy et al., 2002). Total alkalinity varied from 80.0 to 142.0 mg L^{-1} in present experiment. Mazumder et al.(1997) recorded 90 to 120 mg L^{-1} total alkalinity in different water bodies of West Bengal. Free CO_2 of pond water was recorded from 10.0 mg L^{-1} to 14.5 mg L^{-1}. The free CO_2 did not vary among the treatments.The upper limit of free carbon dioxide has been recommended as 25 mg L^{-1} for the safeguard of fish culture (Hynes, 1970).The pH, total alkalinity and CO_2 recorded values are similar to Kohinoor et al.(1998), Mazumder et al.(1997) and Hynes (1970).

4.8.4 Discussion on plankton abundance and density of expt 3

The numerical data of phytoplanktons and zooplanktons presented in Tables 4.3.8 and 4.3.9 did not show significant differences among the treatments. High abundance of phytoplanktons and zooplanktons in treatment T3 might have supported the highest production of fishes in the treatment. The biomass of phytoplanktons and zooplanktons varied significantly among the sampling dates but did not vary among the treatments ($P<0.05$). All the planktons of treatments represented from 39 genera in which 26 genera belonged from phytoplanktons and 13 genera from zooplanktons. Four group of phytoplanktons Chlorophyceae, Cyanophyceae, Euglinophyceae and Bacillariophyceae and three group of zooplanktons; Rotifera, Protozoa and Crustacea was reported in this experiment was identical with group of planktons reported by Wahab et al.(1994), Azim et al.(2002), Padmavathi and Prasad (2009), Hussein (2009) and Ponce Palafox, (2010). Padmavathi and Prasad (2009), Hussein (2009) and Ponce Palafox (2010) found that the major groups of phytoplanktons were represented from Chlorophyceae, Cyanophyceae, Euglinophyceae and Bacillariophyceae groups in carp ponds while zooplankton population mainly belong from Crustacea, Rotifera and Protozoa groups. The abundance and diversity of planktons in experimental ponds was largely affected by low sediments deposited into pond's bottom.

All experiments of research work were carried during February to October months of 2012, 2013 and 2014 AD in the same research station. There was minor variations in the water quality parameters due to seasonal variation but the climate change was not so vast to affect fish growth**.**

CHAPTER 5

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The results obtained from present study led to develop following conclusions:

1) SIS diversity and their abundance are in rivers, lakes, marshy land, ponds and other aquatic bodies of Nepal. The abundance of *Mystus* spp, *Anguila* spp, *Clupisoma* spp, *Notopterus* spp, *Mastacembelus* spp, *Amphipnous* spp are less than *A, mola*, *P. ticto* and *E. denricus, C. reba, A. morar, O. bacaila, Noemachilus* spp, *Baralius* spp, *Chela lubaca*, *Colisa fasciatus*, *Chanda* spp, *P. shophore*, *P. sarana*.
2) The diversity indices; Simpson's index (0.04 to 0.08) Shannon Weiner index (2.85 to 3.53) and Margalef's index (8.74 to 13.48) were found to be the highest in Saptari district of Nepal (sampling station S1).
3) *A. mola* showed the best production performance when examined for the growth and production assessment in comparision with *Puntius ticto* and *Esomus denricus*. So it can be used for commercial utilization.
4) The silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristychthys nobilis*), rohu (*Labeo rohita*) and naini (*Cirrhinus mrigala*), were not negatively affected from the feeding habit of *A. mola* when co-stocked in pond condition, so it is concluded that *A. mola* can be reared in combination with above mentioned carps.
5) Hence it was concluded from the present experiment that the combination of four carp species viz. silver carp (*Hypophthalmicthys molitrix*), bighead carp (*Aristychthys nobilis*), rohu (*Labeo rohita*) and naini (*Cirrhinus mrigala*) stocked at the rate of 15000 ha^{-1} and together with one SIS *Amblypharyngodon mola* 100000 ha^{-1} may be the standardized appropriate culture package of carp- small indigenous fish species (SIS) polyculture in Nepal**.**
6) Stocking density of fish species in polyculture and monoculture methods of fish farming is directly related with fish production so stocking density of carps in experiment two and three was kept 15000 $ha^{-1}$and stocking density of SIS species in experiment one was kept unchanged in all treatments and

replications however to achieve the standardized stocking density according to aims and objective of present research three different stocking density of SIS was tested in experiment three. The standardized stocking density of carps 15000 $ha^{-1}$and SIS 100000 $ha^{-1}$was obtained from experiment three in overall experiments.

5.2 Recommendations

- The present study of SIS abundance and diversity developed the area for further investigations in future so that status, assemblage and distribution of SIS can be kept into information to maintain icthyobiodiversity profile of country.
- The fries of *A. mola, P. ticto, E. denricus* were collected from wild source or natural habitat in this experiment. It brought the problem of mixing of fries of other unwanted fish species such as *C. nama, C. fasciatus* etc, so to ensure the pure breed of SIS species for carp SIS poly culture method it is recommended to develop the provision for pure seed either from induced breeding technique or monoculture of SIS in farm condition.
- The increase in mortality rate of juveniles of *A. mola* in the experiment of carp SIS polyculture by repeated netting process for carp growth check up suggests recommending the environmental friendly netting system by the use of appropriate mesh size net.
- To maintain the initial stocking ratio of carp and SIS numbers throughout the culture period for achievement of high yield, it is recommended for the partial harvesting of *A. mola* several times.
- The more research and extension work for carp-SIS polyculture, diversification, up-scaling of breeding, SIS role in nutrition and livelihood seems to be essential step in the context of Nepal.
- Focus on understanding the biology of some important SIS species is essential to understand their interaction with carp fishes for the promotion of appropriate management.
- Investigation should be done to evaluate the trade-offs of intensifying aquaculture production against loss of traditional culture systems. This should lead to a balanced promotion of aquaculture and biodiversity protection.

CHAPTER 6

6. SUMMARY

The overall objective of present study was to find out the stocking combination of carp fish species to the most suitable SIS species under the appropriate srocking ratio between SIS and carp in pond condition of Nepal. The aim of study was to develop a technically simple low-cost fish culture system which could give high yield of fishes and financial return within short period of time after stocking and it would also support in minimization of micronutrient malnutrition problem of the country. This research work will play a vital role for the improvement of the financial condition of the country, farmers and fishermen.

The present study included two parts SIS survey and research experiments regarding growth and production of SIS and carp. The field survey for SIS diversity and abundance was carried out in 8 districts or sampling stations, Saptari (S1), Sirha (S2), Dhanusha (S3), Mahottari (S4), Sarlahi (S5), Rauthat (S6), Bara (S7), Parsa (S8) of Terai Nepal and three sampling sites (fish markets) for each sampling station were S1-Bhardah, Hanumannagar & Rajbiraj; S2-Sirha, Lahan & Bandipur; S3-Janakpur, Mahendranagar & khajuri; S4-Jaleshwar, Ramgopalpur & Gaushala; S5-Malangwa, Lalbandi & Barhathwa; S6-Gaur, Gadura & Chapur; S7-Kalaiya, Nijgadh & Jitpur; S8-Birgunj, Chapkuiyan & Bindbasinimaisthan. Diversity and abundance of SIS was done by the identification of SIS on spot, weight & length measurement, landing of SIS week $^{-1}$ and by questions methods. A few unidentified samples of SIS were preserved in 10 % formalin and they were brought for identification to the laboratory in Janakpur. A total of 55 species of SIS belonging to16 families and 38 genera were recorded from the sampling stations during the entire study period. The less SIS diversity in sampling stations S2, S3, S4, S5, S6, S7 and S8 in comparision to S1 remained probably due to the less abundant water bodies such as permanent rivers, large rivers, marshy land and increased activities of aquaculture in the peripheral area of sampling stations.Three SIS species *A. mola*, *P. ticto* and *E. denricus* were recorded in the highest abundance from the eight sampling stations. The diversity of small indigenous fish species (SIS) was calculated by Shannon diversity index calculation (H) = $- p_i \sum \ln(p_i)$, Margalef index = (N-1)/LN (N), Simpson diversity index calculation $= \sum (p_i)^2$ (Magurran, 1988 ; McIntosh,1967 ; Rosenzweig, 1995) formula. The Shanon index, Sampson index, Margelef index and species richness was high in S1 sampling station and these index were low in S4 sampling station.

First experiment was carried out for the growth and production assessment of three SIS species viz *A. mola*, *P. ticto* and *E. denricus*. The experiment was conducted in earthen ponds, each of 100 m^2 size in Fisheries Development and Training centre Janakpur, under CRD method, in which 3 treatments and 3 replications were allocated randomly for each SIS species. Prestocking and post stocking of fish pond's management was done according to Roy et al. (2002). The SIS species *A. mola*, *P. ticto* and *E. denricus* were stocked at the rate of 20, 0000 ha^{-1} in the first experiment. The water quality and planktons analysis was carried out on the basis of forghtnightly and monthly sampling to maintain the ideal condition for fishculture. All the water quality parameters remained in suitable range of fishculture. Some insignificant variation in water quality parameters found in experiment. Planktons abundance was optimum in the experimental ponds SIS species were grown for 120 days by monoculture method. There was the highest growth rate rate of *A. mola* in all three reared SIS species. The highest gross fish production of *A. mola* was 1,825 kg $ha^{-1}yr^{-1}$ in experiment one and it was followed by the production of *P. ticto* and *E. denricus*. Measurement of Growth and production performance of *A. mola*, *P. ticto* and *E. denricus* helped to establish SIS species for experiments two and three.

In the second experiment, the carp fish species silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristychthys nobilis*), rohu (*Labeo rohita*), naini (*Cirrhinus mrigala*), grass carp (*Ctenopharyngodon idella*) and common carp (*Cyprinius carpio*) were cultured with the SIS species *A. mola* in three different combinations by semi intensive polyculture method. The experiment was conducted by CRD method, in which 3 treatments and 3 replications were allocated randomly for each combination of carp and SIS species. Prestocking and post stocking of fish pond's management was done according to Roy et al. (2002). Carp were stocked at the rate of 15, 000 ha^{-1} and SIS at the rate of 50, 000 ha^{-1}. The water quality and planktons analysis was carried out on the basis of forghtnightly and monthly sampling to maintain the ideal condition for fishculture. Water quality parameters of experiment remained in suitable range for fishculture. The insignificant variation was found in transparency, total alkalinit and pH of the experiment. Planktons abundance was optimum or high in the experimental ponds. Carp and SIS were reared for 120 days. The combination of silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristychthys nobilis*), rohu (*Labeo rohita*), naini (*Cirrhinus mrigala*) and *A. mola* of T2 treatment was the most suitable combination for the growth and production of carp. The gross fish production in combination of silver carp, bighead carp, rohu and naini with *A mola* of T2 treatment gave the best production performance 4559.4 kg ha^{-1} y^{-1}.

Experiment three was conducted for the determination of stocking ratio of *A. mola* with the combination of silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristychthys nobilis*), rohu (*Labeo rohita*) and naini (*Cirrhinus mrigala*). The experiment was conducted by CRD method, in which 3 treatments and 3 replications were allocated randomly for each stocking density of SIS species *A. mola*. Prestocking and post stocking of fish pond's management was done according to Roy *et al*. (2002). Three stocking densities of *A. mola* 50,000 ha^{-1}, 10, 0000 ha^{-1} and 20, 0000 ha^{-1} were tested in the experiment 3. The water quality and planktons analysis was carried out on the basis of forghtnightly and monthly sampling to maintain the ideal condition for fishculture. All the water quality parameters remained in suitable range of fishculture. Some insignificant variation in water quality parameters found in experiment. Planktons abundance was high in the experimental ponds that supported the growth of fishes. Carp and SIS were reared for 120 days. The best fish production result was obtained from T3 treatment. It was 4991.3 kg $ha^{-1}yr^{-1}$in the stocking ratio of *A. mola* with carp fishes silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristychthys nobilis*), rohu (*Labeo rohita*) and naini (*Cirrhinus mrigala*) of treatment T3. The combination of *A. mola* stocked at other two ratios also gave better production performance than the treatment T1 (control).

Though all the water quality parameters of aquatic environment in experiments one, two and three minorly varied from one another but statistically it was found to be insignificant. This also showed no effect on the fish growth and hence production.

Hence it was concluded from the present experiment that the combination of four carp species viz. silver carp (*Hypophthalmicthys molitrix*), bighead carp (*Aristychthys nobilis*), rohu (*Labeorohita*) and naini (*Cirrhinusmrigala*) stocked at the rate of 15000 ha^{-1} and together with one SIS *Amblypharyngodon mola* 100000 ha^{-1} may be the standardized appropriate culture package of carp- small indigenous fish species (SIS) polyculture in Nepal**.**

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APPENDIX A

Water quality, planktons, fish stocking & harvesting data of experiment 1

Table A1 Forghtnightly dial temp (^oC) of pond water at middle depth (50 cm) in treatment 1 of expt. I

Date	p2	P5	P9	mean
2012.06.18	30	30	30	30
2012.07.03	30.5	30.5	31	30.67
2012.07.18	31.2	31.2	31.2	31.2
2012.08.02	31.2	31.5	31.5	31.4
2012.08.18	32.2	32.2	32.2	32.2
2012.09.02	32.5	33	33	32.83
2012.09.17	32	32	32	32
2012.10.02	30.8	30.8	30.8	30.8
2012.10.17	30.5	30.2	30.2	30.3

Table A2 Forghtnightly dial temp (^oC) of pond water at middle depth (50 cm) in treatment 2 of expt. I

Date	P1	P4	P8	mean
2012.06.18	30	30	30	30
2012.07.03	30.2	30.2	30.5	30.3
2012.07.18	30.5	31	31	30.83
2012.08.02	31.5	31.5	31.5	31.5
2012.08.18	32	32	32.2	32.07
2012.09.02	32	32	32.5	32.17
2012.09.17	32.5	32.5	32	32.33
2012.10.02	31	31	30.5	30.83
2012.10.17	30.5	30.2	30.2	30.3

Table A3 Forghtnightly dial temp (oC) of pond water at middle depth (50 cm) in treatment 3 of expt. I

Date	P3	P6	P7	mean
2012.06.18	30	30	30	30
2012.07.03	30.2	30.3	30.3	30.27
2012.07.18	30.5	30.5	30.5	30.5
2012.08.02	31	31	31	31
2012.08.18	31.2	31.2	31.2	31.2
2012.09.02	31.5	31.5	31.5	31.5
2012.09.17	31.8	32	32	31.93
2012.10.02	31.5	31.5	31.5	31.5
2012.10.17	30.5	30.5	30.5	30.5

Table A4 Forghtnightly dial temp (^oC) of pond water at middle depth (50 cm) in treatment 4 of expt. I

Date	P10	P11	P12	mean
2012.06.18	30.2	30.1	30.2	30.17
2012.07.03	31.4	31.7	31.1	31.4
2012.07.18	31.6	32	32.1	31.9
2012.08.02	32.1	32.5	32.5	32.37
2012.08.18	33	32.8	33.1	32.97
2012.09.02	33.1	33	33.1	33.07
2012.09.17	32.2	32.5	32.6	32.43
2012.10.02	31	31.2	31.1	31.1
2012.10.17	30.1	30.2	30.5	30.27

Table A5 Dissolved oxygen (mg L^{-1}) of treatment 1 in Experiment I

Date	p2	P5	P9	mean
2012.06.18	6.1	6.1	6	6.07
2012.07.03	6	6	6	6
2012.07.18	5.8	5.6	5.8	5.73
2012.08.02	5.4	5.2	5.3	5.3
2012.08.18	5	5.2	4.8	5
2012.09.02	5.2	5.2	4.8	5.07
2012.09.17	4.8	4.2	4.2	4.4
2012.10.02	5	5.1	5.2	5.1
2012.10.17	4.6	4.8	5.2	4.87

Table A6 Dissolved oxygen (mg L^{-1}) of treatment 2 in Experiment I

Date	P1	P4	P8	mean
2012.06.18	6	6.1	6.2	6.1
2012.07.03	6.2	6.4	6	6.2
2012.07.18	6	5.6	5.8	5.8
2012.08.02	5.4	5.8	5.8	5.67
2012.08.18	5	5.5	4.8	5.1
2012.09.02	5.6	5.4	4.8	5.27
2012.09.17	5	5.4	4.6	5
2012.10.02	5.8	5.6	5.2	5.53
2012.10.17	5	4.8	5.2	5

Table A 7 Dissolved oxygen (mg L^{-1}) of treatment 3 in Experiment I

Date	P3	P6	P7	mean
2012.06.18	6.2	6.1	6.4	6.23
2012.07.03	6.2	6	6.1	6.1
2012.07.18	6	6.2	5.8	6
2012.08.02	5.8	5.6	5.3	5.57
2012.08.18	5.4	5.6	5	5.33
2012.09.02	5.4	5.2	5	5.2
2012.09.17	4.8	4.8	5	4.87
2012.10.02	5.2	5.1	5.4	5.23
2012.10.17	5	4.8	5.2	5

Table A8 Dissolved oxygen (mg L^{-1}) of treatment 4 in Experiment I

Date	P10	P11	P12	mean
2012.06.18	6.5	6.4	6.2	6.37
2012.07.03	6	6.2	6.2	6.13
2012.07.18	6.2	6	5.8	6
2012.08.02	6	6	5.3	5.77
2012.08.18	5.6	5.8	5.2	5.53
2012.09.02	5.5	5.5	4.8	5.27
2012.09.17	5.2	4.7	4.8	4.9
2012.10.02	5.5	5.8	5.2	5.5
2012.10.17	5.4	4.8	5.2	5.13

Table A9 P^H of treatment 1 in expt. 1

Date	P2	P5	P9	mean
2012.06.18	7.5	7.5	7.4	7.47
2012.07.03	7.6	7.5	7.5	7.53
2012.07.18	7.4	7.4	7.5	7.43
2012.08.02	8	8	7.8	7.93
2012.08.18	7.6	7.8	7.8	7.73
2012.09.02	7.5	7.6	7.5	7.53
2012.09.17	7.2	7.2	7.5	7.3
2012.10.02	7.6	7.6	7.4	7.53
2012.10.17	7.5	7.5	7.4	7.47

Table A10 P^H of treatment 2 in expt. 1

Date	P1	P4	P8	mean
2012.06.18	7.4	7.4	7.6	7.47
2012.07.03	7.5	7.6	7.5	7.53
2012.07.18	7.6	7.5	7.6	7.57
2012.08.02	7.9	7.8	7.9	7.87
2012.08.18	8	8.2	8	8.07
2012.09.02	7.8	7.5	7.8	7.7
2012.09.17	7.4	7.2	7.5	7.37
2012.10.02	7.8	7.4	7.2	7.47
2012.10.17	7.4	7.2	7.4	7.33

Table A 11 P^H of treatment 3 in expt. 1

Date	P3	P6	P7	mean
2012.06.18	7.6	7.5	7.8	7.63
2012.07.03	7.5	7.4	7.6	7.5
2012.07.18	7.5	7.7	7.5	7.57
2012.08.02	8.1	8.2	7.8	8.03
2012.08.18	7.7	7.8	7.5	7.67
2012.09.02	7.6	7.4	7.5	7.5
2012.09.17	7.2	7.2	7.4	7.27
2012.10.02	7.6	7.5	7.4	7.5
2012.10.17	7.4	7.3	7.4	7.37

Table A 12 P^H of treatment 4 in expt. 1

Date	P10	P11	P12	mean
2012.06.18	7.7	7.5	7.6	7.6
2012.07.03	7.6	7.5	7.6	7.57
2012.07.18	7.6	7.5	7.8	7.63
2012.08.02	8.2	8.2	7.9	8.1
2012.08.18	8	7.9	7.8	7.9
2012.09.02	7.5	7.6	7.5	7.53
2012.09.17	7.4	7.4	7.5	7.43
2012.10.02	7.8	7.6	7.6	7.67
2012.10.17	7.5	7.5	7.4	7.47

Table A13 CO_2 (mg L^{-1}) of treatment 1 in expt. 1

Date	P2	P5	P9	mean
2012.06.18	11.2	11.2	13.2	11.87
2012.07.03	11.5	11.5	11.5	11.5
2012.07.18	11.6	11.8	13.2	12.2
2012.08.02	11.6	11.8	11.8	11.73
2012.08.18	12.4	11.2	11.2	11.6
2012.09.02	12.8	12.8	12.4	12.67
2012.09.17	13	13.2	14	13.4
2012.10.02	12.8	12.6	12.8	12.73
2012.10.17	13.8	13.8	14	13.87

Table A14 CO_2 (mg L^{-1}) of treatment 2 in expt. 1

Date	P1	P4	P8	mean
2012.06.18	10.5	11.2	11.2	10.97
2012.07.03	11.2	11.5	12.2	11.63
2012.07.18	12.5	11.8	13.2	12.5
2012.08.02	11.6	11.8	11.8	11.73
2012.08.18	13.5	13.6	13.6	13.57
2012.09.02	14	14	14.2	14.07
2012.09.17	12.5	13	13.2	12.9
2012.10.02	12.8	12.8	12.6	12.73
2012.10.17	13.2	13.5	13.5	13.4

