Final Technical Report

on

FORMULATION AND EVALUATION OF LOW COST FISH FEED FOR SUPPLEMENTATION IN THE RICE-FISH SYSTEM OF APATANI PLATEAU, ARUNACHAL PRADESH

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Chapter 1

GENERAL INTRODUCTION AND OBJECTIVES

Apatani Plateau of lower Subansiri district of Arunachal Pradesh (26° 55' to 28°21' N and 92° 40' to 94° 21' E) dominated by Apatani tribe are involved in Integrated Agriculture Aquaculture (IAA) in their wet rice fields since many years. The plateau is bowl-shaped surrounded by high hills and interspersed with paddy fields and bamboo–pine groves. Inhabitants of this valley are divided into a number of clans and each clan lives in a clearly defined part of the village. They worship the sun (Donyi) and the moon (Polo) and there are several fascinating myths attached to their deities and their origin which serves to reinforce their uniqueness as compared to the neighbouring communities. Almost all their festivals are connected to nature conservation and community welfare.

The Apatani tribe practice the culture of fish in rice fields merged with their traditional agronomic practices over the past 50 years. This IAA is free from the use of agrochemicals and additional input of supplementary feed for fish and is popularly known as 'aji ngui assonii' (Saikia and Das, 2004). They basically follow the traditional agronomic practices for rice even in rice-fish combination pertaining to field preparation and maintenance. Field preparation starts in April, occasionally continues up to late May, and rice seedlings are planted in May-June. The strains of common carp (*Cyprinus carpio*) are stocked at fry stage (3–5 cm), after just ten days of transplanting the rice and reared in the field for about 3 to 4 months. However, limited availability of natural feed and short duration of the rearing period do not allow the fish to gain much biomass (Halwart and Gupta, 2004). As a result, only 150 to 250 kg ha^{-1} of fish (*Cyprinus carpio*) per season are harvested from the system (Saikia and Das, 2004), which is much lower comparing to similar systems in China (Zhang, 1995; Halwart, 1998).

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Administering supplementary feeding material to the fish in the paddy fields may increase the secondary productivity (Halwart and Gupta, 2004). Locally available ingredients such as agro-based by-products and other organic wastes may be used as feed input in the system, which may a promising solution from the perspective of the rural economy and sustainability.

The present research project had the following objectives:

1. To investigate the environmental quality and the availability of natural fish feed in rice environment.
2. To characterize the feeding habit of the stocked fish along with their food preferences.
3. To select available resources from the agro-based by-products of the Apatani plateau.
4. To determine the nutritional values of the local feed ingredients.
5. To formulate the suitable feed using composite mixture of local ingredients.
6. To conduct efficacy test for formulated feed under laboratory condition.
7. To prepare an extension manual on processing and formulation of the fish feed to promote rice-fish based farming systems of the area.

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Chapter 2

DESCRIPTION ON THE STUDY AREA AND LAYOUT OF THE STUDY

Location

The Apatani Plateau, bifurcated by the river Kele, is located in Lower Subansiri District, Ziro, Arunachal Pradesh. The plateau is bowl-shaped surrounded by high hills and interspersed with paddy fields and bamboo-pine groves. The valley lies at an altitude of 1524 m with temperatures on the cooler side and its population density is 554 person/km^2. The valley enjoys cool subtropical climate with 2,350 mm annual rainfall. Ziro is famous for paddy-cum-fish cultivation. It may be mentioned here that the agrarian hill tribe in this region has cultured fish in rice fields merged with their traditional agronomic practices over the past 50 years. Their practice, locally termed *aji ngui assonii*, is free from the use of agro-chemicals and additional input of supplementary feed for fish (Saikia and Das 2004). The Apatanis belong to the Tibeto-Mongolid stock (Haimendorf 1962). Literally the word Apatani is from 'Apa' means addressing someone out of affection and 'Tani' means the descendents of Abotani, who is considered as the forefather of the Apatani. Apatani people perform different ritual ceremonies like Myoko, Murung, and Dree of which Myoko is the most important festival. There are seven major villages namely Hong, Bulla, Hari, Hija, Bamin–michi, Mudang-Tage and Dutta (Dollo *et al.*, 2009). For the present study five stations from Apatani plateau were selected (Long. 27°33'-27°35'E and Lat. 093°49' to 093°50'N). These were Bamin-michi, Hari, Bulla, Hiza and Hong (Figure 2.1). The study was undertaken to formulate fish-feed using local resources for enhanced fish productivity in the rice-fish system of Apatani Plateau.