Table A15 CO_2 (mg L^{-1}) of treatment 3 in expt. 1

Date	P3	P6	P7	mean
2012.06.18	11	10.5	11.2	10.9
2012.07.03	11.5	11.2	12	11.57
2012.07.18	12	12.5	12.5	12.33
2012.08.02	11.6	11.8	11.8	11.73
2012.08.18	12.5	13	13.2	12.9
2012.09.02	13.5	13.8	14	13.77
2012.09.17	12.5	12.2	12	12.23
2012.10.02	12.5	12.8	12.6	12.63
2012.10.17	13	13.5	12.5	13

Table A16 CO_2 (mg L^{-1}) of treatment 4 in expt. 1

Date	P10	P11	P12	mean
2012.06.18	10	11.2	10.5	10.57
2012.07.03	10.5	11	11.2	10.9
2012.07.18	11.6	11.5	11.5	11.53
2012.08.02	12.5	12.5	12.6	12.53
2012.08.18	12	12.2	12.5	12.23
2012.09.02	12.8	12.6	13	12.8
2012.09.17	13.2	13.4	13.2	13.27
2012.10.02	13	13.5	12.8	13.1
2012.10.17	13.5	13	23.2	16.57

Table A17 Total Alkalinity (mg L^{-1}) of treatment 1 in expt. 1

Date	p2	P5	P9	mean
2012.06.18	101.38	100.64	100.8	100.94
2012.07.03	105.6	106.2	105.08	105.63
2012.07.18	101.38	103.5	104.4	103.09
2012.08.02	130.5	121.8	115.8	122.7
2012.08.18	105.08	104.4	103.5	104.33
2012.09.02	110.26	112.8	105.3	109.45
2012.09.17	106.2	105.8	106.2	106.07
2012.10.02	100.8	101.38	104.4	102.19
2012.10.17	90.28	93.24	85.84	89.79

Table A18 Total Alkalinity (mg L^{-1}) of treatment 2 in expt. 1

Date	P1	P4	P8	mean
2012.06.18	100.8	101.24	100.64	100.89
2012.07.03	104.5	103.5	102.6	103.53
2012.07.18	105.8	105.08	106.2	105.69
2012.08.02	108.2	110.24	110.26	109.57
2012.08.18	110.4	130.5	121.7	120.87
2012.09.02	104.6	102.6	102.6	103.27
2012.09.17	102.3	100.6	101.38	101.43
2012.10.02	98.33	93.24	99.9	97.16
2012.10.17	93.24	82.88	97.34	91.15

Table A19 Total Alkalinity (mg L^{-1}) of treatment 3 in expt. 1

Date	P3	P7	P6	mean
2012.06.18	102.6	103.5	104.4	103.5
2012.07.03	104.4	102.4	102.6	103.13
2012.07.18	106.2	105.08	104.4	105.23
2012.08.02	119.24	130.5	121.8	123.85
2012.08.18	110.24	110.26	106.2	108.9
2012.09.02	104.4	104.4	103.5	104.1
2012.09.17	102.6	101.38	100.64	101.54
2012.10.02	101.38	100.8	99.9	100.69
2012.10.17	90.28	93.24	94.72	92.75

Table A20 Total Alkalinity (mg L^{-1}) of treatment 4 in expt. 1

Date	P10	P11	P12	mean
2012.06.18	101.38	100.64	100.8	100.94
2012.07.03	100.8	103.5	101.38	101.89
2012.07.18	102.4	106.2	104.4	104.33
2012.08.02	106.2	121.6	130.5	119.43
2012.08.18	110.26	105.08	106.2	107.18
2012.09.02	119.25	110.26	118	115.84
2012.09.17	112	115	104.4	110.47
2012.10.02	100.8	102.6	101.38	101.59
2012.10.17	99.9	94.72	99.2	97.94

Table A21 Transparency (cm) of Treatment 1 in expt. 1

Date	P2	P5	P9	mean
2012.06.18	32	30	30	30.6
2012.07.03	28	30	28	28.6
2012.07.18	28	29	28	28.3
2012.08.02	25	23	24	24
2012.08.18	26	25	24	25
2012.09.02	22	25	22	23
2012.09.17	20	21	20	20.3
2012.10.02	21	22	20	21
2012.10.17	22	21	21	21.3

Table A22 Transparency (cm) of Treatment 2 in expt. 1

Date	P1	P4	P8	mean
2012.06.18	30	32	34	32
2012.07.03	33	31	35	33
2012.07.18	32	34	33	33
2012.08.02	27	25	28	26.66
2012.08.18	26	25	24	25
2012.09.02	20	21	22	21
2012.09.17	20	21	22	21
2012.10.02	22	20	21	21
2012.10.17	20	21	21	20.66

Table A23 Transparency (cm) of Treatment 3 in expt. 1

Date	P3	P6	P7	mean
2012.06.18	29	30	31	30
2012.07.03	30	31	33	31.33
2012.07.18	29	28	28	28.33
2012.08.02	26	26	25	25.66
2012.08.18	26	25	24	25
2012.09.02	23	22	21	22
2012.09.17	19	20	19	19.33
2012.10.02	20	20	22	20.66
2012.10.17	20	20	21	20.33

Table A24 Transparency (cm) of Treatment 4 in expt. 1

Date	P10	P11	P12	mean
2012.06.18	31	29	30	30
2012.07.03	31	30	32	31
2012.07.18	29	27	27	27.6
2012.08.02	24	24	24	24
2012.08.18	27	25	22	24.6
2012.09.02	20	21	24	21.6
2012.09.17	22	24	20	22
2012.10.02	20	20	20	20
2012.10.17	22	21	21	21.3

Table A25 Initial stocking weight of fish (g $fish^{-1}$) in Experiment 1

Treatment	Pond	*A. mola*	*P. ticto*	*E.denricus*
1	P2	1.4		
1	P5	1.5		
1	P9	1.6		
Average		1.5		
S, E.		0.047		
2	P1		1.5	
2	P4		1.4	
2	P8		1.6	
Average			1.5	
S, E.			0.047	
3	P3			0.8
3	P6			1
3	P7			1.2
Average				1
S, E.				0.094

Table A 26 Initial total weight of fish (g $pond^{-1}$) at stocking in Experiment 1

Treatment	Pond	*A. mola*	*P. ticto*	*E.denricus*
1	P2	2800		
1	P5	3000		
1	P9	3200		
Average		3000		
S, E.		94.28		
2	P1		3000	
2	P4		2800	
2	P8		3200	
Average			3000	
S, E.			94.28	
3	P3			1600
3	P6			2000
3	P7			2400
Average				2000
S, E.				188.56

Table A27 Final weight of fish (g fish^{-1}) at harvesting in Experiment 1

Treatment	Pond	*A. mola*	*P. ticto*	*E.denricus*
1	P2	2.9		
1	P5	3.2		
1	P9	3.7		
Average		3.26		
S, E.		0.19		
2	P1		2.5	
2	P4		3.3	
2	P8		3.5	
Average			3.1	
S, E.			0.24	
3	P3			2.3
3	P6			2.5
3	P7			2.6
Average				2.46
S, E.				0.72

Table A28 Final total weight of fish (g pond^{-1}) at harvesting in Experiment 1

Treatment	Pond	*A. mola*	*P. ticto*	*E.denricus*
1	P2	9860		
1	P5	11200		
1	P9	12580		
Average		1121.33		
S, E.		641.13		
2	P1		7500	
2	P4		10560	
2	P8		10850	
Average			9636.66	
S, E.			874.96	
3	P3			6900
3	P6			7875
3	P7			8580
Average				7785
S, E.				397.68

Table A 29 Net total weight of fish (g pond^{-1}) at harvesting in Experiment 1

Treatment	Pond	*A. mola*	*P. ticto*	*E.denricus*
1	P2	7060		
1	P5	8200		
1	P9	9380		
Average		8213.33		
S, E.		546.85		
2	P1		4500	
2	P4		7760	
2	P8		7650	
Average			6636.66	
S, E.			872.67	
3	P3			5300
3	P6			5875
3	P7			6180
Average				5785
S, E.				210.64

Table A30 Net Daily weight gain by fish (g fish^{-1}) in Experiment I

Treatment	Pond	*A. mola*	*P. ticto*	*E.denricus*
1	P2	0.011811		
1	P5	0.013386		
1	P9	0.016535		
Average		0.013911		
S, E.		0.001134		
2	P1		0.007874	
2	P4		0.014961	
2	P8		0.014961	
Average			0.012599	
S, E.			0.001929	
3	P3			0.011811
3	P6			0.011811
3	P7			0.011024
Average				0.011549
S, E.				0.000214

Table A31 Plankton abundance (units L^{-1}) in pond water of Experiment 1

			Chlorophyceae															Cyanophyceae			Euglenophyceae		Bacillariophyceae			
Months	Treatment	Ponds	*Chiorella*	*Coelastrum*	*characium*	*Actinastrum*	*Closterium*	*Chlamydomonas*	*Oedogonium*	*oocystis*	*Pediastrum*	*Selenastrum*	*Spirogyra*	*Tetraedron*	*Tetraspora*	*Volvox*	*Ulothrix*	*Anabaena*	*Microcystis*	*Oscillatoria*	*Euglina*	*Phacus*	*Fragillaria*	*Cyclotella*	*Synedra*	*Nevicula*
0		2	2100	0	0	0	0	0	0	760	0	0	0	0	0	0	0	0	0	0	900	0	0	0	0	600
0	T1	5	1600	0	0	0	0	0	0	900	0	0	0	0	0	0	0	0	0	0	880	900	850	0	0	840
0		9	4200	700	500	0	0	0	0	800	0	0	0	0	0	0	0	0	0	0	700	700	780	1500	2200	3400
0		1	4750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1020	1000	1800	1000	0
0	T2	4	5000	0	0	0	0	0	0	0	1400	0	0	0	0	0	0	0	0	0	0	800	940	2000	2400	900
0		8	6200	0	0	0	0	0	0	1100	1000	0	0	0	0	0	0	0	500	0	1600	920	700	900	860	1600
0		3	4200	0	0	0	0	0	0	960	1200	0	0	860	0	0	0	0	0	700	1400	1020	920	700	3000	800
0	T3	6	4550	0	0	0	800	0	0	1040	900	860	0	0	0	0	0	0	0	0	2000	760	500	650	1500	1800
0		7	4000	0	0	0	0	0	0	1000	700	0	0	0	840	0	780	0	0	0	1500	1000	700	800	0	800
1		2	6400	0	0	800	0	0	0	0	800	0	0	0	0	0	0	900	0	0	860	1200	4000	500	2100	1000
1	T1	5	6420	0	0	0	0	760	0	0	0	0	900	0	0	900	0	0	0	0	900	1640	960	0	800	1250
1		9	1500	0	0	0	0	0	0	3800	0	0	0	0	0	0	0	0	0	0	0	900	1020	800	3200	4000
1		1	1200	0	700	0	0	0	0	6200	0	0	0	0	0	0	0	0	0	0	1100	800	1200	0	1260	1600
1	T2	4	2500	900	0	0	900	0	500	1040	0	0	0	0	0	0	0	0	0	0	2100	0	1600	700	2400	3500
1		8	3000	0	0	0	0	0	0	900	1500	0	0	1100	0	0	2000	0	0	0	0	0	0	800	900	0
1		3	8000	0	0	0	0	0	0	0	1230	700	0	0	0	0	0	0	0	0	0	0	0	1100	1500	0
1	T3	6	5000	0	0	0	0	0	0	0	2200	0	0	0	0	0	0	0	840	0	2000	0	0	920	1800	0
1		7	6200	0	0	0	0	0	0	10200	1850	0	0	0	900	0	0	0	0	0	2400	1020	0	100	0	740
2		2	10020	0	0	0	0	900	0	15000	1600	0	0	0	1260	0	0	700	0	0	0	1260	1420	700	2140	1450
2	T1	5	8000	0	0	0	0	0	0	4000	0	0	0	0	0	0	0	0	0	920	0	2000	1100	4200	3100	800
2		9	6500	820	0	0	0	0	0	1020	2000	0	1240	0	0	800	0	0	0	0	0	2200	800	3600	2400	2000
2	T2	1	2000	0	0	0	1200	0	0	5100	2820	0	0	0	0	0	0	0	0	0	0	2400	920	2400	980	2400
2		4	1800	0	0	0	1020	0	0	7800	0	0	0	0	0	0	0	0	0	0	3460	900	3400	900	2700	900

2		8	3200	0	0	800	0	0	0	10500	0	2200	0	1300	0	0	0	0	0	0	3000	0	940	1000	2200	3200
2		3	2900	0	0	900	0	0	0	4000	900	0	0	0	900	0	0	0	0	0	5400	0	1600	1100	0	1240
2	T3	6	6100	0	800	2000	0	0	0	2200	700	0	0	0	3000	0	1020	0	0	0	9660	1600	2000	1250	0	980
2		7	4600	0	1100	0	0	0	0	0	1600	0	0	0	0	0	0	0	0	0	4000	3200	550	920	0	800
3		2	4820	0	0	0	0	0	1200	0	0	0	0	0	0	0	0	1200	0	0	2000	2400	800	800	4000	700
3	T1	5	6200	0	0	0	0	0	0	0	3200	0	0	0	0	0	0	0	0	1250	0	0	740	1020	6300	2500
3		9	6400	500	0	0	0	2200	0	1880	3000	0	0	2200	0	0	0	0	0	0	1020	3000	940	2100	800	2000
3		1	8200	0	0	0	0	0	0	3000	1000	0	800	0	0	1420	0	0	1640	0	1200	2500	1050	1860	3100	700
3	T2	4	2800	0	0	0	0	0	0	5200	0	1200	1000	0	0	0	0	0	0	0	1650	860	920	500	2000	1020
3		8	2800	0	0	0	0	0	0	4000	0	0	0	0	2000	0	0	0	0	0	1880	920	1200	2500	4200	900
3		3	4250	0	0	0	2100	0	0	1020	0	0	0	0	0	0	3000	0	0	0	800	1100	0	0	3460	0
3	T3	6	3800	0	900	0	0	0	0	2880	0	0	0	0	0	0	0	0	0	0	940	2000	0	0	2220	0
3		7	3020	0	0	0	0	1100	900	0	0	0	0	0	700	0	0	800	0	0	800	1500	0	0	900	0

Table A 32 Zooplankton (units L^{-1}) in pond water of Experiment 1

Months	Treatment	Pond	*Cyclops*	*Daphnia*	*Cerio*	*Moina*	*Nauplius*	*Diaptomus*	*Diffugia*	*Brachionus*	*Keratella*	*Monostyla*	*Trichocera*	*Filinia*	*Aplanchana*
1		2	0	0	0	0	1020	0	0	360	550	0	660	0	0
1	T1	5	0	0	0	0	0	0	0	0	0	0	0	0	0
1		9	340	0	0	350	0	400	740	0	0	0	800	0	880
1		1	0	0	0	0	760	0	0	0	500	0	0	0	0
1	T2	4	0	0	0	0	0	0	0	500	0	0	0	780	0
1		8	940	0	600	0	0	0	0	640	0	0	0	0	0
1		3	1880	650	0	0	0	0	0	800	0	740	0	0	600
1	T3	7	0	0	0	680	1200	0	0	1020	0	0	900	0	0
1		6	2000	0	0	0	0	740	0	560	900	0	0	0	0
2	T1	2	0	0	0	0	0	0	1320	1580	0	0	0	0	0

2		5	0	0	860	0	0	0	1880	1880	0	0	0	0	0
2		9	0	0	0	0	2000	0	0	2000	0	0	0	0	600
2		1	1260	900	0	0	0	0	0	1640	0	0	0	900	0
2	T2	4	0	0	0	800	3000	0	0	0	1500	0	0	0	0
2		8	0	0	0	0	0	0	0	0	0	0	760	740	0
2		3	0	0	1000	0	0	0	3000	0	1200	0	0	0	0
2	T3	7	0	0	0	0	0	950	0	0	0	1020	0	0	0
2		6	1020	0	0	0	0	0	0	0	0	0	0	0	0
3		2	900	1000	0	0	4000	0	1020	0	0	0	0	0	900
3	T1	5	0	0	0	0	0	0	2900	2900	0	0	0	0	0
3		9	0	0	730	930	0	0	0	0	1620	0	1020	0	0
3		1	0	0	0	0	3200	0	0	0	0	0	2200	0	0
3	T2	4	0	0	0	0	2500	0	0	0	0	0	1400	0	0
3		8	3000	800	0	930	0	1020	0	0	0	0	900	2100	0
3		3	0	0	0	0	0	0	2880	3000	0	0	0	0	0
3	T3	7	0	0	0	0	0	0	0	0	0	0	0	0	1000
3		6	0	0	0	1650	0	0	0	0	0	0	0	0	0
4		2	0	1800	1240	0	850	0	0	630	0	900	0	0	0
4	T1	5	2900	0	0	0	1000	0	0	720	0	740	0	0	1880
4		9	0	0	0	0	0	0	1200	1020	2000	0	4000	0	0
4		1	0	0	0	0	0	0	5000	1880	0	0	0	0	0
4	T2	4	0	0	0	0	0	0	0	900	0	0	0	3000	0
4		8	500	0	0	0	0	0	0	640	0	0	0	0	1460
4		3	0	600	0	0	1250	0	0	5000	0	0	0	0	1000
4	T3	7	800	440	1460	0	1880	0	0	2200	0	0	900	0	0
4		6	0	0	0	2500	1600	0	0	870	0	0	2000	0	0

APPENDIX B

Water quality, planktons, fish stocking & harvesting data of experiment 2

Table B1 Forghtnightly dial temp (^oC) of pond water at middle depth (50 cm) in treatment 1 of expt. 2

Date	P3	P6	P8	mean
013-2-15	27.5	27.6	27.2	27.43
013-3-01	28.1	28.3	28.1	28.16
013-317	28.5	28.6	28.7	28.6
013-3-31	29.2	29.3	29.4	29.3
013-4-15	29.8	30.1	30.2	30.03
013-4-30	30.5	30.4	30.7	30.53
013-5-16	31	31.2	31.2	31.13
013-5-31	31.6	31.6	31.8	31.66
013-6-13	32.4	32.5	32.7	32.53

Table B2 Forghtnightly dial temp (^oC) of pond water at middle depth (50 cm) in treatment 2 of expt. 2

Date	P2	P9	P12	mean
013-2-15	27.2	27.4	27.4	27.33
013-3-01	27.8	28.1	27.9	27.93
013-317	28.5	28.5	28.6	28.53
013-3-31	29.1	29.5	29.4	29.33
013-4-15	29.5	30.2	29.8	29.83
013-4-30	30.2	30.8	30.7	30.56
013-5-16	31.1	31.4	31.6	31.36
013-5-31	32.1	32.3	32.6	32.33
013-6-13	32.5	32.5	33.1	32.7

Table B3 Forghtnightly dial temp (^oC) of pond water at middle depth (50 cm) in treatment 3 of expt. 2

Date	P5	P4	P11	mean
013-2-15	27.2	27.1	27.5	27.26
013-3-01	27.9	27.8	28.1	27.93
013-317	28.5	28.5	28.5	28.5
013-3-31	29.1	29.1	29.5	29.23
013-4-15	30.2	30.1	30.1	30.13
013-4-30	30.7	30.2	30.8	30.56
013-5-16	31.2	31.5	31.5	31.4
013-5-31	32.6	32.2	32.1	32.3
013-6-13	33.1	33.2	33.1	33.13

Table B4 Forghtnightly dial temp (^{o}C) of pond water at middle depth (50 cm) in treatment 4 of expt. 2

Date	P1	P7	P10	mean
013-2-15	27.5	27.5	27.2	27.4
013-3-01	27.6	28.1	25.1	26.93
013-317	28.2	28.9	28.5	28.53
013-3-31	29.1	29.5	28.2	28.93
013-4-15	29.9	30.1	29.5	29.83
013-4-30	30.5	31.1	30.9	30.83
013-5-16	31.5	31.5	31.6	31.53
013-5-31	32.1	32.1	32.2	32.13
013-6-13	32.8	33.5	33.5	33.26

Table B5 Dissolved oxygen (mg L^{-1}) in pond water at 0900 h in treatment 1 of Experiment 2

Date	P3	P6	P8	mean
013-2-15	6.2	6	6.2	6.13
013-3-01	7.6	8.2	7.4	7.73
013-317	8.2	8.5	8	8.23
013-3-31	6	6.4	7.5	6.63
013-4-15	8.5	6	8	7.5
013-4-30	8.5	8.2	7.4	8.03
013-5-16	4.1	4	4.2	4.1
013-5-31	5.1	5.5	5.1	5.23
013-6-13	6.5	7	7	6.83

Table B6 Dissolved oxygen (mg L^{-1}) in pond water at 0900 h in treatment 2 of Experiment 2

Date	P2	P9	P12	Mean
013-2-15	6.2	6.2	6.4	6.26
013-3-01	8.5	7.6	8	8.03
013-317	8	8.4	8.4	8.26
013-3-31	7.4	10.1	8.6	8.7
013-4-15	6.4	7.6	6.4	6.8
013-4-30	4.2	8.2	7.4	6.6
013-5-16	5.1	6.1	8.2	6.46
013-5-31	5.2	6	7.2	6.13
013-6-13	7.4	5.2	6.5	6.36

Table B7 Dissolved oxygen (mg L^{-1}) in pond water at 0900 h in treatment 3 of Experiment 2

Date	P4	P5	P11	Mean
013-2-15	8.4	7.6	7.1	7.7
013-3-01	8	8	7.4	7.8
013-317	7.6	8.4	8	8
013-3-31	10.1	10.1	8.6	9.6
013-4-15	6	7.2	7.1	6.75
013-4-30	7.2	8.6	7.4	7.73
013-5-16	5.1	4.6	5.2	4.96
013-5-31	6.4	6.4	6	6.26
013-6-13	7.2	6	6.1	6.43

Table B8 Dissolved oxygen (mg L^{-1}) in pond water at 0900 h in treatment 4 of Experiment 2

Date	P1	P7	P10	Mean
013-2-15	6.2	6.4	6	6.2
013-3-01	8.1	8	7.6	7.9
013-317	7.4	8.1	10.2	8.5
013-3-31	8.2	10.1	8.4	8.9
013-4-15	6	6.4	6.5	6.3
013-4-30	7.1	8	7.4	7.5
013-5-16	8.1	7.4	8	7.8
013-5-31	6	7.1	7.1	6.7
013-6-13	4.1	5.2	4.6	4.6

Table B 9 P^H of pond water in treatment 1 of expt. 2

Date	P3	P6	P8	Mean
013-2-15	8	7.8	7.7	7.83
013-3-01	7.7	8.2	8.2	8.03
013-317	8	8	7.8	7.93
013-3-31	7.6	7.5	7.5	7.53
013-4-15	8.5	8.2	8.5	8.4
013-4-30	7.9	8.5	7.8	8.06
013-5-16	7.8	7.7	7.5	7.66
013-5-31	8.2	8	7.7	7.96
013-6-13	7.8	8	7.8	7.86

Table B10 P^H of pond water in treatment 2 of expt. 2

Date	P2	P9	P12	Mean
013-2-15	8.5	8.5	8	8.33
013-3-01	7.7	7.8	8.2	7.9
013-317	8	7.8	7.7	7.83
013-3-31	7.8	8	7.8	7.86
013-4-15	8.2	8.2	8.5	8.3
013-4-30	8.2	7.7	7.8	7.9
013-5-16	7.8	8	7.7	7.83
013-5-31	7.7	7.7	8.2	7.86
013-6-13	8.2	7.7	8.5	8.13

Table B11 P^H of pond water in treatment 3 of expt. 2

Date	P4	P5	P11	Mean
013-2-15	8.5	8	8.2	8.23
013-3-01	8	8.2	8	8.06
013-317	7.8	8.5	8.5	8.26
013-3-31	8.2	7.8	7.7	7.9
013-4-15	7.7	7.7	7.8	7.73
013-4-30	8	8.2	8	8.06
013-5-16	7.7	8.5	8.2	8.13
013-5-31	7.8	7.7	8	7.83
013-6-13	7.7	8	7.7	7.8

Table B12 P^H of pond water in treatment 4 of expt. 2

Date	P1	P7	P10	Mean
013-2-15	7.7	8	8.2	7.96
013-3-01	7.8	8.2	8	8
013-317	8.5	7.7	7.8	8
013-3-31	8	8.5	8.5	8.33
013-4-15	8.5	8.5	8	8.33
013-4-30	8.2	7.8	8.2	8.06
013-5-16	7.7	8	7.8	7.83
013-5-31	8	7.7	8	7.9
013-6-13	8.2	7.7	8	7.96

Table B13 Total Alkalinity (mg L^{-1}) of pond water in treatment 1 of expt. 2

Date	P3	P6	P8	Mean
013-2-15	101	100	135	112
013-3-01	124	123	140	129
013-317	140	135	124	133
013-3-31	100	140	89	109.66
013-4-15	94	100	116	103.33
013-4-30	135	124	140	133
013-5-16	152	140	135	142.33
013-5-31	116	110	124	116.66
013-6-13	124	123	127	124.66

Table B14 Total Alkalinity (mg L^{-1}) of pond water in treatment 2 of expt. 2

Date	P2	P9	P12	Mean
013-2-15	110	84	116	103.33
013-3-01	124	135	124	127.66
013-317	140	146	94	126.66
013-3-31	127	135	140	134
013-4-15	135	124	145	134.66
013-4-30	101	132	152	128.33
013-5-16	94	102	124	106.66
013-5-31	116	110	135	120.33
013-6-13	135	116	101	117.33

Table B15 Total Alkalinity (mg L^{-1}) of pond water in treatment 3 of expt. 2

Date	P4	P5	P11	Mean
013-2-15	100	124	116	113.33
013-3-01	140	152	124	138.66
013-317	135	140	135	136.66
013-3-31	116	124	89	109.66
013-4-15	124	116	140	126.66
013-4-30	76	101	124	100.33
013-5-16	116	95	135	115.33
013-5-31	135	135	124	131.33
013-6-13	124	101	140	121.66

Table B16 Total Alkalinity (mg L^{-1}) of pond water in treatment 4 of expt. 2

Date	P1	P7	P10	Mean
013-2-15	101	124	135	120
013-3-01	124	100	133	119
013-317	116	140	124	126.66
013-3-31	140	152	152	148
013-4-15	116	135	140	130.33
013-4-30	142	124	89	118.33
013-5-16	152	116	101	123
013-5-31	100	133	116	116.33
013-6-13	124	140	124	129.33

Table B17 CO_2 (mg L^{-1}) of pond water in treatment 1 of expt.2

Date	P3	P6	P8	Mean
013-2-15	10.5	11.2	12.4	11.36
013-3-01	11.2	12	14.2	12.46
013-3-17	12	14.6	13.2	13.26
013-3-31	12.8	16.2	16.4	15.13
013-4-15	14.6	13	14	13.86
013-4-30	12.5	14.2	16.2	14.3
013-5-16	16	12.4	13.6	14
013-5-31	13.8	16.2	16	15.33
013-6-13	14	14.2	16.4	14.86

Table B 18 CO_2 (mg L^{-1}) of pond water in treatment 2 of expt. 2

Date	P2	P9	P12	Mean
013-2-15	10.5	11.2	12.6	11.43
013-3-01	11.2	12.2	14.2	12.53
013-3-17	12.6	12.8	12.8	12.73
013-3-31	12.6	12.8	16.2	13.86
013-4-15	13	13.2	16	14.06
013-4-30	13.5	13.6	14.6	13.9
013-5-16	13.8	13.8	16	14.53
013-5-31	14	14.2	14.2	14.13
013-6-13	14.2	14.5	14	14.23

Table B19 CO_2 (mg L^{-1}) of pond water in treatment 3 of expt. 2

Date	P4	P5	P11	Mean
013-2-15	11.2	12	12.6	11.93
013-3-01	11.5	10.6	14.2	12.1
013-3-17	11.8	14.2	16.2	14.06
013-3-31	11.8	16.2	16	14.66
013-4-15	12.4	12.2	14.6	13.06
013-4-30	12.4	13.6	13.6	13.2
013-5-16	12.8	12.6	14.2	13.2
013-5-31	13.2	13	16.6	14.26
013-6-13	13.8	14	16	14.6

TableB20 CO_2 (mg L^{-1}) of pond water in treatment 4 of expt.2

Date	P1	P7	P10	Mean
013-2-15	10.5	11.2	12.6	11.43
013-3-01	11.4	12.2	14.6	12.73
013-3-17	12	14.2	10.4	12.2
013-3-31	14.2	13.6	16.2	14.66
013-4-15	13.4	16	14	14.46
013-4-30	16.2	12.4	16.4	15
013-5-16	12.5	14.2	14.8	13.83
013-5-31	12.2	13	12	12.4
013-6-13	14.2	14.2	12.4	13.6

Table B 21 Transparency (cm) of pond water in Treatment 1 of expt. 2

Date	P3	P6	P23	Mean
013-2-15	30	20.33	31	27.11
013-3-01	32	21.00	31	28
013-3-17	27	18.67	29	24.88
013-3-31	24	16.00	24	21.33
013-4-15	22	16.33	27	21.77
013-4-30	24	16.33	25	21.77
013-5-16	20	16.33	29	21.77
013-5-31	20	13.33	20	17.77
013-6-13	21	15	32	22.66

Table B22 Transparency(cm) of pond water in Treatment 2 of expt. 2

Date	P2	P9	P12	Mean
013-2-15	24	30	31	28.33
013-3-01	30	36	30	32
013-3-17	28	40	40	36
013-3-31	30	26	36	30.66
013-4-15	32	24	30	28.66
013-4-30	24	30	40	31.33
013-5-16	26	28	34	29.33
013-5-31	28	24	26	26
013-6-13	25	26	25	25.33

Table B 23 Transparency(cm) of pond water in Treatment 3 of expt. 2

Date	P13	P17	P21	Mean
013-2-15	30	32	34	32
013-3-01	33	31	35	33
013-317	32	34	33	33
013-3-31	27	25	28	26.66
013-4-15	26	25	24	25
013-4-30	17	21	22	20
013-5-16	18	21	22	20.33
013-5-31	18	20	21	19.66
013-6-13	16	21	21	19.33

Table B 24 Transparency (cm) of pond water in Treatment 4 of expt. 2

Date	P13	P17	P21	Mean
013-2-15	24	32	34	30
013-3-01	26	31	36	31
013-317	24	34	40	32.66
013-3-31	28	28	38	31.33
013-4-15	30	30	30	30
013-4-30	26	24	32	27.33
013-5-16	20	26	28	24.66
013-5-31	22	28	24	24.66
013-6-13	26	30	24	26.66

Table B 25 Initial stocking weight of fish (g fish^{-1}) in Experiment 2

Treatment	Pond	Silver carp	Bighead carp	Rohu	Mrigala	Grass carp	Common carp	*A. mola*
2	P3	9	9	9.5	8.6			1
2	P6	8.6	8.6	9.8	9.2			1.2
2	P8	10	10	10.7	9.2			1.4
Average		9.2	9.2	10	9			1.2
S, E.		0.33	0.33	0.29	0.16			0.09
3	P2	9.8	8.7	10	8.8	8.2		0.9
3	P9	9.2	8.5	9.8	9.2	8.5		1.3
3	P12	8.6	8.9	10.2	9	8.8		1.4
Average		9.2	8.7	10	9	8.5		1.2
S, E.		0.48	0.16	0.16	0.16	0.24		0.124
4	P4	9.2	8.5	10.2	9.2	8.5	9.5	1.2
4	P5	9.5	8.6	10	8.6	8.8	9.2	1
4	P11	8.9	9	9.8	9.2	8.2	9.8	1.4
Average		9.2	8.7	10	9	8.5	9.5	1.2
S, E.		0.24	0.21	0.16	0.28	0.24	0.141	0.094
Control	P1	9.2	9	9.8	9.2	8.8	9.4	
Control	P7	8.6	8.6	10.2	9.2	8.2	9.2	
Control	P10	9.8	8.5	10	8.6	8.5	9.9	
Average		9.2	8.7	10	9	8.5	9.5	
S, E.		0.48	0.21	0.16	0.28	0.24	0.16	

Table B 26 Initial total weight of fish (g pond^{-1}) in Experiment 2

Treatment	Pond	S. carp	B. carp	Rohu	Mrigala	G. carp	C. carp	*A. mola*
2	P3	576	234	323	223.6			500
2	P6	550.4	223.6	333.2	239.2			600
2	P8	640	260	363.8	239.2			700
Average		588.8	239.2	340	542.5			1333.3
S, E.		21.75	8.83	10.01	89.16			216.88
3	P2	588	191.4	300	202.4	123		450
3	P9	552	187	294	211.6	127.5		650
3	P12	516	195.8	306	207	132		700
Average		552	191.4	300	207	294.5		1333.3
S, E.		16.97	2.07	2.82	2.16	48.24		220.63
4	P4	478.4	127.5	234.6	138	59.5	361	600
4	P5	494	129	230	129	61.6	349.6	500
4	P11	462.8	135	225.4	138	57.4	372.4	700
Average		478.4	130.5	230	135	140.2	834.7	1333.3
S, E.		7.35	1.87	2.16	2.44	23.32	136.82	216.82
Control	P1	478.4	135	225.4	138	61.6	357.2	
Control	P7	447.2	129	234.6	138	57.4	349.6	
Control	P10	509.6	127.5	230	129	59.4	376.6	
Average		478.4	130.5	230	135	59.4	361.1	
S, E.		14.7	1.87	2.16	2.44	0.99	6.56	

Table B 27 Final harvesting weight of fish (g fish^{-1}) in Experiment 2

Treatment	Pond	S. carp	B. carp	Rohu	Mrigala	G. carp	C. carp	*A. mola*
2	P3	135	90	85	85			3.2
2	P6	132	92	90	90			3
2	P8	135	85	85	85			3
Average		134	89	86.67	86.67			3.06
S, E.		0.81	1.69	1.9	1.36			0.05
3	P2	132	85	80	85	80		3
3	P9	135	90	75	82	75		3
3	P12	130	82	75	80	75		3
Average		132.33	85.67	76.67	82.33	76.67		3
S, E.		1.18	1.9	1.36	1.18	1.36		0
4	P4	130	85	78	76	78	100	3
4	P5	125	82	75	75	75	100	3
4	P11	132	88	75	80	80	102	3
Average		129	85	76	77	77.67	100.67	3
S, E.		1.69	1.41	0.81	1.24	1.18	0.54	0
T1(ctrl)	P1	105	85	75	72	75	90	
T1(ctrl)	P7	110	85	70	75	80	87	
T1(ctrl)	P10	115	88	70	70	78	85	
Average		110	86	71.66	72.33	77.66	87.33	
S, E.		2.35	0.81	1.36	1.18	1.18	1.18	

Table B 28 Final total weight of fish (g pond^{-1}) in Experiment 2

Treatment	Pond	S. carp	B. carp	Rohu	Mrigala	G. carp	C. carp	*A. mola*
T2	P3	7830	1980	2465	1955			2752
T2	P6	7788	2024	2700	1980			2475
T2	P8	7830	1785	2550	1955			2675
Average		7816	1929.67	2571.67	1963.3			2634
S, E.		11.43	59.96	56.09	6.8			67.38
T3	P2	6996	1530	2000	1615	1040		2520
T3	P9	7155	1530	1800	1558	975		2400
T3	P12	6890	1476	1875	1600	900		2291
Average		7013.67	1512	1891.67	1591	971.67		2403.66
S, E.		62.87	14.69	47.63	13.92	33.02		53.99
T4	P4	6110	935	1326	912	390	3100	2240
T4	P5	6000	902	1350	900	375	3100	2430
T4	P11	6336	968	1350	960	480	3060	2720
Average		6148.67	935	1342	924	415	3086.7	2463.3
S, E.		80.75	15.55	6.53	14.96	26.77	16.88	113.92
T1 (ctrl)	P1	4935	1020	1500	864	375	2970	
T1 (ctrl)	P7	5405	1105	1470	900	480	2784	
T1 (ctrl)	P10	5280	1144	1330	770	468	2805	
Average		5206.66	1089.66	1433.33	844.66	441	2853	
S, E.		114.75	29.89	42.77	31.64	27.09	48.02	

Table B 29 Net mean fish yield (kg pond^{-1}) in Experiment 2

Treatment	Pond	S. carp	B. carp	Rohu	Mrigala	G. carp	C. carp	*A. mola*
T2	P3	7.254	1.746	2.142	1.7314	0	0	2.252
T2	P6	7.237	1.8004	2.3668	1.7408	0	0	1.875
T2	P8	7.19	1.525	2.1862	1.7158	0	0	1.975
Average		7.227	1.69	2.231	1.729	0	0	2.034
S, E.		0.01	0.06	0.05	0	0	0	0.09
T3	P2	6.408	1.3386	1.7	1.4126	0.917		2.07
T3	P9	6.603	1.343	1.506	1.3464	0.8475		1.75
T3	P12	6.374	1.2802	1.569	1.393	0.768		2.159
Average		6.461	1.32	1.591	1.384	0.844		1.993
S, E.		0.05	0.01	0.04	0.01	0.03		0.1
T4	P4	5.6316	0.8075	1.0914	0.774	0.3305	2.739	1.64
T4	P5	5.506	0.773	1.12	0.771	0.3134	2.7504	1.93
T4	P11	5.8732	0.833	1.1246	0.822	0.4226	2.6876	2.02
Average		5.67	0.804	1.112	0.789	0.355	2.725	1.863
S, E.		0.08	0.01	0	0.01	0.02	0.01	0.09
T1	P1	4.4566	0.885	1.2746	0.726	0.3134	2.6128	0
T1	P7	4.9578	0.976	1.2354	0.762	0.4226	2.4344	0
T1	P10	4.7704	1.0165	1.1	0.641	0.4086	2.4284	0
Average		4.728	0.959	1.203	0.709	0.381	2.491	0
S, E.		0.11	0.03	0.04	0.02	0.02	0.04	0

Table B 30 Net Daily weight gain by fish (g fish^{-1}) in Experiment 2

Treatment	Pond	S. carp	B. carp	Rohu	Mrigala	G. carp	C. carp	*A. mola*
T2	P3	1.05	0.675	0.629	0.636			0.018
T2	P6	1.028	0.695	0.668	0.672			0.015
T2	P8	1.041	0.625	0.619	0.631			0.013
Average		1.039	0.665	0.638	0.646			0.015
S, E.		0	0.01	0.01	0.01			0
T3	P2	1.018	0.635	0.583	0.635	0.598		0.017
T3	P9	1.048	0.679	0.543	0.606	0.554		0.014
T3	P12	1.011	0.609	0.54	0.591	0.551		0.013
Average		1.025	0.641	0.555	0.61	0.567		0.014
S, E.		0	0.01	0.01	0.01	0.02		0
T4	P4	1.006	0.637	0.565	0.556	0.579	0.754	0.015
T4	P5	0.962	0.614	0.541	0.553	0..551	0.756	0.016
T4	P11	1.025	0.658	0.543	0.59	0.598	0.768	0.013
Average		0.997	0.636	0.549	0.566	0.576	0.759	0.014
S, E.		0.01	0.01	0	0	0.01		0
T1(ctrl)	P1	0.798	0.633	0.543	0.523	0.551	0.671	
T1(ctrl)	P7	0.845	0.636	0.498	0.548	0.598	0.648	
T1(ctrl)	P10	0.876	0.662	0.5	0.511	0.579	0.625	
Average		0.839	0.643	0.513	0.527	0.576	0.648	
S, E.		0.01	0	0.01	0	0.01	0.01	

Table B 31 Net weight gain by fish (g fish^{-1}) in Experiment 2

Treatment	Pond	S. carp	B. carp	Rohu	Mrigala	G. carp	C. carp	*A. mola*
T2	P3	126	81	75.5	76.4			2.2
T2	P6	123.4	83.4	80.2	80.8			1.8
T2	P8	125	75	74.3	75.8			1.6
Average		124.8	79.8	76.666	77.666			1.867
S, E.		0.61	2.03	1.46	1.28			0.14
T3	P2	122.2	76.3	70	76.2	71.8		2.1
T3	P9	125.8	81.5	65.2	72.8	66.5		1.7
T3	P12	121.4	73.1	64.8	71	66.2		1.6
Average		123.333	76.967	66.666	73.333	68.167		1.8
S, E.		1.1	1.99	1.36	1.24	1.48		0.12
T4	P4	120.8	76.5	67.8	66.8	69.5	90.5	1.8
T4	P5	115.5	73.7	65	66.4	66.2	90.8	2
T4	P11	123.1	79	65.2	70.8	71.8	92.2	1.6
Average		119.8	76.4	66	68	69.167	91.167	1.8
S, E.		1.83	1.24	0.73	1.14	1.32	0.42	0.09
T1(ctrl)	P1	95.8	76	65.2	62.8	66.2	80.6	
T1(ctrl)	P7	101.4	76.4	59.8	65.8	71.8	77.8	
T1(ctrl)	P10	105.2	79.5	60	61.4	69.5	75.1	
Average		100.8	77.3	61.666	63.333	69.167	77.833	
S, E.		2.22	0.9	1.44	1.05	1.32	1.29	