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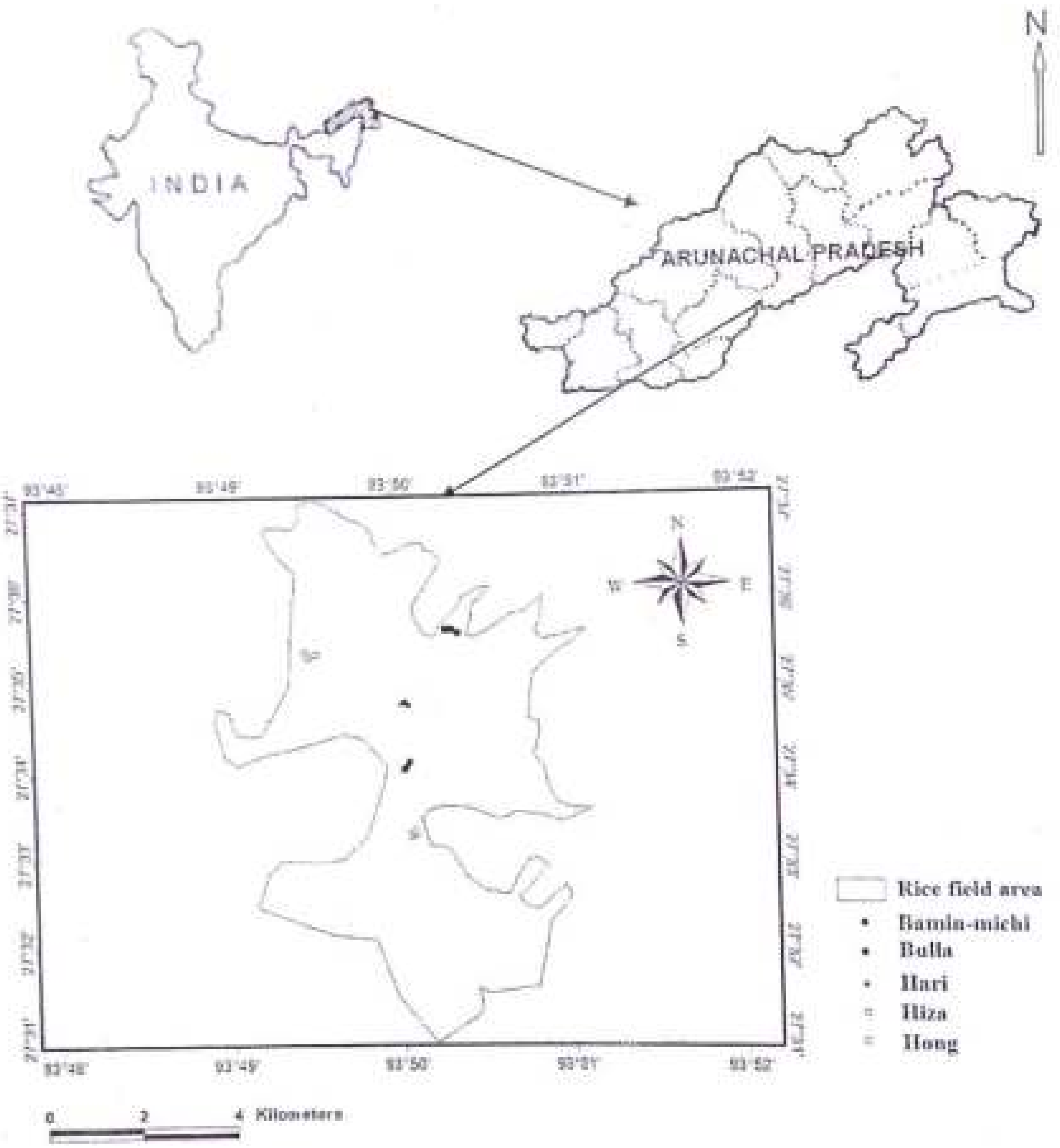