Table B32 Phyto plankton abundance (units L^{-1}) in pond water of Experiment 2

			Chlorophyceae															**Cyanophyceae**			**Euglenophyceae**		**Bacillariophyceae**			
Months	Treatment	Ponds	*Chiorella*	*Coelastrum*	*characium*	*Actinastrum*	*Closterium*	*Chlamydomonas*	*Oedogonium*	*oocystis*	*Pediastrum*	*Selenastrum*	*Spirogyra*	*Tetraedron*	*Tetraspora*	*Volvox*	*Ulothrix*	*Anabaena*	*Microcystis*	*Oscillatoria*	*Euglina*	*Phacus*	*Fragillaria*	*Cyclotella*	*Synedra*	*Nevicula*
0		3	2500	0	0	0	860	0	0	1000	1500	0	0	700	0	0	0	820	0	0	800	0	0	0	0	0
0	T1	6	3000	0	0	0	0	0	0	1200	1200	0	0	0	0	0	0	0	0	0	940	800	0	900	0	0
0		8	2100	700	700	0	700	560	0	900	2000	2100	0	0	800	0	0	0	800	0	800	920	0	1600	0	0
0		2	1600	0	0	0	0	0	0	700	0	0	0	0	0	0	0	0	0	0	760	1020	0	800	800	0
0	T2	9	2800	0	0	0	0	0	0	800	0	0	0	0	0	0	900	0	0	0	1200	760	1420	1800	1420	0
0		12	2800	0	0	700	0	0	0	0	0	0	0	0	0	0	0	0	0	800	900	1000	1100	2400	2400	1860
0		4	5000	0	0	0	0	680	0	4000	0	0	0	0	660	0	0	0	0	0	880	900	800	900	980	2140
0	T3	5	6200	0	0	0	820	0	0	1020	900	0	0	0	0	0	0	0	0	0	700	0	920	3200	2700	1000
0		11	4200	0	0	0	0	0	0	0	0	900	0	840	0	0	0	0	0	0	0	0	3400	1240	2200	1250
0		1	4550	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1600	940	980	0	4000
0	T4	7	4000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1600	3200	1600	0	900	1600
0		10	2400	0	0	0	0	0	0	3800	0	0	0	0	0	0	0	0	0	0	1400	2400	500	800	1500	3500
1		3	14220	800	800	0	1600	840	0	6200	0	0	840	0	900	700	0	900	0	700	1000	860	0	0	1800	0
1	T1	6	12300	920	0	0	0	0	900	1040	0	700	0	1100	0	0	1800	0	0	0	9500	920	0	700	1720	0
1		8	16000	0	0	1200	0	0	0	900	700	0	0	0	0	0	0	0	0	0	3400	1100	700	800	3000	0
1		2	8000	0	0	0	0	0	0	0	900	0	0	1200	0	0	0	0	0	0	1100	2000	0	1100	6500	0
1	T2	9	5000	0	0	0	0	0	0	0	920	0	0	0	1100	0	0	0	0	0	2100	1500	800	920	1100	2880
1		12	6200	0	0	0	0	0	0	#####	1600	0	0	0	0	0	0	0	0	0	1020	900	0	700	900	1020
1		4	10020	0	0	0	0	0	0	#####	1880	0	0	0	0	0	0	0	820	0	1200	0	920	1860	1700	740
1	T3	5	8000	0	0	0	2000	900	0	4000	0	0	0	0	0	0	2000	0	0	0	1650	850	500	1600	0	1450
1		11	6500	580	1020	0	3200	0	0	1020	3000	800	1020	1140	0	900	0	0	0	0	1880	780	2200	1200	800	800

1		1	4200	0	0	0	0	0	0	760	2820	0	0	0	2400	0	0	0	0	900	2000	1000	1000	2300	2400	2000
1	T4	7	4750	0	0	0	2880	0	0	900	0	0	0	0	1600	0	0	0	0	0	2400	940	2400	600	940	800
1		10	12000	0	0	0	0	0	0	800	0	0	0	0	200	0	0	1020	0	0	0	700	860	840	3600	0
2		3	2000	0	0	900	0	0	0	0	0	0	0	0	3200	0	0	0	0	0	0	700	3000	3400	900	0
2	T1	6	1800	0	0	2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	760	1500	0	2000	0
2		8	3200	0	0	0	0	0	1020	3500	0	0	0	0	0	0	0	0	0	0	0	800	0	4200	0	2900
2		2	2900	0	900	0	0	1240	0	3000	0	0	900	0	0	0	0	0	0	0	3460	0	0	3600	0	3750
2	T2	9	1500	0	0	0	0	0	0	2880	3200	1650	0	2200	0	1200	9600	0	0	0	860	0	0	2400	0	0
2		12	1200	0	0	0	0	0	0	1400	3000	2200	0	0	0	0	0	0	0	0	900	0	800	900	3100	0
2		4	4250	0	0	0	4220	0	0	900	4600	0	0	0	0	0	0	0	0	0	0	0	1020	1000	2000	0
2	T3	5	3800	1020	0	0	0	0	0	700	0	0	0	0	0	0	0	0	900	1600	2000	940	2100	1100	4200	0
2		11	3020	0	0	0	0	0	0	1600	0	0	0	0	0	920	0	0	0	0	0	1050	1860	1250	3460	700
2		1	4000	0	0	0	0	0	0	1880	0	0	1400	0	0	0	0	0	0	0	2500	1200	500	100	2220	920
2	T4	7	4500	0	0	1020	0	0	0	3000	2640	0	0	0	2900	0	0	0	0	0	2200	1640	2500	700	0	0
2		10	3300	0	0	0	5400	920	0	5200	1500	0	0	0	4000	0	0	1240	0	0	2000	900	1020	0	2100	0
3		3	6420	0	0	0	0	2000	800	0	1200	0	0	3600	0	0	0	0	0	0	2800	800	1200	0	800	0
3	T1	6	5500	0	840	0	0	1000	0	0	0	760	0	0	0	1300	0	0	0	0	2000	2500	1600	1500	3200	0
3		8	5880	0	0	900	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1500	0	0	1800	1260	0
3		2	6400	0	0	1000	0	0	0	5100	1600	2000	1880	0	0	0	0	0	0	4200	1020	920	0	2000	2400	680
3	T2	9	6000	0	0	0	0	0	0	7800	2000	800	2000	0	0	0	2200	0	0	0	1260	1200	2000	900	0	1000
3		12	5400	0	0	2000	0	0	0	#####	3200	0	1360	0	0	0	0	0	0	0	2000	1480	550	800	0	0
3		4	6100	800	0	0	0	0	0	4000	0	0	0	900	800	0	0	0	0	2600	2200	2300	800	700	4000	0
3	T3	5	4600	0	0	0	0	0	0	2200	0	0	0	0	0	0	0	0	0	1500	2400	0	740	2500	6300	0
3		11	4820	0	0	820	0	3400	0	1100	0	1000	0	0	0	0	0	0	0	700	3000	3000	920	2000	800	5000
3		1	6200	0	1100	0	0	0	0	960	9600	0	0	0	0	0	0	0	0	1000	5400	2500	700	700	0	0
3	T4	7	6400	0	0	0	0	0	0	1040	0	0	0	0	900	0	0	0	0	900	9660	2400	4000	1020	2140	0
3		10	8200	0	0	0	0	0	0	1000	2200	0	0	700	0	0	0	0	0	700	4000	2600	960	900	3100	0

Table B33 Zooplankton (units L^{-1}) in pond water of Experiment 2

Months	Treatment	Pond	*Cyclops*	*Daphnia*	*Cerio*	*Moina*	*Nauplius*	*Diaptomus*	*Diffugia*	*Brachionus*	*Keratella*	*Monostyla*	*Trichocera*	*Filinia*	*Aplanchana*
1		3	580	0	0	0	1500	0	900	0	460	0	900	0	960
1	T1	6	900	0	0	0	0	680	0	0	0	0	0	0	0
1		8	930	760	550	0	0	0	0	720	0	0	0	0	0
1		2	0	0	0	0	1200	0	0	0	0	0	0	0	0
1	T2	9	0	0	0	0	1020	0	0	700	540	0	0	0	0
1		12	1880	0	0	700	1600	0	0	800	0	0	540	0	0
1		4	1000	720	0	0	0	900	1100	930	0	0	0	800	0
1	T3	5	0	0	0	0	0	0	0	1020	0	0	0	0	700
1		11	2220	0	940	0	0	0	0	640	840	0	0	0	0
1		1	0	0	0	740	0	0	0	2000	0	0	0	0	0
1	T4	7	0	0	0	0	3200	0	2200	1880	0	920	0	0	0
1		10	0	0	0	0	2400	0	0	1650	0	0	0	0	0
2		3	0	0	0	0	2000	0	0	2160	0	0	1020	0	500
2	T1	6	1350	0	0	0	0	1100	0	0	1450	0	0	0	0
2		8	0	800	0	0	0	0	0	0	0	0	0	950	0
2		2	0	0	1200	0	0	0	3000	0	1630	0	0	0	0
2	T2	9	0	0	0	0	0	0	0	0	0	0	0	0	0
2		12	1140	0	0	824	0	0	0	0	0	0	0	0	0
2		4	1020	900	0	0	3850	0	1450	2880	0	0	0	0	0
2	T3	5	0	0	0	0	0	0	3300	4600	0	0	0	0	1280
2		11	0	0	0	0	3000	0	0	2880	0	1120	920	0	0
2	T4	1	0	0	0	690	0	0	0	0	0	0	2000	0	0
2		7	0	0	800	0	2850	0	0	0	1520	0	1530	0	0

2		10	3200	1800	0	0	0	0	0	0	0	0	720	0	0
3		3	0	720	0	0	0	0	0	0	0	0	0	0	0
3	T1	6	0	0	0	1850	0	1210	3800	0	0	0	0	2300	0
3		8	0	0	0	0	1100	0	0	0	0	0	0	0	0
3		2	0	0	0	0	850	0	0	900	0	740	0	0	0
3	T2	9	2130	0	0	0	730	0	0	960	0	0	0	0	2000
3		12	0	0	0	0	0	0	1200	3050	0	0	0	0	0
3		4	0	0	1060	0	0	0	920	2140	0	0	0	0	0
3	T3	5	0	0	0	0	0	0	0	5000	0	0	0	0	0
3		11	0	0	0	0	960	0	0	800	0	0	3000	0	0
3		1	600	0	0	2630	920	0	0	1250	0	0	4000	0	1200
3	T4	7	940	450	0	0	1880	0	0	1100	2000	0	2200	3000	0
3		10	0		0	0	1600	0	0	900	0	0	800	0	0
4		3	0	0	0	0	0	0	5000	1020	0	850	0	0	0
4	T1	6	0	0	0	0	0	1120	0	0	0	0	0	0	0
4		8	800	900	0	1020	0	0	0	0	0	0	0	0	0
4		2	0	0	900	0	0	0	0	0	0	0	0	0	1020
4	T2	9	0	0	0	0	0	0	0	0	0	0	0	0	900
4		12	0	0	0	0	1780	0	0	0	1880	0	0	0	1240
4		4	460	0	0	0	2200	0	0	0	1700	0	0	660	0
4	T3	5	0	0	0	840	0	0	0	1580	1020	0	0	0	0
4		11	650	0	700	0	0	800	1500	0	0	0	0	0	0
4		1	0	0	0	0	0	0	1640	0	0	0	0	0	2850
4	T4	7	0	0	0	1150	0	0	0	1350	0	0	0	0	0
4		10	0	0	0	980	0	0	0	780	1120	0	0	0	0

APPENDIX C

WATER QUALITY, PLANKTONS, FISH STOCKING & HARVESTING DATA OF EXPERIMENT 3

Table C1 Forghtnightly dial temp (^oC) of pond water at middle depth (50 cm) in treatment 1 of expt. 3

Date	P6	P11	P12	Mean
013-6-15	33	33.1	33	33.03
013-6-30	32.6	33	32.8	32.8
013-7-16	32.4	31	32.1	31.83
013-7-31	31.7	30.5	31.4	31.2
013-8-15	31.5	31.5	31	31.33
013-8-30	31.1	30.8	30.5	30.8
013-9-14	29.5	27.5	29.7	28.9
013-9-29	26.1	25.5	26.1	25.9
013-10-13	25.5	25.2	26	25.57

Table C2 Forghtnightly dial temp (^oC) of pond water at middle depth (50 cm) in treatment 2 of expt. 3

Date	P1	P5	P9	Mean
013-6-15	33.1	33	33	33.03
013-6-30	33	32.8	32.6	32.8
013-7-16	31	32.1	32.4	31.83
013-7-31	30.5	31.4	31.7	31.2
013-8-15	31.5	31	31.5	31.33
013-8-30	30.8	30.5	31.1	30.8
013-9-14	27.5	29.7	29.5	28.9
013-9-29	25.5	26.1	26.1	25.9
013-10-13	25.2	26	25.5	25.57

Table C3 Forghtnightly dial temp (^oC) of pond water at middle depth (50 cm) in treatment 3 of expt. 3

Date	P3	P8	P10	Mean
013-6-15	32.8	33	33.1	32.97
013-6-30	33.1	32.8	32.5	32.8
013-7-16	32.5	32.5	33	32.67
013-7-31	31.2	32	32.5	31.9
013-8-15	31	31.5	31.7	31.4
013-8-30	30.7	31	31.1	30.93
013-9-14	29.5	30.2	30.5	30.07
013-9-29	29.2	29.1	30	29.43
013-10-13	28.5	29	29.2	28.9

Table C4 Forghtnightly dial temp (^{o}C) of pond water at middle depth (50 cm) in treatment 4 of expt. 3

Date	P4	P7	P19	Mean
013-6-15	33	32.8	33	32.93
013-6-30	32.2	33	32.5	32.57
013-7-16	32	32.2	32.1	32.1
013-7-31	32.5	32.5	32	32.33
013-8-15	32	32	32.1	32.03
013-8-30	31.4	32.1	31.8	31.77
013-9-14	30.5	31.1	31.1	30.9
013-9-29	30.1	30.5	30.4	30.33
013-10-13	29.8	29.5	29.5	29.6

Table C5 Dissolved oxygen (mg L^{-1}) in pond water at 0900 h in treatment 1 of Experiment 3

Date	P6	P11	P12	Mean
013-6-15	3.8	3.5	3.5	3.6
013-6-30	4.2	4.5	4.7	4.47
013-7-16	5.5	5.4	6	5.63
013-7-31	6.1	6.2	5.8	6.03
013-8-15	7.5	8.2	8.5	8.07
013-8-30	8.1	7.9	7.6	7.87
013-9-14	7.8	8.6	8.1	8.17
013-9-29	6.1	6.5	6.4	6.53
013-10-13	6.4	6.3	6	6.23

Table C6 Dissolved oxygen (mg L^{-1}) in pond water at 0900 h in treatment 2 of Experiment 3

Date	P1	P5	P9	Mean
013-6-15	3.6	3.8	3.5	3.63
013-6-30	4	4.2	4.5	4.23
013-7-16	5.7	5.4	6	5.7
013-7-31	6	6.2	6.3	6.17
013-8-15	7.6	8.2	8.1	7.97
013-8-30	8.3	7.9	7.6	7.93
013-9-14	7.8	8.6	8.4	8.27
013-9-29	6.6	6.5	6.4	6.5
013-10-13	6.4	6.3	6.6	6.43

Table C7 Dissolved oxygen (mg L^{-1}) in pond water at 0900 h in treatment 3 of Experiment 3

Date	P3	P8	P10	Mean
013-6-15	3.4	3.7	3.5	3.53
013-6-30	4.9	4.5	4.7	4.7
013-7-16	5.5	5.6	6.2	5.77
013-7-31	6.3	5.7	6.4	6.13
013-8-15	7.4	8.2	8.4	8
013-8-30	8.3	7.9	8.8	8.33
013-9-14	8.7	8.6	9.3	8.87
013-9-29	8.4	8.2	9.6	8.73
013-10-13	6.4	7.3	8.2	7.3

Table C8 Dissolved oxygen (mg L^{-1}) in pond water at 0900 h in treatment 4 of Experiment 3

Date	P4	P7	P9	Mean
013-6-15	4	3.7	4.6	4.1
013-6-30	5	4.6	4.8	4.8
013-7-16	6	5.6	6.2	5.93
013-7-31	6.3	6.6	6.4	6.43
013-8-15	7.4	8.2	8	7.87
013-8-30	8.6	9.6	8.8	9
013-9-14	9.1	8.6	9.6	9.1
013-9-29	8.4	10	9.6	9.33
013-10-13	6.4	7.3	8.4	7.37

Table C 9 P^H of pond water in treatment 1 of expt. 3

Date	P6	P11	P12	Mean
013-6-15	7.6	7.8	8	7.8
013-6-30	7.8	8.5	8.2	8.17
013-7-16	8	8	7.8	7.93
013-7-31	8.2	7.9	7.7	7.93
013-8-15	8	8.5	7.8	8.1
013-8-30	7.6	7.5	8	7.7
013-9-14	7.7	7.7	7.8	7.73
013-9-29	7.5	7.5	7.6	7.53
013-10-13	7.8	7.5	7.8	7.7

Table C 10 P^H of pond water in treatment 2 of expt. 3

Date	P1	P5	P9	Mean
013-6-15	8	8.2	7.5	7.9
013-6-30	7.8	7.5	8	7.77
013-7-16	7.8	7.5	7.8	7.7
013-7-31	7.5	8	8.2	7.9
013-8-15	7.8	8.5	8	8.1
013-8-30	7.4	7.6	7.5	7.5
013-9-14	8.5	8.2	8	8.23
013-9-29	7.6	7.6	7.5	7.57
013-10-13	7.8	7.6	7.5	7.63

Table C 11 P^H of pond water in treatment 3 of expt. 3

Date	P3	P8	P10	Mean
013-6-15	7.7	7.5	7.6	7.6
013-6-30	7.6	7.5	7.6	7.57
013-7-16	7.6	7.5	7.8	7.63
013-7-31	8.2	8.2	7.9	8.1
013-8-15	8	7.9	7.8	7.9
013-8-30	7.5	7.6	7.5	7.53
013-9-14	7.4	7.4	7.5	7.43
013-9-29	7.8	7.6	7.6	7.67
013-10-13	7.5	7.5	7.4	7.47

Table C 12 P^H of pond water in treatment 4 of expt. 3

Date	P4	P7	P9	Mean
013-6-15	7.8	8.2	7.6	7.87
013-6-30	8.5	7.5	7.5	7.83
013-7-16	8	7.5	7.6	7.7
013-7-31	7.9	8	7.9	7.93
013-8-15	8.5	8.5	8	8.33
013-8-30	7.5	7.6	7.8	7.63
013-9-14	7.7	8.2	7.5	7.8
013-9-29	7.5	7.6	7.7	7.6
013-10-13	7.8	7.6	7.5	7.63

Table C13 Total Alkalinity (mg L^{-1}) of pond water in treatment 1 of expt. 3

Date	P6	P11	P12	Mean
013-6-15	84	85	80	83
013-6-30	78	75	76	76.33
013-7-16	77	80	81	79.33
013-7-31	110	112	115	112.33
013-8-15	105	107	101	104.33
013-8-30	98	95	88	93.67
013-9-14	115	120	122	119
013-9-29	81	93	95	89.67
013-10-13	80	81	85	82

Table C14 Total Alkalinity (mg L^{-1}) of pond water in treatment 2 of expt. I

Date	P1	P5	P9	Mean
013-6-15	122	120	142	128
013-6-30	115	121	129	121.65
013-7-16	95	105	121	107
013-7-31	127	103	125	118.33
013-8-15	97	95	102	98
013-8-30	131	117	106	118
013-9-14	106	101	98	101.67
013-9-29	119	113	107	113
013-10-13	97	99	106	100.67

Table C15 Total Alkalinity (mg L^{-1}) of pond water in treatment 3 of expt. 3

Date	P1	P4	P9	Mean
013-6-15	115	132	122	123
013-6-30	113	124	117	118
013-7-16	117	109	121	115.67
013-7-31	121	122	119	120.67
013-8-15	120	116	107	114.33
013-8-30	105	112	106	107.67
013-9-14	103	108	110	107
013-9-29	110	114	107	110.33
013-10-13	99	102	102	101

Table C16 Total Alkalinity (mg L^{-1}) of pond water in treatment 4 of expt. 3

Date	P4	P7	P9	Mean
013-6-15	127	122	125	124.67
013-6-30	122	119	121	120.67
013-7-16	111	108	104	107.67
013-7-31	121	120	118	119.67
013-8-15	115	107	110	110.67
013-8-30	119	115	121	118.33
013-9-14	98	95	103	98.67
013-9-29	96	98	99	97.67
013-10-13	125	110	113	116

Table C 17 CO_2 (mg L^{-1}) of pond water in treatment 1 of expt. 3

Month	P6	P11	P12	Mean
013-6-15	14	13.5	13.4	13.63
013-6-30	12.8	14.2	12.5	13.17
013-7-16	12	13.2	14.2	13.13
013-7-31	12.5	12	12.5	12.33
013-8-15	10	11.4	10.8	10.73
013-8-30	13.2	13	13.5	13.23
013-9-14	12	12.1	12.4	12.17
013-9-29	11.8	11.5	12	11.77
013-10-13	10	10.2	12	10.73