Figure 1. Map showing the sampling stations

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Climate

Ziro experiences a temperate climate. Summers are cool, though the area witnesses extensive rainfall during the monsoons and winters are cold. The summer season starts in April till the end of June and the monsoons start in July and end in September. Winter sets in by November and lasts throughout February. The climate is largely influenced by the nature of terrain depending upon altitude and location of place. Annual rainfall in the south is heavier than that in the northern areas of the district. During the monsoon period more than 70 percent of the rain over the southern half occurs while in the northern portions it is about 60 percent. Variability of rain fall for the monsoon and the year, as a whole, are relatively small. Average annual rainfall of the district headquarters, Ziro recorded an average rainfall of 59.85 mm and the total rainfall was 718.2 mm during the year 2012. In the year 2013 the average rainfall was 60.28 mm and the total rainfall recorded was 723.4 mm. Relative humidity is always high throughout the year except in the winter months being slightly less humid.

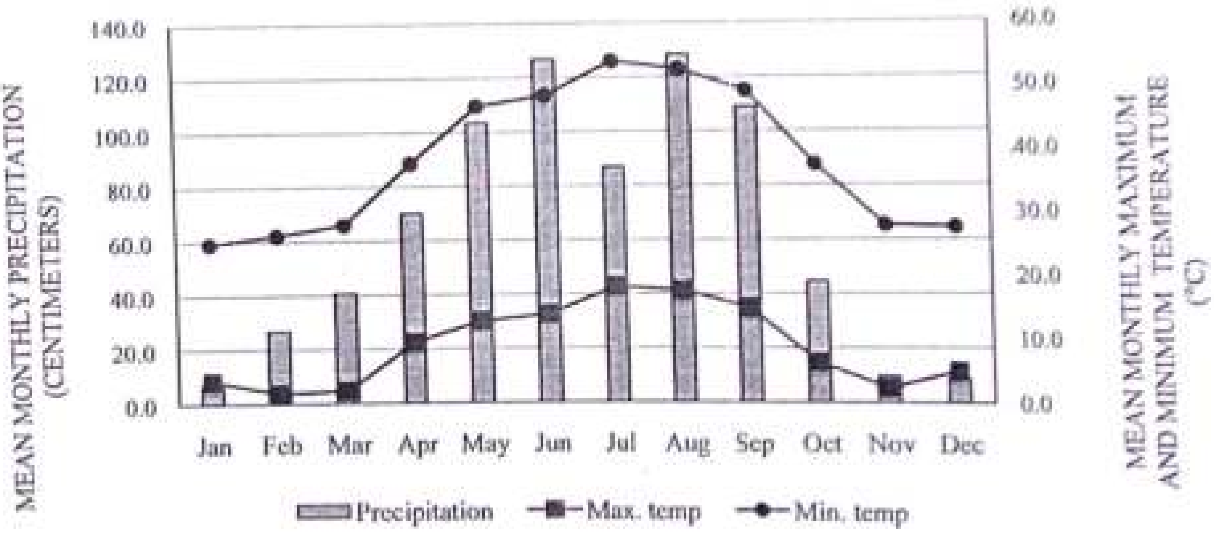

Figure 2. Climatogram of the study area depicting the average monthly precipitation, maximum and minimum temperatures for three years i.e. 2012, 2013 and 2014