Table C 18 CO_2 (mg L^{-1}) of pond water in treatment 2 of expt. 3

Month	P1	P5	P9	Mean
013-6-15	12.5	14	13.5	13.33
013-6-30	14	13.4	14.5	13.97
013-7-16	13	13.2	14	13.4
013-7-31	12	11.8	13.2	12.33
013-8-15	11.2	10.5	12	11.23
013-8-30	10.2	11.6	12	11.27
013-9-14	12	12	12.2	12.07
013-9-29	10.8	11	11.4	11.07
013-10-13	11.4	10.8	11.2	11.13

Table C 19 CO_2 (mg L^{-1}) of pond water in treatment 3 of expt. 3

Month	P3	P8	P10	Mean
013-6-15	13.2	13.5	13.5	13.4
013-6-30	13	14.2	12.2	13.13
013-7-16	13.2	13.2	13	13.13
013-7-31	14	12	12	12.67
013-8-15	12.5	11.6	14	12.7
013-8-30	11.8	13	14.2	13
013-9-14	12.2	12.2	12	12.13
013-9-29	10.4	11.6	10.6	10.87
013-10-13	10	11.2	10.2	10.47

Table C 20 CO_2 (mg L^{-1}) of pond water in treatment 4 of expt. 3

Month	P4	P7	P9	Mean
013-6-15	12.5	13.5	13.4	13.13
013-6-30	10	14.2	12.5	12.23
013-7-16	13.2	13.2	14.2	13.53
013-7-31	12	12	12.5	12.17
013-8-15	11.8	11.4	10.8	11.33
013-8-30	10	13	13.5	12.17
013-9-14	12.6	12.1	12.4	12.37
013-9-29	11.2	11.5	12	11.57
013-10-13	10	10.2	12	10.73

Table C 21 Transparency (cm) of pond water in Treatment 1 of expt. 3

Month	P6	P11	P12	Mean
013-6-15	20	22	21	21
013-6-30	20	22	21	21
013-7-16	22	20	21	21
013-7-31	21	20	22	21
013-8-15	25	24	22	23.67
013-8-30	22	20	20	20.67
013-9-14	27	25	24	25.33
013-9-29	25	24	22	23.67
013-10-13	21	20	20	20.33

Table C 22 Transparency (cm) of pond water in Treatment 2 of expt. 3

Month	P1	P5	P9	Mean
013-6-15	21	23	20	21.33
013-6-30	22	20	22	21.33
013-7-16	20	23	22	21.67
013-7-31	20	21	20	20.33
013-8-15	27	25	20	24
013-8-30	25	27	28	26.67
013-9-14	25	26	28	26.33
013-9-29	26	25	24	25
013-10-13	21	18	21	20

Table C23 Transparency(cm) of pond water in Treatment 3 of expt. 3

Month	P3	P8	P10	Mean
013-6-15	20	22	21	21
013-6-30	21	20	21	20.67
013-7-16	22	20	20	20.67
013-7-31	20	20	21	20.33
013-8-15	24	26	26	25.33
013-8-30	25	30	29	28
013-9-14	27	31	30	29
013-9-29	28	35	30	31
013-10-13	22	20	21	21

Table C 24 Transparency (cm) of pond water in Treatment 4 of expt. 3

Month	P4	P7	P9	Mean
013-6-15	23	20	23	22
013-6-30	23	22	23	22.67
013-7-16	20	21	23	21.33
013-7-31	21	20	22	21
013-8-15	24	25	23	24
013-8-30	26	29	31	28.67
013-9-14	28	30	32	30
013-9-29	30	32	34	32
013-10-13	20	21	21	20.67

Table C27 Initial weight of fish (g $fish^{-1}$) at stocking in Experiment 3

Treatment	Pond	S. carp	B. carp	Rohu	Mrigala	*A. mola*
2	6	6.2	6.8	7.8	7.6	1.2
2	11	6.5	7.2	8.1	8	1.6
2	12	6.8	7	8.1	8.4	1.7
Average		6.5	7	8	8	1.5
S, E.		0.14	0.94	0.08	0.18	0.12
3	1	6.3	6.9	7.6	7.9	1.3
3	4	6.7	7.1	8	8	1.5
3	9	6.5	7	8.4	8.1	1.7
Average		6.5	7	8	8	1.5
S, E.		0.09	0.04	0.18	0.04	0.09
4	3	6.4	6.7	7.9	7.6	1.2
4	8	6.7	7.3	7.8	8.1	1.6
4	10	6.4	7	8.3	8.3	1.7
Average		6.5	7	8	8	1.5
S, E.		0.08	0.14	0.12	0.16	0.12
Control	4	6.2	6.3	7.9	7.8	
Control	7	6.7	6.7	8.1	8.2	
Control	9	6.6	6.5	8	8	
Average		6.5	7	8	8	
S, E.		0.12	0.17	0.04	0.09	

Table C28 Initial total weight of fish (g $pond^{-1}$) at stocking in Experiment 3

Treatment	Pond	Silver carp	Bighead carp	Rohu	Mrigala	*A. mola*
2	6	396.8	176.8	265.2	197.6	600
2	11	416	187.2	275.4	208	800
2	12	435.2	182	275.4	218.4	850
Average		416	182	272	208	750
S, E.		9.05	2.41	2.77	4.9	62.36
3	1	403.2	179.4	258.4	205.4	1300
3	4	428.8	184.6	272	208	1500
3	9	416	182	285.6	210.6	1700
Average		416	182	272	208	1500
S, E.		6.03	1.22	6.41	1.22	94.28
4	3	409.6	174.2	268.6	197.6	2400
4	8	428.8	189.8	265.2	210.6	3200
4	10	409.6	182	282.2	215.8	3400
Average		416	182	272	208	3000
S, E.		5.22	3.67	4.24	4.41	249.44
Control	4	396.8	163.8	268.6	202.8	
Control	7	428.8	174.2	275.4	213.2	
Control	9	422.4	169	272	208	
Average		416	169	272	208	
S, E.		7.98	2.45	1.6	2.45	

Table C29 Final weight of fish (g fish^{-1}) at harvesting in Experiment 3

Treatment	Pond	Silver carp	Bighead carp	Rohu	Mrigala	*A. mola*
2	6	148	136	110	118	3
2	11	147	135	108	116	3
2	12	147	134	106	114	3.2
Average		147.3	135	108	116	3.066
S, E.		1.51	0.27	0.47	0.94	0.054433
3	1	148	138	128	133	2.9
3	4	150	135	125	132	3.1
3	9	150	136	125	133	3.2
Average		149.33	136.33	126	132.66	3.06
S, E.		0.54	0.72	0.81	0.27	0.07
4	3	146	135	112	128	3
4	8	144	137	110	125	2.8
4	10	145	133	109	124	3.2
Average		145	135	110.33	125.66	3
S, E.		0.04	0.94	0.72	0.98	0.09
Control	4	136	120	105	115	
Control	7	135	121	103	117	
Control	9	136	125	106	120	
Average		135.66	122	104.66	117.33	
S, E.		0.27	1.24	0.72	1.18	

Table C30 Final total weight of fish (g pond^{-1}) at harvesting in Experiment 3

Treatment	Pond	Silver carp	Bighead carp	Rohu	Mrigala	*A. mola*
2	6	7548	2720	2750	2360	2400
2	11	7644	2835	3024	2320	2320
2	12	7497	2680	2968	2280	2608
Aveage		7563	2745	2914	2320	2442.667
S, E.		35.18	37.93	68.24	18.85	70.08
3	1	7696	2760	3328	2660	5340
3	4	7950	2835	3125	2376	5460
3	9	8550	2992	3750	3059	5550
Average		8065.3	2862.3	3401	2698.3	5450
S, E.		206.72	55.8	150.29	161.74	0.04
4	3	7300	2430	2688	2304	5376
4	8	7344	2603	2750	2500	5295
4	10	7250	2660	2834	2480	5475
Average		7298	2564.3	757.3	2428	5382
S, E.		22.17	56.46	34.54	50.84	0.04
Control	4	6936	2640	2835	2530	
Control	7	6750	2420	2472	2340	
Control	9	6800	2500	2650	2400	
Average		6828.6	2520	2652.3	2423.3	
S, E.		45.37	52.49	85.56	45.78	

Table C31 Net total weight gain (g pond^{-1}) at harvesting in Experiment 3

Treatment	Pond	S. carp	B. carp	Rohu	Mrigala	*A. mola*
2	6	7132	2538	2478	2152	1750
2	11	7228	2653	2752	2112	1650
2	12	7081	2498	2696	2072	1758
Average		7147	2563	2642	2112	1719.3
S, E.		35.18	37.93	68.24	18.85	28.36
3	1	7280	2578	3056	2452	4640
3	4	7534	2653	2853	2168	5870
3	9	8134	2810	3478	2851	5120
Average		7649.3	2680.3	3129	2490.3	5210
S, E.		206.72	55.8	150.29	161.74	292.23
4	3	6884	2248	2416	2096	4496.3
4	8	6928	2421	2478	2292	4142
4	10	6834	2478	2562	2272	5090
Average		6882	2382.3	2485.3	2220	4576.1
S, E.		22.17	56.46	34.54	50.84	225.8
Control	4	6520	2458	2563	2322	
Control	7	6334	2238	2200	2132	
Control	9	6384	2318	2378	2192	
Average		6412.6	2338	2380.3	2215.3	
S, E.		45.37	52.49	85.56	45.78	

Table C32 Net Daily weight gain by fish (g fish^{-1}) in Experiment 3

Treatment	Pond	S. carp	B. carp	Rohu	Mrigala	*A. mola*
2	6	1.125	1.025	0.811	0.876	0.0142
2	11	1.115	1.014	0.792	0.857	0.0111
2	12	1.112	1.007	0.776	0.838	0.0119
Average		1.11	1.01	0.79	0.85	0.0124
, E.		0.0032	0.00428	0.0083	0.00896	0.000759
3	1	1.124	1.0404	0.955	0.992	0.0126
3	4	1.137	1.015	0.928	0.984	0.0126
3	9	1.138	1.023	0.925	0.991	0.0119
Average		1.13	1.02	0.93	0.98	0.0123
S, E.		0.0037	0.00612	0.0078	0.00206	0.000191
4	3	1.107	1.018	0.826	0.955	0.0142
4	8	1.089	1.029	0.811	0.927	0.0095
4	10	1.1	1	0.799	0.918	0.0119
Average		1.09	1.01	0.81	0.93	0.01
S, E.		0.0043	0.0069	0.0064	0.0091	0.001108
Control	4	1.103	0.902	0.7706	0.8507	
Control	7	1.018	0.907	0.753	0.863	
Control	9	1.026	0.9404	0.777	0.888	
Average		1.04	0.91	0.76	0.86	
S, E.		0.0221	0.00984	0.0059	0.00896	

Table C33 Plankton abundance (units L^{-1}) in pond water of Experiment 3

			Chlorophyceae															Cyanophyceae			Euglenophyceae		Bacillariophyceae			
Months	Treatment	Ponds	*Chiorella*	*Coelastrum*	*characium*	*Actinastrum*	*Closterium*	*Chlamydomonas*	*Oedogonium*	*oocystis*	*Pediastrum*	*Selenastrum*	*Spirogyra*	*Tetraedron*	*Tetraspora*	*Volvox*	*Ulothrix*	*Anabaena*	*Microcystis*	*Oscillatoria*	*Euglina*	*Phacus*	*Fragillaria*	*Cyclotella*	*Synedra*	*Nevicula*
0		2	2000	0	650	0	0	0	0	900	650	0	0	0	500	0	0	0	0	0	860	700	0	0	0	740
0	T1	11	1800	0	0	0	0	0	0	700	800	0	0	0	0	0	0	0	0	0	900	760	0	800	2140	1450
0		12	3200	0	0	0	0	0	0	1600	500	0	0	0	0	0	0	0	0	0	0	800	0	0	3100	800
0		1	2900	0	0	0	700	0	0	1880	0	0	0	0	0	0	0	0	0	0	1100	0	500	700	2400	2000
0	T2	4	1500	0	0	0	0	0	0	3000	0	0	0	900	0	0	0	0	0	0	2100	0	0	800	980	800
0		9	1200	0	0	0	0	0	0	5200	0	2000	0	0	700	0	0	0	0	0	1020	0	0	1100	2700	1000
0		3	2500	0	700	0	0	700	0	4000	0	0	0	0	0	0	640	0	0	0	1200	0	700	920	2200	1250
0	T3	8	3000	0	0	700	800	0	0	1020	1020	0	0	0	0	0	0	0	0	0	1650	940	0	100	0	4000
0		10	2100	800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	660	1880	1050	800	700	0	1600
0		5	1600	0	0	0	0	0	0	0	0	0	0	1200	0	0	0	0	0	0	2000	920	0	0	0	3500
0	T4	7	2800	0	0	0	0	900	0	0	0	0	0	0	0	0	0	0	0	0	2400	1200	920	0	4000	0
0		9	2800	0	0	0	0	0	0	3800	0	0	0	0	0	0	2000	0	0	0	0	1480	500	1500	6300	0
1		2	4250	0	0	0	1200	0	0	6200	0	0	0	0	900	0	0	0	760	0	0	2300	700	1800	800	0
1	T1	11	3800	0	0	0	920	0	0	1040	0	920	0	1420	0	0	0	0	0	0	0	2400	4000	2000	3100	0
1		12	3020	0	0	0	0	0	0	900	1500	0	0	0	0	840	0	0	0	800	0	2600	960	900	2000	0
1		1	4000	0	0	0	0	0	0	0	1230	0	0	0	0	0	0	700	0	0	3460	900	1020	700	4200	1860
1	T2	4	4500	0	800	0	0	0	0	0	2200	0	1020	0	0	0	0	0	0	0	3000	0	1200	1860	3460	2140
1		9	3300	8000	0	1020	0	0	0	10200	1850	0	0	0	0	0	0	0	0	0	5400	0	1600	1600	2220	0
1		3	5000	0	0	0	0	1020	0	15000	1600	0	0	0	1680	0	0	0	0	0	9660	1600	0	1200	900	0
1	T3	8	6200	0	0	0	0	0	0	4000	0	800	0	0	0	0	0	0	0	0	4000	3200	0	2300	1700	0
1		10	4200	0	0	0	2400	0	0	1020	2000	0	0	1600	0	0	0	0	0	0	2000	2400	2200	600	0	2900
1	T4	5	4550	0	0	0	2700	0	1050	760	2820	0	0	0	0	0	1320	0	0	0	0	0	1000	840	800	3750

1		7	4000	0	0	0	3200	0	0	900	0	0	0	0	0	920	0	0	0	0	2500	800	2400	3400	2400	5000
1		9	6400	0	0	0	0	0	0	800	0	0	0	0	1400	0	0	0	0	0	2200	920	860	0	940	0
2		2	6420	0	0	900	0	0	0	0	0	0	0	0	2200	0	0	0	0	0	2000	1020	3000	900	3600	0
2	T1	11	5500	0	0	0	0	1000	0	0	0	0	0	0	2000	0	0	0	920	0	2800	760	1500	1600	0	0
2		12	5880	0	0	0	0	0	0	3500	0	0	900	2000	0	0	0	0	0	1100	1200	1000	0	800	2100	0
2		1	6400	0	0	0	0	0	1000	3000	0	2420	750	0	0	0	0	900	0	0	900	1200	0	1800	800	0
2	T2	4	6000	0	0	0	0	0	0	2880	3200	1650	0	0	0	0	0	0	0	0	880	1640	0	2400	3200	0
2		9	5400	0	0	0	0	0	0	1400	3000	0	0	0	0	0	0	0	0	0	700	900	0	900	1260	0
2		3	6100	0	0	0	0	0	0	1000	1000	0	0	0	0	0	0	0	0	0	0	800	1420	3200	2400	2880
2	T3	8	4600	0	0	0	5000	0	0	1200	0	0	0	0	3400	1000	0	0	0	0	0	2500	1100	1240	900	1020
2		10	4820	0	0	0	0	0	0	900	0	0	1150	2250	1000	780	0	0	0	0	1600	0	800	980	1500	0
2		5	6200	0	1020	2000	0	0	0	700	0	0	0	0	0	0	10500	0	0	1020	1400	0	920	800	1800	0
2	T4	7	6400	0	900	650	0	0	0	800	2640	0	0	0	0	0	0	0	0	0	2000	3000	3400	700	1720	0
2		9	8200	0	0	0	0	1250	0	0	1650	0	0	0	0	0	0	0	0	0	1500	2500	940	2500	3000	0
3		2	14220	0	0	0	4000	2000	0	0	1000	0	0	0	0	0	0	0	0	0	1020	860	1600	2000	6500	0
3	T1	11	12300	0	0	0	0	1000	0	0	0	0	0	0	0	0	0	0	0	4000	1260	920	2000	700	1100	0
3		12	16000	0	0	900	0	0	750	0	0	900	0	900	0	0	0	0	800	0	2000	1100	550	1020	0	0
3		1	8000	1200	0	760	0	0	0	5100	1600	2000	1500	0	0	0	0	0	0	0	2200	2000	800	900	0	0
3	T2	4	5000	0	0	2000	0	0	0	7800	1520	800	2000	0	0	0	0	900	0	0	2400	1500	740	0	0	0
3		9	6200	0	0	1000	0	0	0	10500	3200	0	1000	0	0	1100	0	0	0	0	800	900	920	4200	800	700
3		3	10020	0	0	0	0	0	0	4000	0	0	0	0	800	0	0	0	0	2050	940	0	800	3600	1420	920
3	T3	8	8000	0	0	0	0	3200	0	2200	0	0	0	0	0	0	0	0	0	1020	800	850	1020	2400	900	680
3		10	6500	0	800	0	0	0	0	1100	0	1650	0	0	0	0	0	0	0	840	760	780	2100	900	2000	1000
3		5	4200	0	0	0	0	0	0	960	6000	0	0	1400	0	0	0	0	0	750	1000	1000	1860	1000	0	0
3	T4	7	4750	0	0	0	0	0	0	1040	0	0	0	0	1020	0	2400	0	0	900	9500	940	500	1100	0	0
3		9	12000	0	0	0	0	0	0	1000	5000	1200	0	0	0	0	0	0	0	600	3400	700	2500	1250	0	0

Table C 34 Zooplankton (units L^{-1}) in pond water of Experiment 3

Months	Treatment	Pond	*Cyclops*	*Daphnia*	*Cerio*	*Moina*	*Nauplius*	*Diaptomus*	*Diffugia*	*Brachionus*	*Keratella*	*Monostyla*	*Trichocerca*	*Filinia*	*Aplanchana*
1		2	1020	0	730	0	900	760	0	630	500	0	0	0	0
1	T1	11	0	0	0	0	1000	0	0	0	0	0	0	0	0
1		12	930	0	900	0	0	0	1200	0	0	0	860	0	1000
1		1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	T2	4	0	0	0	0	0	0	0	790	700	0	0	0	0
1		6	1320	0	0	700	0	0	0	800	0	0	660	0	0
1		3	1000	800	840	0	1650	0	1000	700	0	0	0	0	0
1	T3	8	0	0	0	0	0	800	0	1135	0	0	0	0	0
1		10	2220	0	0	0	0	0	0	935	0	0	0	0	800
1		5	0	0	0	740	0	0	0	2140	900	0	0	0	0
1	T4	7	0	0	0	0	1730	0	0	2200	0	0	0	780	0
1		9	0	0	0	0	2400	0	2800	1400	0	0	0	0	0
2		2	1880	0	0	0	3000	0	0	2160	0	0	920	0	0
2	T1	11	0	0	0	0	0	0	0	0	0	1050	0	0	0
2		12	0	0	1020	0	0	1080	0	0	0	0	0	0	0
2		1	0	1800	0	0	0	0	3335	0	1630	0	0	0	540
2	T2	4	0	0	0	0	0	0	0	0	1490	0	0	0	0
2		6	1140	0	0	824	0	0	0	0	0	0	0	920	0
2		3	600	900	0	0	4000	0	4000	3200	0	0	0	0	0
2	T3	8	900	0	0	0	2820	0	3300	5000	0	0	1100	0	0
2		10	0	0	0	0	3000	0	0	2880	0	0	920	0	0
2		5	0	0	0	690	0	0	0	0	0	0	2000	0	1420
2	T4	7	0	0	800	0	0	1000	0	0	0	0	0	0	0
2		9	0	0	0	0	0	0	0	0	0	860	0	0	0
3	T1	2	3400	720	0	0	0	0	0	0	0	0	0	0	0
3		11	0	0	0	1850	0	0	1445	0	1500	0	0	0	0

3		12	0	0	0	0	1100	0	0	0	0	0	0	0	0
3		1	0	0	0	0	850	0	0	900	0	930	0	0	0
3	T2	4	2130	0	0	0	730	0	0	1250	0	0	0	0	2540
3		6	0	0	0	0	0	0	1450	2140	0	0	0	0	0
3		3	0	0	0	0	0	0	5000	3050	0	0	0	2000	0
3	T3	8	0	0	1005	0	0	0	0	5200	0	0	0	0	0
3		10	0	0	0	0	960	0	0	800	0	0	3000	0	0
3		5	580	0	0	2630	920	0	0	960	0	0	3800	0	0
3	T4	7	0	450	0	0	1880	0	0	1100	1950	0	2140	0	0
3		9	0		0	0	1600	0	0	890	0	0	1080	0	1320
4		2	0	0	0	0	0	0	1150	960	0	740	0	0	0
4	T1	11	0	0	0	0	0	1120	0	0	0	0	0	3100	0
4		12	800	900	0	1020	0	0	0	0	0	0	0	0	0
4		1	0	0	650	0	0	0	0	0	0	0	0	0	0
4	T2	4	0	0	0	0	0	0	0	0	0	0	0	0	1105
4		6	0	0	0	0	0	0	0	0	2010	0	0	0	900
4		3	460	0	0	0	0	0	0	0	1740	0	0	0	0
4	T3	8	0	0	0	840	2150	0	0	0	1150	0	540	0	0
4		10	650	0	0	0	1930	0	1800	1760	0	0	0	700	0
4		5	0	0	900	0	0	0	1640	2460	0	800	0	0	0
4	T4	7	0	0	0	1150	0	0	0	1350	0	0	0	0	3000
4		9	980	0	0	980	0	700	0	900	1120	0	0	0	0

APPENDIX D

Data of SIS survey

Questions of SIS survey;

- Did you know about maximum and minimum size of SISspeccies in this locality?

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- What are the types of SIS species in this area?

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- Say the SIS species which are found in spring, summer and monsoon seasons?

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- How much SIS species are brought for sell in local market for a week?

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- Which on SIS species is found throughout the year either in low or high quantity?

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- Which SIS species have high demand on consumers preference?

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- Are the SIS species brought from India for sell generally, rarely or never?

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- What are the sources for SIS collection?

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- When gravid SIS didare found in market?

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- Are the local people use unconventional methods for SIS collection?

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- From where SIS arrive in stagnant water bodies of this area?

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- What is the rate of SIS landing between present and last few years?

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- What are the methods for SIS collection?

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- For how long time do you preserve SIS between capture and sell?

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- Is it possible to distinguish locally produced SIS and brought from elsewhere?

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- What is about SIS consumption in your family? Is it frequently or occasionly?

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- What is about financial return from SIS sell?

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- Inform about the price per kg SIS and and carp species?

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- What do you suggest to maintain SIS diversity?

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- Lastly please inform the choice of consumers among mara, pothi and dedhuwa? (All questions were developed into Nepali.)

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Table D1 Relative landing of SIS species station wise kg week^{-1} of yr in 2012

sampling station	sampling sites	Months				
		15/2/2012	15/3/2012	15/4/2012	15/5/2012	15/6/2012
S1	S1a	25	30	36	42	81
	S1b	20	23	30	35	45
	S1c	26	28	34	40	60
sub total	Mean±S.E	23.6±1.51	27±1.69	33.3±1.44	39±1.69	62±8.52
S2	S2a	6.8	7.2	8.5	9	14.5
	S2b	6	7	9	8	9
	S2c	7.5	6.5	10.5	8.4	9
sub total	Mean±S.E	6.7±0.35	6.9±0.16	9.3±0.49	8.4±0.23	10.8±1.49
S3	S3a	7.2	7.5	8.5	9.2	15.5
	S3b	5.5	6	8	10.5	8.5
	S3c	6	7	9.5	8.5	7
sub total	Mean±S.E	6.2±0.41	6.8±0.36	8.6±0.36	9.4±0.47	10.3±2.13
S4	S4a	5.4	5.5	7	7.2	9.2
	S4b	5	4.5	5.5	4.7	5
	S4c	4.5	6	4.2	5	4.8
sub total	Mean±S.E	4.9±0.21	5.3±0.36	5.5±0.66	5.6±0.64	6.3±1.17
S5	S5a	4.2	4.6	5.2	7.3	8.4
	S5b	4	6	5.3	6	5.5
	S5c	5	5.2	5	4	7
sub total	Mean±S.E	4.4±0.24	5.2±0.33	5.1±0.07	5.7±0.78	6.9±0.68
S6	S6a	6.5	6.6	7.2	8.5	10.5
	S6b	5	6	7.5	6	7
	S6c	4.5	5.5	8	7	7.5
sub total	Mean±S.E	5.3±0.49	6±0.25	7.5±0.19	7.1±0.59	8.3±0.89
S7	S7a	5.2	7.2	7.5	8.5	13.2
	S7b	4	6	8.5	8	9.4
	S7c	4	7	9.5	7.6	8
sub total	Mean±S.E	4.4±0.32	6.7±0.30	8.5±0.47	8±0.21	10.2±1.26
S8	S8a	5.8	6.5	8.5	10.5	13.5
	S8b	6	8	8	8.5	11.4
	S8c	7	7.5	7	8	10.5
sub total	Mean±S.E	6.2±0.30	7.3±0.36	7.8±0.36	9±0.62	11.8±0.72

Table D2 **S**pecies wise relative landing of SIS kg week^{-1} of yr in Feb to march 2012

S/no	Species	S1	S2	S3	S4	S5	S6	S7	S8
1	*Amblypharyngodon mola*	5	3.5	3	2.1	2.5	3	4	3.5
2	*Esomus danricus*	3	2	1.5	1	1	2	2.5	2
3	*Puntius chola*	2	1	1.2	1	1	1	1.5	2
4	*Puntius sarana*	2	1	1.2	0.5	1	1	1	1
5	*Puntius conchonius*	2	1	1	0.5	0.5	0.5	1	1.5
6	*Puntius sophore*	4	2.5	1.2	1.5	0.5	1	1.5	2

7	*Puntius ticto*	4	2.5	2	2	2	2	2.5	2
8	*Aspidoparia morar*	15	0	0	0	0	0	0	0
9	*Aspidoparia jaya*	5	0	0	0	0	0	0	0
10	*Barilius barila*	3	0.5	0.5	0	0.5	0.5	0	0
11	*Barilius bendelisis*	5	1	0.5	0	1	1	0	1.5
12	*Barilius barana*	3.5	0.5	0.5	0	0.5	1	0	0.5
13	*Barilius vagra*	4.2	0.5	1	0	1	0.5	0	1
14	*Chela lubuca*	4	2	1.5	1	1	1.5	2	1.5
15	*Danio devario*	2.5	0	1	0.5	1	0.5	0	0.5
16	*Danio rerio*	2	0		0	0	0	0	0
17	*Crossocheilus latius*	2	1	0.5	0	1	0.5	0	0
18	*Cirrhinus reba*	3	2	1	1	1	1.5	1.5	1
19	*Labeo dero*	3	0.5	1	0	0.5	0	0	0
20	*Oxygaster bacaila*	9	0.5	0.5	0.5	1	3	2	1
21	*Osteobrama cotio*	2	0	0	0	0	0	0	1
22	*Rasbora daniconius*	1.5	0	0	0	0	0	0	0
23	*Rasbora elanga*	1.5	0	0	0	0	0	0	0
24	*Semiplotus semiplotus*	4	0	0	0	0	0	0	0
25	*Lepidocephalichthys guntea*	4	1	1.5	1	1.3	1.5	2	2
26	*Botia lochata*	2	1	2	0.5	0.5	0	0	0.5
27	*Semileptes gongota*	2.7	0	0	0	0	0	0	0
28	*Noemacheilus bevani*	1.8	1	1	0	0.5	0	0	0
29	*Noemacheilus botia*	1.5	0.5	1	0	0.5	0	0	0
30	*Mystus tengra*	5	1	1	1	0.5	1	1	1.5
31	*Mystus vittatus*	7	1	1	1	1	0.5	1.5	1.5
32	*Alia colia*	4	0	0	0	0	0	0	0
33	*Clupisoma garua*	4	0	0	0	0	0	0	0
34	*Etropiichthys vacha*	7	0	0	0	0	0	0	0
35	*Pseudeutropius murius*	4	0	0	0	0	0	0	0
36	*Heteropneustes fossilis*	6	1	1.5	1	0.5	1	1.5	1
37	*Clarius batrachus*	3	1	1	0.5	0.5	1	1	1
38	*Anguilla bengalensis*	5	0.5	0	0	0	0.5	0	0.5
39	*Xenentodon cancilla*	4	1	0.5	0	0	0	0	1
40	*Notopterus notopterus*	3	0.5	0.5	0.5	0.5	0.5	1	1
41	*Chanda nama*	4	1	1.5	1	0.5	1	2	2
42	*Chanda ranga*	2	1	1.5	0.5	0.5	1	0.2	0.5
43	*Amphipnous chuchia*	3	1	0.5	0.5	0.5	0.7	1	1
44	*Channa gachua*	4	2.5	2	1	1	1	2	2.1
45	*Channa marulius*	5	1.5	1	0.5	0.5	0.5	1.5	2
46	*Channa punctatus*	4	1.5	1	0.5	0.5	1	1	1.5
47	*Channa striatus*	2	0.5	0.5	0.5	0.5	0.5	1	1
48	*Nandus nandus*	2	0	0	0	0	0	0	0
49	*Badis badis*	1.5	0	0	0	0	0	0	0
50	*Colisa fasciatus*	4	2	1.5	1	1	1.5	2	1
51	*Glossogobius guiris*	4	1	0.5	0.5	0.5	1	1	0.5

52	*Annabas testudineus*	3	1	1.5	1	1	1	2	1
53	*Mastacembelus armatus*	3	1.5	2	0.7	0.5	1	1	0.5
54	*Mastacembelus puncalus*	2	1	1	0.5	0.5	0.5	1	1
55	*Macrognathus aculeatus*	2	1	0.5	0.5	0.5	1	0.6	1

Table no. D3 Species wise total weight and number of SIS in all sampling stations

SN	**SIS**	**Total wt.kg**	**kg^{-1} no. of fish**	**No. of fish**
1	*Amblypharyngodon mola*	26.6	150	3990
2	*Esomus danricus*	15	300	4500
3	*Puntius chola*	10.7	150	1605
4	*Puntius sarana*	8.7	50	435
5	*Puntius conchonius*	8	120	960
6	*Puntius sophore*	12.2	120	1464
7	*Puntius ticto*	19	200	3800
8	*Aspidoparia morar*	15	150	2250
9	*Aspidoparia jaya*	5	150	750
10	*Barilius barila*	5	120	600
11	*Barilius bendelisis*	10	80	800
12	*Barilius barana*	6.5	100	650
13	*Barilius vagra*	8.2	100	820
14	*Chela lubuca*	12.5	120	1500
15	*Danio devario*	6	150	900
16	*Danio rerio*	2	150	300
17	*Crossocheilus latius*	5	60	300
18	*Cirrhinus reba*	12	80	960
19	*Labeo dero*	5	30	150
20	*Oxygaster bacaila*	17.5	130	2275
21	*Osteobrama cotio*	3	125	375
22	*Rasbora daniconius*	1.5	140	210
23	*Rasbora elanga*	1.5	140	210
24	*Semiplotus semiplotus*	4	60	240
25	*Lepidocephalichthys guntea*	13.3	160	2128
26	*Botia lochata*	6.5	160	1040
27	*Semileptes gongota*	2.7	120	324
28	*Noemacheilus bevani*	4.3	200	860
29	*Noemacheilus botia*	2.5	200	500
30	*Mystus tengra*	12	40	480
31	*Mystus vittatus*	14.5	45	652.5
32	*Alia colia*	4	25	100
33	*Clupisoma garua*	4	15	60
34	*Etropiichthys vacha*	7	15	105
35	*Pseudeutropius murius*	13.5	20	270
36	*Heteropneustes fossilis*	13	18	234
37	*Clarius batrachus*	9	18	162
38	*Anguilla bengalensis*	6.5	10	65
39	*Xenentodon cancilla*	6.5	45	293

40	*Notopterus notopterus*	7.5	6	45
41	*Chanda nama*	13	100	1300
42	*Chanda ranga*	7.2	110	792
43	*Amphipnous chuchia*	8.2	110	902
44	*Channa gachua*	15.6	6	94
45	*Channa marulius*	12.5	25	313
46	*Channa punctatus*	11	8	88
47	*Channa striatus*	6.5	10	65
48	*Nandus nandus*	2	5	10
49	*Badis badis*	1.5	30	45
50	*Colisa fasciatus*	14	40	560
51	*Glossogobius guiris*	9	120	1080
52	*Annabas testudineus*	11.5	30	345
53	*Mastacembelus armatus*	10.2	35	357
54	*Mastacembelus puncalus*	7.5	40	300
55	*Macrognathus aculeatus*	7.1	40	284

Table D4 Relative price of SIS species Rs kg^{-1} yr^{-1}in 2012/2013 (N C = Rs)

(Figures in bracket shows the range)

SISspecies	S1	S2	S3	S4	S5	S6	S7	S8
A. mola	400	350	500	425	425	300	350	350
	(300-500)	(300-400)	(400-600)	(350-500)	(350-500)	(250-350)	(300-400)	(300-400)
E.dendricus	250	250	300	250	300	225	225	325
	(200-300)	(200-300)	(250-350)	(200-300)	(250-350)	(200-250)	(200-250)	(300-350)
P. ticto	175	175	175	250	200	200	225	275
	(150-200)	(150-250)	(200-350)	(200-300)	(150-250)	(150-250)	(200-250)	(250-300)
A. morar	500	500	0	0	0	0	0	0
	(400-600)	(400-600)	0	0	0	0	0	0
C. lubuca	350	300	350	300	250	250	240	300
	300-400	(250-350)	(300-400)	(250-350)	(200-300)	(200-300)	(225-350)	(250-350)
M. tengra	550	500	700	700	500	500	500	700
	(400-700)	(400-600)	(600-800)	(600-800)	(400-600)	(400-600)	(400-600)	(600-800)
M. vittatus	550	500	700	700	500	500	500	700
	(400-700)	(400-600)	(600-800)	(600-800)	(400-600)	(400-600)	(400-600)	(600-800)
C. garua	1000	1000	0	0	0	0	0	0
	(800-1200)	(800-1200)	0	0	0	0	0	(800-1200)
H. fossilis	700	650	750	750	650	650	650	750
	(600-800)	(600-700)	(700-800)	(700-800)	(600-700)	(600-700)	(600-700)	(700-800)
C. batrachus	700	650	750	750	650	650	650	650
	(600-800)	(600-700)	(700-800)	(700-800)	(600-700)	(600-700)	(600-700)	(600-700)
C. marulius	350	350	450	450	350	350	350	450
	(300-400)	(300-400)	(400-500)	(400-500)	(300-400)	(300-400)	(300-400)	(400-500)
C. punctatus	350	350	450	450	350	350	350	450
	(300-400)	(300-400)	(400-500)	(400-500)	(300-400)	(300-400)	(300-400)	(400-500)
C. nama	300	300	300	300	300	225	225	300

	(250-350)	(250-350)	(250-350)	(250-350)	(250-350)	(200-250)	(200-250)	(250-350)
C. ranga	300	300	300	300	300	225	225	300
	(250-350)	(250-350)	(250-350)	(250-350)	(250-350)	(200-250)	(200-250)	(250-350)
M. armatus	750	750	1000	1000	750	550	550	900
	(700-800)	(700-800)	(800-1200)	(800-1000)	(700-800)	(500-600)	(500-600)	(800-1000)
M. puncalus	750	750	1000	900	750	550	550	900
	(700-800)	(700-800)	(800-1200)	(800-1000)	(700-800)	(500-600)	(500-600)	(800-1000)

APPENDIX E

Photographs of SIS survey and experiments

Chanda nama (SIS)

Colisa fasciatus (SIS)

Glossogobius guirus (SIS)

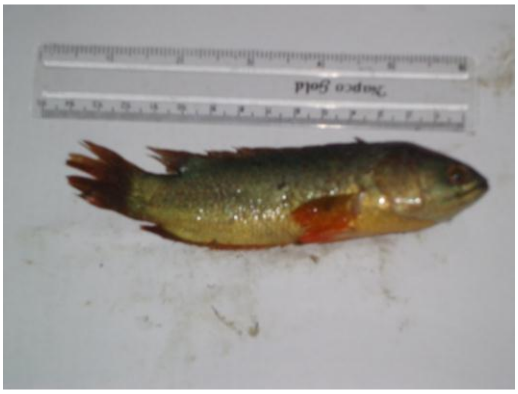
Notopterus notopterus (SIS)

Puntius sarana & *Puntius ticto* (SIS)

N.botia (SIS) in S3 station

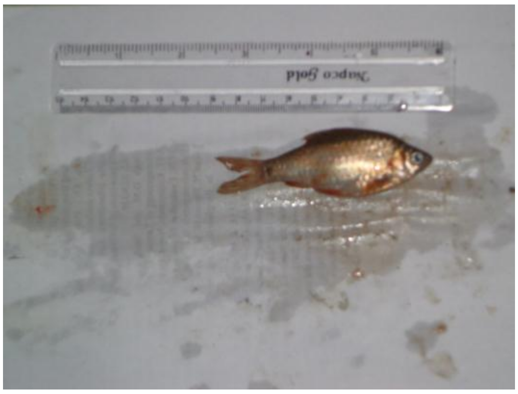
Cirrhinus reba

Puntius sarana



Anabas testudineus

Channa gachuwa



Puntius sophore

Mystus tengra

Photos of SIS

O.bacaila (SIS) in S1 station

Channa spp. (SIS) in S1 station

A.morar (SIS) in S 7 station

H.fossilis (SIS) in S 3 station

Mystus spp. (SIS) in S 1 station

O.bacaila (SIS) in S 1 station

Photos of SIS

SIS in S 1 station

Koshi River at (S1 station)

Fisher Man at S1 station

Water flow in Koshi

A. benglansis (SIS) in S 6 station

SIS in S1 station

Photographs of Carp SIS culture experiments

Experimental Ponds in Janakpur

Netting for growth check up

Netting process in ponds

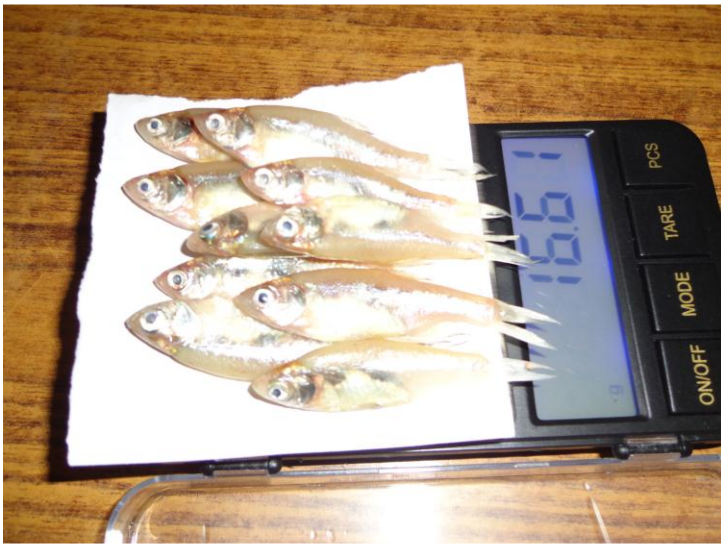
Photographs of Carp SIS culture experiments

Netting for gorowth checkup

Netting for gorowth checkup (Sis)

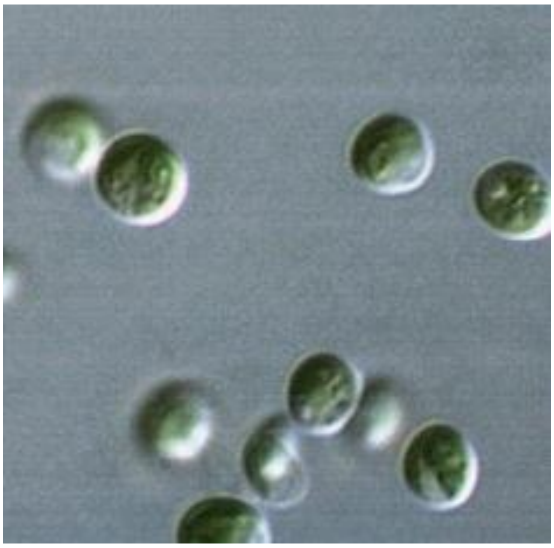
Measurement DO and temp. (DO meter)

Fish weight measurement

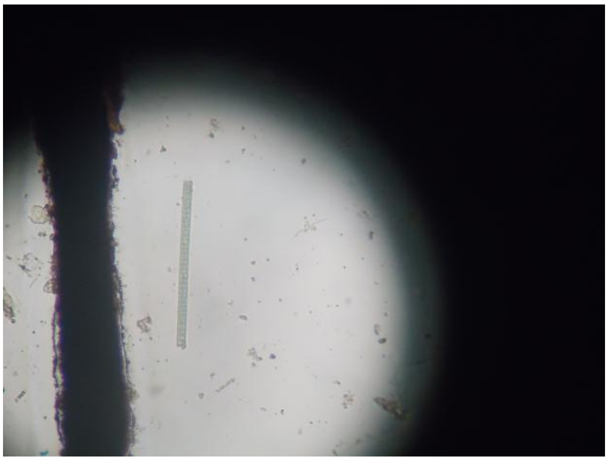


Weighing *A. mola*

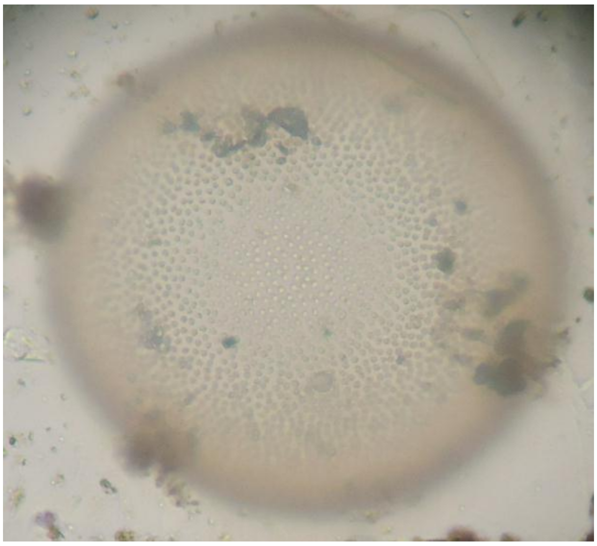
Photo of Phytoplanktos



Chlorella spp.

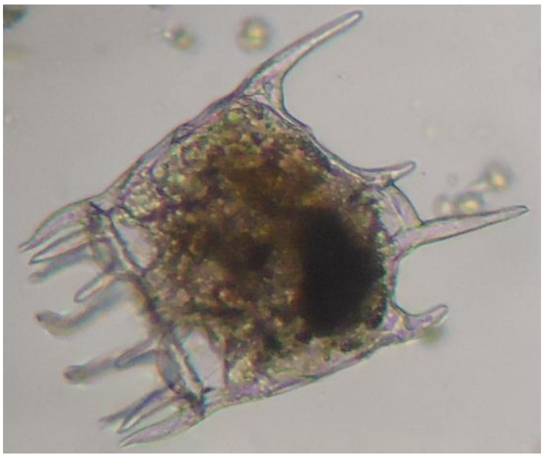


Ulothrix spp.

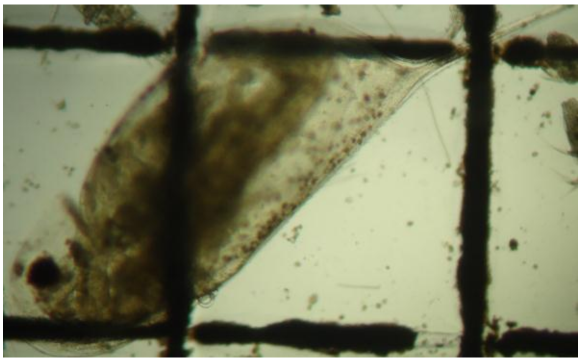


Volvox spp.

Photo of zooplanktons



Brachiomus spp.



Daphnia spp.

Keratella spp.

Cyclops spp.

Photo of zooplanktons

Moina spp.

Philinia spp.

Trochosphera spp.

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CERTIFICATE OF PARTICIPATION

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Evaluation of production performance among three small indigenous fish species (SIS) *A.mola, E.dendricus* and *P.ticto* under different management systems for sustainable rural livelihood in Nepal

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Abstract : Fishes are important for the livelihoods, food and income source to the rural people in terai Nepal. To increase the carp fish production the common use of piscides and change in agricultural patterns in Nepal, there is the rapid decline in the population of small indigenous fish species (sis). The small indigenous fishes still plays an important role in the fulfillment of protein, vitamins and minerals to the rural poor in Nepal. Three small indigenous fish species*P* ticto, *A mola* and *E dendricus* which are largely found in warm water bodies of Nepal were examined for the production performance under monoculture and mixed culture system of the farm ponds of Janakpur Nepal for 127 days. The experiment was carried out for the finding of the best species of small indigenous fish species which can be reared with carp species in future.Three different treatments were undertaken, viz, treatment 1 was stocked with monoculture of *A mola,* treatment 2 was stocked with monocultμre of *P ticto* and treatment 3 was stocked with *E dendricus* and ctrl (treatment 4) was stocked with mixed culture of *P ticto, A mola,* and *E dendricus.* The fish species were stocked @ 2000 ha^{-1} in treatments; T1, T2, T3 and all three sis species in mixed culture at the same proportion of 2000 ha^{-1} in the control ponds.The experiment was carried in CRBD design. Supplemental feed comprising of rice bran and mustard oil cake in the ratio of 2:1were supplied to three treatments and control ponds everyday throughout the study period. Ponds were fertilized with both organic and inorganic fertilizers. The results indicated that mixed culture of only sis gave a relatively high production of 1.335 kg/ha/yr,monoculture of *A mola* gave a production of 2.43 tons/ha and offers a better financial return.

Key words: SIS, Phytoplankton Mola Pothee Dedhuwa.

INTRODUCTION

The conservation and production potentials of large numbers of small indigenous fish of Nepal through aquaculture have remained unexplored. There are many small fish, such as punti (*Puntius* sp.), mola (*Amblypharyngodon mola*), and chela (*Chela lubuca*), that are unexplored for their production for freshwater aquaculture. SIS used to be abundantly available in rivers, streams, ponds, Potentials beels, ditches, and floodplains in the past, but these species have gradually been disappearing from the natural systems, which in turn severely affects biodiversity. These fish provide the main source of animal protein for all rural households, particularly low-income households. Special attention needs to be given to the culture of sis because they are important sources of vitamin A and minerals (Roos et al.2002)[1].Comparative studies show that the nutritional significance of sis is higher compared to larger fishes. The poor farmers participate in open water capture fishery either as temporary occupation or on accession so as to supplement nutrition and income for their livelihood. Despite the great importance of sis in Nepal, very few attempts have been made to study their biological aspects

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and culture potentials. Some preliminary studies have been conducted on *A mola, Gudusia chapra,* and *Colisha fasciatus* by Mustafa (1991)[2], Afroze and Hossain (1990)[3] have undertaken some experiments on *A mola* and other small indigenous fishes and Akhteruzzaman et al. (1998)[4] reported their preliminary attempt to culture *A mola, L bata,* and *Colisha fasciatus* sis in ponds of Bangladesh. *Amblypharyngodon mola, Esomus dendricus, Puntius shophore, Puntius ticto, Puntius sarana, Labeo dero ,Cirrhinus reba, Chanda nama* and *Colisha fasciatus* are the common sis species that grow in shallow ponds and rice fields in Nepal. They can breed in the stagnant water bodies. These species are normally cooked and eaten whole. Their effect on the diet is further enhanced since the bones also provide a source of calcium. The present study have been systematically conducted to assess the production potentials of three important sis, *Amblypharyngodon mola, Esomus dendricus* and *puntius ticto*, in monoculture and mixed culture systems.

MATERIALS AND METHOD

The growth and production performance of *P. ticto, A. mola* and *E. dentricus* was conducted in twelve earthen ponds of Janakpur ; each one pond was of approximately 100 m^2 (12.5 x 8 x 1.5m) size. The ponds were located in the government fish farm of Janakpur municipility. Janakpur is the district headquarters of Dhanusha district, Tarai Nepal. It is situated in 26.7 N latitude, 85.92 E longitudes and 66 m above sea level. The experiment was conducted from June to November 2012 for 127 days onward. Experimental design was carried out in CRBD (complete randomized block design) method. The experiment had three treatments; T1, T2, T3 and three replications. The monoculture of *A mola P ticto* and *E dendricus* were treatments T1, T2, T3 and the mixed culture of sis *A mola, P ticto, E dendricus* was ctrl (T4). The treatments were randomly allocated into the experimental ponds. All the experimental ponds were drained, dried and limed (CaO) at the rate of 250 kg/ha. Pond water filling was done up to 1.0m deep and fertilized with cow dung, urea and DAP @ 1000kg/ha, 12.5 kg/ha and 25 kg/ha respectively. SIS species were stocked after the fertilization of seven days. The stocking density of each one type of sis was 200000 fingerlings ha^{-1}in each treatment and control. The average stocking size of *A. mola, P. ticto* and *E . dendricus* were 1.5 gm, to1.0 gm. All ponds were subjected to treat with the same regime of feed and fertilizer application after of the post stocking management. The rice bran and mustard oil cake were used for supplementary feed into 2:1 ratio at the rate of 5% of body weight of standing crop. At the end of experiment all three species of sis were harvested, counted and weighed to estimate the weight gain from all experimental ponds. The survival percentage of three sis species were not estimated because of self recruiting habit of all experimental SIS in the pond water condition. The sechi disc visibility (transparency) was monitored fortnightly in each experimental pond of the treatments to adjust the use of fertilizers. Temperature, P^H, D.O, total alkalinity and free Co_2 were measured fortnightly of each one experimental pond. Composite water samples were collected fortnightly at 8.0 to 9.0 a m. The water temp, DO, and P^H were measured at the spot using digital DO meter (YSI Model-58 and pH by a digital pH meter (CORNING pH meter 445). The free CO_2 and total alkalinity of pond water was analyzed after APHA (1980)[5] and Boyd (1982)[6]. The water samples were also collected monthly for the analysis of phytoplankton's identification and enumeration. Identification of plankton to genus level was carried out using the keys from Ward and Whipple (1959)[7], Prescott (1962)[8] and Bellinger (1992)[9]. Plankton's number was estimated by following Azim (2001)[10].

RESULTS

Water Quality

The water quality parameters were found in within of suitable range for fish culture. The mean value of each one water quality parameter of all treatments was presented in table 1.1. The temperature record was found between 30.2 °c to 32.5 °c with the mean value 31.15 ± 0.51 in T_1. The water temperature was found between 30.2°c to 32.5 °c with the mean value 31.27 ± 0.31 in T2. The water temperature was found in between30.0°c to31.8°c with the mean value of 30.93 ± 0.38 and 30.0 °c to 32.2 °c with the mean value of 31.03 ± 0.45 in T_3 and T_4 (ctrl) respectively. The mean value of water transparency was shown in table 1.1. It was varied between minimum records of 19 cm to the maximum record of 33 cm. The mean value of water transparency was 24.70 ± 0.25, 25.93

±0.30, and 24.74 ± 0.006 and 24.70 ± 0.17 in T_1, T_2, T_3 and T_4 treatments. The experimental ponds of all treatments were always alkaline during the experiment period. The mean value of P^H in all treatments were recorded as; 7.55±0.061, 7.60 ± 0.076, 7.56 ± 0.068 and 7.66 ± 0.067 consequently in T_1, T_2, T_3 and T_4. The variation and mean value of P^H in all treatments and control was shown in table 1.1. The variation in DO in the whole experiment was form 4.2 mg/l 6.4 mg/l. The mean value of dissolved oxygen in all treatments; T_1, T_2, T_3 and T_4 were 5.52 ± 0.26, 5.28 ± 0.32, 5.50 ± 0.29, 5.62±1.874 table 1.1.The total alkalinity ranged from 75 to 121 mg/l during the experiment period (Table 1.1). The mean value of total alkalinity in all treatments T_1, T_2, T_3 and T4 were 93.30 ±1.73, 97.78 ±0.41, 93.15 ±0.06, 93.89 ± 0.18 respectively. The free CO_2 of pond water in experiment was recorded between10.0 mg/l to 14.2 mg/l with the mean value of all treatments. T_1, T2, T3 and T_4 consequently 12.24 ±0.52, 12.61 ±0.58, 12.34 ± 0.50 and 12.61±1.02 (Table 1.1).

Table 1.1 Water quality parameters in ponds of treatments T1, T2, T3 and T4

Treatments	Pond no.	Temperature C^0	Transparency (cm)	D O (mg/l)	pH	Total alkalinity (mg/l)	CO_2 (mg/l)
T1	P2	31.13 ± 0.3	24.88 ± 1.327	5.55 ± 0.159	7.54 ± 0.079	92 ± 5.011	12.3 ± 0.290
	P5	31.15 ± 0.301	25.11 ± 1.241	5.62 ± 0.151	7.56 ± 0.076	94.22 ± 5.24	12.21 ± 0.309
	P9	31.15 ± 0.308	24.11 ± 1.252	5.37 ± 0.195	7.53 ± 0.052	93.66 ± 5.37	12.21 ± 0.321
Mean		**31.15±0.51**	**24.70 ±0.25**	**5.52 ± 0.26**	**7.54 ± 0.016**	**93.30 ± 1.73**	**12.24 ± 0.52**
T2	P1	31.21 ± 0.286	25.55 ± 3.056	5.32 ± 0.179	7.64 ± 0.078	97.22 ± 4.54	12.42 ±0.654
	P4	31.26 ± 0.333	25.55 ± 3.137	5.26 ± 0.195	7.53 ± 0.104	97.33 ± 4.72	12.83 ± 0.553
	P8	31.32 ± 0.322	26.66 ± 3.415	5.25 ± 0.202	7.61 ± 0.084	98.77 ± 5.19	12.57 ± 0.592
Mean		**31.27 ± 0.31**	**25.93 ±0.30**	**5.28± 0.32**	**7.60 ± 0.139**	**97.78 ± 0.41**	**12.61 ± 0.58**
T3	P3	30.91 ± 0.212	24.66 ± 1.433	5.55 ± 0.172	7.57 ± 0.140	93.22 ± 4.6	12.23 ± 0.261
	P6	30.94 ± 0.220	24.66 ± 1.462	5.48 ± 0.180	7.55 ± 0.175	93.22 ± 5.1	12.42 ± 0.273
	P7	30.94 ± 0.220	24.88 ± 1.611	5.46 ± 0.172	7.54 ± 0.091	93.0 ±4.941	12.36 ± 0.356
Mean		**30.93 ± 0.38**	**24.74 ± 0.06**	**5.50 ± 0.29**	**7.56 0.125**	**93.15 ± 0.06**	**12.34 ± 0.50**
T4	P10	31.04 ± 0.248	25.11 ± 1.494	5.76 ±1.922	7.7 ± 0.150	94.33 ± 4.72	12.12 ± 0.405
	P11	31.03 ± 0.266	24.55 ± 1.191	5.68 ± 1.896	7.63 ± 0.147	93.66 ± 4.47	12.32 ±0.307
	P12	31.01 ± 0.267	24.44 ± 1.454	5.41 ± 1.803	7.63 ± 0.095	93.67 ± 4.46	13.38 ± 1.263
Mean		**31.03 ± 0.45**	**24.70 ± 0.17**	**5.62 ± 1.874**	**7.66 ± 0.124**	**93.89 ± 0.18**	**12.61 ± 1.02**

Plankton Population

The total number of phytoplankton species and their abundance during the experimental period was shown in table 1.2. Altogether four group of phytoplankton was recorded in the experiment; Chlorophyceae, Cyanophyceae, Euglinophyceae and Bacillariophyceae. The Chlorphyceae group contained 15 genera, Cyanophyceae 3 genera, Bacillariophyceae 5 genera and Euglinophyceae 2 genera over the Chorophyceae as dominant group in the present study. The dominant phytoplankton species in all treatments was Chlorella in the present study and it was followed by Euglina.

Fish growth and production

The growth and production performance of three selected species of sis, *P. ticto, A.mola and E. dendricus* was shown in table 1.3. The mean individual stocking weight of *P. ticto* in all the treatments and control was 1.5 gm and 1.4 gm. The mean individual harvesting weight of

Table 1.2 Mean value of phytoplankton abundance (units^{-L}) in all treatments

	Treatments			
Group / Genus	T1	T2	T3	T4 (ctrl)
Chlorophyceae				
Chiorella	10362	9729	9435	10017
Closterium	1018	1012	990	1041
Zygnema	189	185	198	165
Actinastrum	394	381	390	408
Cladophora	121	121	127	141
Chlamydomonas	304	308	294	290
Oedogonium	102	98	111	120
Netrium	123	127	127	135
Pediastrum	201	212	185	205
Selenastrum	54	54	52	64
Spirogyra	488	398	482	432
Tetraedron	245	235	228	252
Tetraspora	155	155	176	210
Volvox	27	26	20	31
Ulothrix	64	68	62	76
Mean ± (S.E)	3461.75±2439.61	3277.25± 2281.04	3219.25±2197.60	3396.75±2340.612
Cyanophyceae				
Anabaena	55	61	70	72
Microcystis	5541	4857	4800	4652
Oscillatoria	488	470	447	494
Mean ± (S.E)	1521±518.31	1347±454.67	1329.25±445.212	1304.5±435.75
Euglenophyceae				
Euglina	9631	7128	6054	6862
Phacus	419	413	430	501
Mean ± (S.E)	2512.25±2516.86	1885.25±1853.592	1621±1567.302	1840.75±1775.28
Bacillariophyceae				
Fragillaria	1837	1898	1826	2021
Diatoma	198	181	207	219
Synedra	1653	1725	1744	1811
Cyclotella	136	112	127	120
Cymbella	1866	1795	1802	1825
Mean ± (S.E)	1422.5±146.547	1427.75±166.258	1426.5±141.244	1499±184.554

P. ticto in T2 was 3 gm, 2.5 gm and 2.7 gm. The survival percentage of *P. ticto* was not carried out as the fish species breed two times during the study period. The net yield of fish *P. ticto* in T2 was 5.52±0.198 kg.

The mean individual stocking weight of mola was 1.36±0.072, 1.3±0.094 and 1.33±0.072 gm in the ponds of treatment T1. As the mola breeds under pond condition, so the survival percentage was not carried out in the result of experiment. The net yield of mola was7.11±0.291 kg in T1. The individual harvesting weight of mola was 2.9 gm 3 gm, 3.2 gm.The mean individual stocking weight of *E. dendricus* (dedhuwa) was 1.0±0.094, 1.06±0.072 and 1.1±0.124 gm in treatmentT3. The individual harvesting weight of dedhuwa was 2.1, 2.2 and 2.6 gm. The survival percentage of *E. dendricus* was not carried out as the fish species breed into pond condition. The net yield of *E. dendricus* (dedhuwa) was the lowest among all three species of sis. The net yield of *E. dendricus* was 5.14±0.471. (Table-1.3). The mean stocking weight of mola in the ponds of treatment 4 (ctrl) was 1.36±0.072, 1.3±0.094, 1.33±0.072 gm, *P ticto* was 1.5±0.124, 1.4±0.047, 1.5±0.094 gm and *E. dendricus* was 1.0±0.094, 1.06±0.072 and 1.1±0.124 gm. The mean individual harvesting weight of mola, *P ticto* and E. *dendricus* in treatment T4 were 2.7, 2.9, 3.1 gm, 2.8, 2.7, 2.4 gm, and 1.9, 2.0, 2.3 gm. The net yield of mola, *P ticto* and E. *dendricus* in all three treatments were 7.11±0.291, 5.52±0.198 and 5.14±0.471 kg. The mean net yield of sis species *A mola*, *P ticto* and E. *dendricus* in T4 were. 5.88±0.404 kg, 5.25±0.422 kg, and 3.90±0.243 kg/ 100 m^{2}. All three species of sis stocked number were much more than total number of harvesting so the survival percentage of any one species was not carried out in T4.

DISCUSSION

The water quality parameters were found within the suitable range for all SIS species in all treatments. The water temperature never rose above 32°c and below of 23°c during the experimental period. Similar observations were recorded from Paliwan et al, (2008)[11] in the tanks of Kolhapur and Paul 1998[12] in the ponds of B A U Mymensigh Bangladesh. They recorded water temperature 26.7-33.7°c, 26-32.4°c and 18.5-32.9°c respectively in the ponds used for fish culture. The transparency of pond water in all treatments were within the suitable range i.e. never more than 30 cm and less than 21 cm. the variation in transparency would be due to abundance of planktons. The transparency ranged between 15-40 cm is regarded as appropriate for fish culture, Boyd (1982)[6]. The P^{H} value of pond water was always recorded between 7.5 to 8.5. Swingle 1967[13] and Boyd 1982[6] recommended, P^{H} value ranging from 7.0 to 9.2 as the suitable for fish culture. The dissolved oxygen (DO) was comparatively good in all treatments; within the range of 6.13+0.54 to 7.03+0.63 mg/l. The planktonic density might be responsible for accelerated rate of photosynthesis in the experimental ponds of all treatments. Banargee et al. , (1990)[14] stated that pond water DO within 5.0 to 10.0 PPM is considered as the ideal for fish production. Openheimer et al., (1978)[15], Wahab et al., (1995)[16] and Roy et al, (2002)[17] recorded similar D O values like to be the present study; 3.18 - 7.58 mg/l, 2.2-7.1 mg/l and 3.65-7.65 mg/l respectively from the ponds of Bangladesh. The total alkalinity ranged from 75 to 115 in T_1, 76 to 121 T_2, 76 to 118 T_3 and 74 to 118 T4. The mean value of total alkalinity in T_1, T_2, T_3 and T_4 were typically found within the suitable range for fresh water fish culture (Oppenheinmer et al., 1978)[15]. The free CO_2 in all treatments, T_1, T_2, T_3 and control (T_4) were within the suitable range. Hynes (1970)[18] stated that in order of safeguard of fisheries interest 25 mg/l of free carbon dioxide has been recommended as upper limit.

Phytoplankton density (units/l) was recorded maximum in treatment T3 and minimum in treatment T2. The phytoplankton diversity was represented by 25 species belonged to class chlorophyeae, bacillariphycae, cyanophycae and Euglinophyceae (Table 1.2).The highest number 13 species of phytoplankton was found from the class cholorophycace and the lowest number of only 2 species was recorded from the class, Englenophycae. There were no significant differences in Phytoplankton densities among the treatments (P>0.05, Table 1.2). Mean total phytoplankton (units^{-1}) ranged from 3461.75±2439.61, 3277.25± 2281.04, 3219.25±2197.60 3396.75±2340.612 in T1, T2, T3 and T4 from class chlorophyeae 1521±518.31, 1347±454.67, 1329.25±445.212, 1304.5±435.75 from class cyanophycae, 2512.25±2516.86, 1885.25±1853.592,

Table 1.3 Production performance of (sis) *A. mola* ,*P. ticto* , *E. dendricus* (Mean ± S.E)

			At stocking			At harvesting			
Treatments	Fish species	Pond no.	Av. Initial wt(g)	No. of fish stock	Initial total wt. kg/100 m²	No. of fish recorded	Mean final wt(g/fish)	Final total wt.kg/100 m²	Net yeild kg/100 m²
T1	*A mola*	P2	1.36±0.072	2000	2.72	3150	2.9	9.135	6.415
		P5	1.3±0.094	2000	2.6	3320	3	9.96	7.36
		P9	1.33±0.072	2000	2.66	3200	3.2	10.24	7.58
Mean±S.E									7.11±0.291
T2	*P. ticto*	P1	1.5±0.124	2000	3	3000	3	9	6
		P4	1.4±0.047	2000	2.8	3200	2.5	8	5.2
		P8	1.5±0.094	2000	3	3100	2.7	8.37	5.37
Mean±S.E									5.52±0.198
T3	*E. dendricus*	P3	1.0±0.094	2000	2	3030	2.1	6.363	4.363
		P7	1.06±0.072	2000	2.12	3150	2.2	6.93	4.81
		P6	1.1±0.124	2000	2.2	3260	2.6	8.476	6.276
Mean±S.E									5.14±0.471
T4 (ctrl)	*A mola*	p12	1.36±0.072	667	0.907	1940	3.8	7.372	5.648
		p11	1.3±0.094	667	0.867	1880	3.5	6.58	5.713
		p10	1.33±0.072	667	0.887	2025	3.6	7.29	6.403
	Mean								6.193±0.196
	P ticto	p12	1.5±0.124	666	0.999	1830	3.6	6.588	5.589
		p11	1.4±0.047	666	0.932	2010	3.5	7.035	6.103
		p10	1.5±0.094	666	0.999	1970	3.5	6.895	5.896
	Mean								5.862±0.121
	E dendricus	p12	1.0±0.094	667	0.667	1920	2.8	5.376	4.709
		p11	1.06±0.072	667	0.707	2150	2.6	5.59	4.4883
		p10	1.1±0.124	667	0.733	1840	2.7	4.968	4.235
	Mean								4.609±0.158
Mean±S.E									5.511±0.036

1621±1567.302 and 1840.75±1775.28 from class Euglinophyceae and 1422.5±146.547, 1427.75±166.258, 1426.5±141.244,and1499±184.554 from class bacillariphycae.

The combined gross productions *A. mola* was significantly higher ($P<0.05$) in treatments T1(2.043 ton $ha^{-1}yr^{-1}$) than in treatments T3 (1.477ton $ha^{-1}yr^{-1}$) and no significant differences noticed between treatment T2 (1.586 ton $ha^{-1}yr^{-1}$), and T3 (1.477ton $ha^{-1}yr^{-1}$) (Table1.3). The production and growth of mola species was the highest in treatment T1 in comparison of the control T4 indicates that mola has negative impact on the growth and production with the other SIS species *P. ticto* and *E. dendricus* might be due to overlapping feeding nich . Ameen et al., (1984)[19] have reported similar result from his experiment in which the growth and production performance of *puntius sarana* negatively affected the growth of mola in composite culture. The mean net yield of mola from monoculture in T1 was 2.043 tons/yr in present study which is higher than the finding of Ameen et al., (1984)[19] 1.75 tons/ha/8 months. Mustafa (1991)[2] obtained a production of 4 to 5 tons/ha/year of *A mola, P. chola* and *Colisa fasciatus* in the composite culture experiment of small indigenous fishes in Bangladesh which is lower than the production performance of *A mola, P. ticto* and *E dendricus* in the monoculture and composite culture experiment of present study. The low production performance of three SIS species of present study in comparison of the result of Mustafa (1991)[2] was perhaps due to the selection of different type of sis species P ticto and E dendricus in spite of *P. chola* and *Colisa fasciatus* in the present experiment. The mean net yield of, *puntius* and *Esomus* in the present study did not show the significant differences (P>0.05).

All three species of SIS during the culture period were found to breed in the ponds. The mola breed in March and May two times in present study period. Afroze and Hossain (1990)[3] reported that the breeding season of A mola starts from May and continued till October with the peak in August in Bangladesh.

CONCLUSION

The small indigenous fish species SIS were very common in the past were now captured in less quantity. The SIS are micronutrient enriched fish species in comparison of carp species. The *A. mola* can be reared with carp species together after standardizations with carp combinations and developing the appropriate stocking density because of the high production performance result obtained from present experiment among three SIS species.

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SMALL INDIGENOUS FISH SPECIES RESOURCES IN THE RIVERS, FLOOD PLAINS AND FLOODED PONDS AREAS OF NEPAL

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Abstract

Importance of small indigenous species of fishes (SIS) is a good resource of our poor and lower income groups in terms of nutrition and economics. The species diversity and production decreased a lot in last few decades due to habitat destruction of water bodies, over exploitation and some other causes. There are 185 fish species in Nepal belonging to 79 genera, 31 families and 11 orders (Shrestha 1995). Altogether 34 species (18%) are threatened (vulnerable, endangered and rare), 90 species (49%) have the status of commonly/occasionally recorded and 61 species (33%) have the status of insufficiently known. The impacts of improved traditional exotic carp culture on native fishes are also examined. The production of eggs per gram body weight of all these 'minnows' and clupeids are comparatively high. At the same time, the natural population stock is very fluctuating between years because no parental care exists though they are highly fecund. But in case of small catfishes, perches and snake-heads the number of eggs per gram body weight is less due to parental care and their population is not so fluctuating. Most of them breed during summer and monsoon period, i.e., April to October at shallow, newly inundated well oxygenated, grass or crop field with minimum water current. Mostly all of the SIS is self-recruiting in the traditional culture and non-cultured water bodies. From the market survey, it is clear that the people of lower income group cannot purchase the 'minnows' and small clupeids for their less supply and high market price. The abundance of 'minnows' and other such as loaches, spiny eels, snake-heads, perches, glass fishes and small catfishes are reduced in such a level that rural poor communities cannot collect it from natural water for their consumption. For conservation of biodiversity and socio-ecological sustainability and to uplift nutritional status it is needed to develop community based management of fisheries sanctuary in the open water and improves traditional fish culture methods need integration of aquaculture system with other species.

Key words: Minnows, Gobi, Catfish, Loaches, Small indigenous species (SIS).

Introduction

Nepal is blessed with numerous inland water bodies which are very rich in diversity of aquatic species. The inland water resources of Nepal totaling 745,000 ha consist of river systems, lakes, reservoirs, village ponds, wetlands and irrigated rice fields. Nepal has more than 6000 rivers and streams. As many as there are 185 fish species in Nepal belonging to 79 genera, 31 families and 11 orders (Shrestha 1995). Altogether 34 species (18%) are threatened (vulnerable, endangered and rare), 90 species (49%) have the status of commonly/occasionally recorded and 61 species (33%) have the insufficient status of present time.

The small indigenous fish species or SIS are fishes which attain not more than 25 cm size and they are self recruiting in the traditional culture and non cultured water bodies. Among the fishing communities, small fish occupy an important position as a popular food item (Hossain *et al.* 1994). Most of the poor population mainly depends on small fish for their daily supply of animal protein (Siddiqui 1985). Thilsted *et al.* (1997) reported that many nutrients such as vitamin A and C, iron, calcium, zinc and iodine which are not found in rice and have to be obtained from other sources. Small fish which are usually eaten whole with the organs and bones contain large amounts of calcium and possibly iron and zinc. Poor people catch the SIS of fishes from open waters and eat frequently though in small amounts. So, SIS of fish is playing a vital role in diet and economy of the rural poor in Nepal.

The present paper deals with diversity status, distribution, breeding, habitat and future management options for the SIS fishery.

Study Area

The study area for present study is Janakpur region as the focal point but the whole study area extended between Saptari districts to Parsa district. The survey of fish markets of the district head quarter and other fish market of the district were visited many times in pre monsoon, monsoon and post monsoon seasons. The sampling of SIS species were done from Saptari, Sirha, Dhanusha, Mahottari, Sarlahi, Rauthat, Bara and Parsa districts.

Materials and Methods

The fish sampling was performed in the sampling sites of all the sampling stations. Altogether eight sampling stations were established at least two sampling sites in a district. on the basis of preliminary survey after getting information about the average landing of indigenous fishes and the aquatic bodies in the periphery of fish market area. The information about maximum size in the term of growth of fishes was obtained from the fishermen and the information was matched with the various literatures. The SIS species were examined counted and returned to the fisher man if the SIS species were identified under the observation in fish markets. Few specimens (5 to 10) of identified species were preserved on 10% formalin and transported to the laboratory of janakpur for the analysis. The fish species identification and conformation were carried out by using the standard keys of Talwar and Jhingran (1991), Jayaram (1999), Shrestha (1981 and 1994) etc. The primary data were obtained from the fisher men about average abundance of SIS species at the present time in that particular area.

Results and Discussion

Habitat of small indigenous fish species

Most of the small indigenous small fishes and air-breathing fishes live in shallow water bodies where physico-chemical nature of the water bodies' change frequently and aquatic vegetation is common. The species available in these habitats are kawai, colisa, snake heads, shinghi, magur, small catfishes, chela, mola, small gobi, and other 'minnows'. But some other small fish like maroar and paunsi live in the river water at certain depth of water. The man-made Koshi barrage dam area is now famous for paunsi and maroar landing. The small catfishes are very common in flood plain areas where minor carps, loaches, chanda etc. are also very common. Riverine small fish like Gagata, Ailia, Botia are common. They need water current and shallow well oxygenated areas newly inundated by flood or rain or runoff water for breeding.

Physical and chemical nature of the habitat

Shallow waters in the river and other stagnant water bodies are preferred by all these small fishes. But some of the small species live in different type of shallow water areas like paddy fields in the high land Barind tract during monsoon and all of them die due to high temperature during dry and hot summer, when the water bodies dry up.

Potentiality of derelict water bodies

River water fed areas are two times better than the rainwater fed ditches in term of ecological condition and 3 times better in term of fish production (Hossain *et al.* 2003). Small fishes are dominant in these ditches and they share about 81% of the total small fish production. Both cultivable and non-cultivable species are common in these ditches.

Icthyodiversity, structure, species and spatial variation

During the entire study period, a total of 55 species of SIS belonging to 16 families and 38 genera were recorded from the sampling stations of study area. Family Cyprinidae formed the largest dominant family, contributing 24 species from all eight sampling stations; family cobitidae formed the sub dominant family contributing 5 species and the rest of families followed order of abundance. The abundance and diversity of SIS species throughout the study is summarized in Table 1 and Fig. 1. A total of 55 SIS species were documented in the whole study period of a year, out of which maximum 55 species were recorded from the sampling station S1, 28 species from the sampling station S7. The richness of SIS species varied greatly at spatial scale. Station 1 (S1) showed higher species richness (55 species) as compared to other stations respectively.

Table 1. Abundance and diversity of small indigenous fish species (sis) in study area.

SN	Family	Species	S1	S2	S3	S4	S5	S6	S7	S8
1	**Cyprinidae**	*Amblypharyngodon mola*	p	Ppp	ppp	ppp	ppp	ppp	pp	pp
2		*Esomus dandricus*	pp	Ppp	ppp	ppp	ppp	ppp	ppp	ppp
3		*Puntius chola*	pp	Ppp	ppp	ppp	ppp	ppp	ppp	ppp
4		*Puntius sarana*	p	Ppp	ppp	pp	pp	ppp	pp	pp
5		*Puntius conchonius*	pp	ppp	ppp	pp	ppp	ppp	pp	pp
6		*Puntius sophore*	pp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
7		*Puntius ticto*	ppp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
8		*Aspidoparia morar*	ppp	*	*	*	*	*	*	*
9		*Aspidoparia jaya*	pp	*	*	*	*	*	*	*
10		*Barilius barila*	pp	ppp	p	*	p	p	*	*
11		*Barilius bendelisis*	pp	ppp	p	*	ppp	p	*	p
12		*Barilius barana*	pp	p	p	*	pp	pp	*	P
13		*Barilius vagra*	pp	p	p	*	pp	pp	*	p
14		*Chela lubuca*	pp	p	p	p	p	p	p	p
15		*Danio devario*	pp	*	p	p	p	p	*	p
16		*Danio rerio*	pp	*		*	*	*	*	*

17		*Crossocheilus latius*	p	p	p	*	p	p	*	*
18		*Cirrhinus reba*	pp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
19		*Labeo dero*	pp	p	p	*	p	*	*	*
20		*Oxygaster bacaila*	pp	p	pp	p	pp	p	p	p
21		*Osteobrama cotio*	pp	*	*	*	*	*	*	p
22		*Rasbora daniconius*	pp	*	*	*	*	*	*	*
23		*Rasbora elanga*	p	*	*	*	*	*	*	*
24		*Semiplotus semiplotus*	p	*	*	*	*	*	*	*
25	**Cobitidae**	*Lepidocephalichthys guntea*	ppp	ppp	ppp	ppp	PPP	ppp	ppp	ppp
26		*Botia lochata*	pp	ppp	ppp	p	pp	*	*	p
27		*Semileptes gongota*	pp	*	*	*	*	*	*	*
28		*Noemacheilus bevani*	pp	p	pp	*	p	*	*	*
29		*Noemacheilus botia*	pp	ppp	ppp	*	p	*	*	*
30	**Bagridae**	*Mystus tengra*	pp	ppp	pp	ppp	ppp	ppp	ppp	ppp
31		*Mystus vittatus*	pp	p	p	p	p	p	p	p
32	**Schilbeidae**	*Alia colia*	pp	*	*	*	*	*	*	*
33		*Clupisoma garua*	pp	*	*	*	*	*	*	*
34		*Etropiichthys vacha*	pp	*	*	*	*	*	*	*
35		*Pseudeutropius murius*	pp	*	*	*	*	*	*	*
36	**Saccobranchidae**	*Heteropneustes fossilis*	ppp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
37	**Claridae**	*Clarius batrachus*	pp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
38	**Anguillidae**	*Anguilla bengalensis*	p	p	*	*	*	p	*	p
39	**Belonidae**	*Xenentodon cancilla*	p	ppp	pp	*	*	*	*	p
40	**Notopteridae**	*Notopterus notopterus*	p	P	ppp	pp	pp	pp	pp	ppp
41	**Ambassidae**	*Chanda nama*	pp	ppp	ppp	ppp	ppp	ppp	pp	ppp
42		*Chanda ranga*	ppp	ppp	ppp	ppp	pp	pp	pp	ppp
43	**Amphipnoidae**	*Amphipnous chuchia*	pp	ppp	ppp	ppp	ppp	ppp	pp	pp
44	**Ophiocephalidae**	*Channa gachua*	ppp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
45		*Channa marulius*	ppp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
46		*Channa punctatus*	pp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
47		*Channa striatus*	p	ppp	pp	ppp	pp	pp	p	p
48	**Nandidae**	*Nandus nandus*	p	*	*	*	*	*	*	*
49		*Badis badis*	p	*	*	*	*	*	*	*
50		*Colisa fasciatus*	ppp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
51	**Gobiidae**	*Glossogobius guiris*	pp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
52	**Anabantidae**	*Annabas testudineus*	ppp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
53	**Mastacembelidae**	*Mastacembelus armatus*	pp	ppp	ppp	ppp	ppp	ppp	ppp	ppp
54		*Mastacembelus puncalus*	pp	ppp	ppp	ppp	ppp	ppp	pp	ppp
55		*Macrognathus aculeatus*	pp	ppp	ppp	ppp	ppp	ppp	pp	pp

The symbols of table signifies; p = 50 no., pp =100 no., ppp =500 to 1000 no., and * absent in present study.

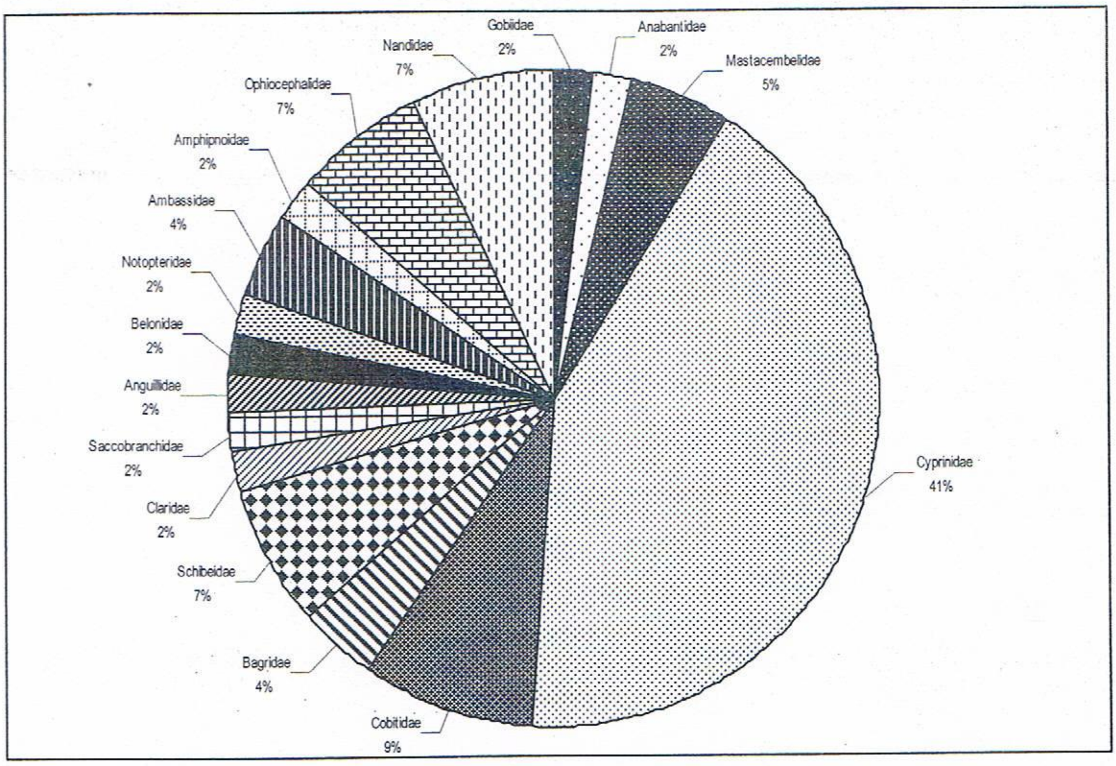

Fig. 1. SIS species diversity in study area.

Altogether 185 species of fishes has been documented from Nepalese natural water bodies Shrestha (1981). Shrestha (1994) reported some more new species of fishes and prepared the documentation of 192 species of fishes. The taxonomic work of Nepalese fish Fauna, the conservation of aspects of fishes and to some extent of breeding of *Tor Putittora* etc. have done in Nepalese context. So far the diversity and abundance of SIS species in Nepal seems to be untouched but the literature from Bangladesh shows out of 260 species of fresh water fishes 140 species are classified as small indigenous fish species (sis). The present study does not occupy the whole area of Nepal but it occupies the major fish production area of Nepal. Altogether 55 species of SIS have been reported in this study which seems lesser than the SIS diversity of Bangladesh.

Reproduction and breeding

All these small fishes breed in the rainy season. The gonadial development starts with the commencement of the increase in atmospheric temperature during February and spawning starts after the first summer rain in the month of April to May and continued up to the end of October. The gravid females and fry are found throughout the year except December, January and February. Some species breed throughout the year with less frequency in the winter months. The *Aspidoparia morar* breeds during winter and prefers low temperature and clear water.

Conclusion

SIS are micronutrient enriched fishes whose culture practice with carp fishes, are possible if they do not compete for the food with carp fishes rearing together. The rearing of SIS may help to solve malnutrition problem in Nepal. The knowledge of SIS diversity is prerequisite condition before the recommendation of them for the carp SIS semi intensive aquaculture in Nepal.

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