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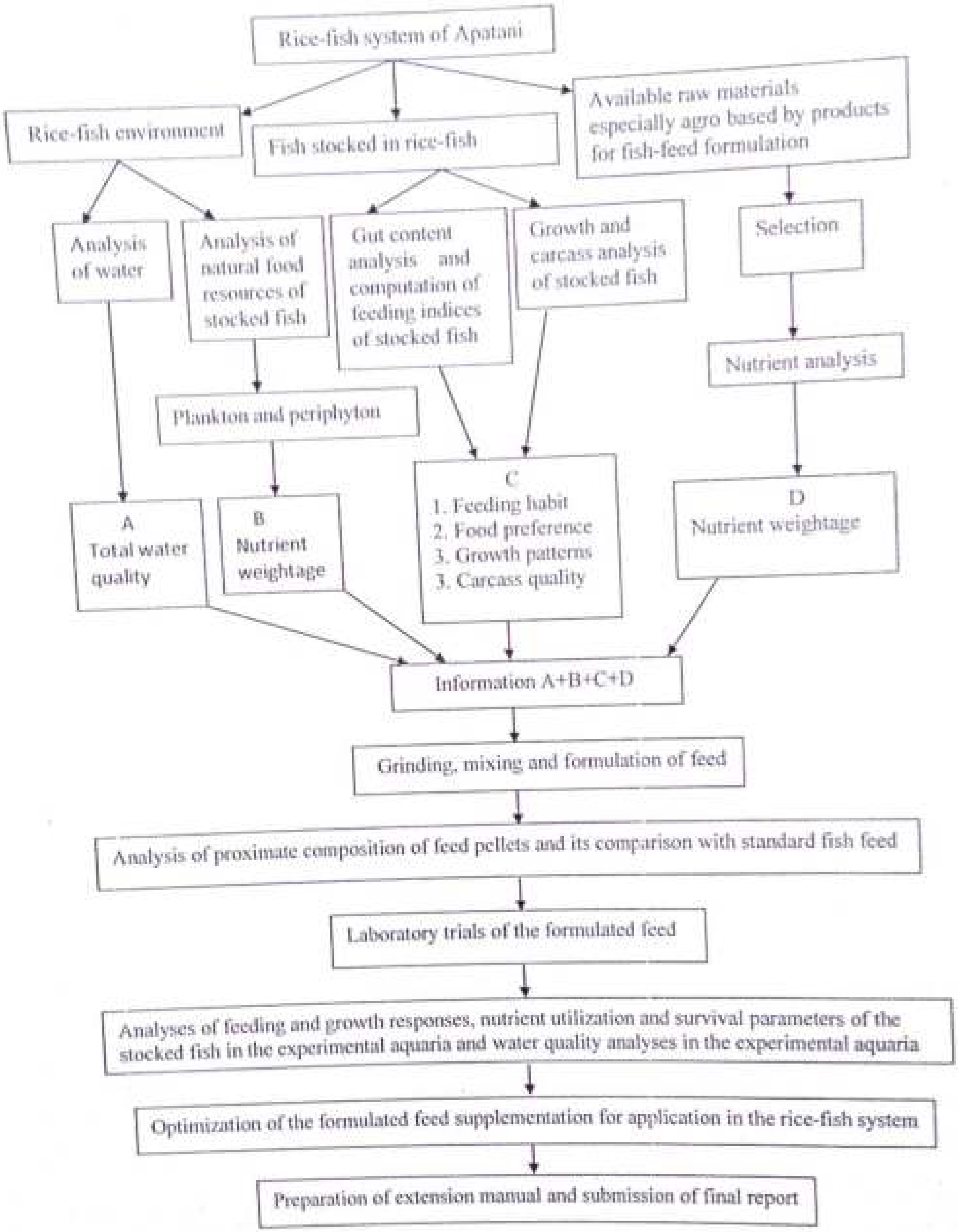
Layout of the study



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Chapter 3

MATERIALS AND METHODS

Physico-chemical properties of the rice field water

In order to assess the natural habitat condition of the stocked fish in rice-fish system water samples of the rice-fish system during the fish stocking stage was collected at monthly intervals from the selected sampling stations. Physico-chemical parameters of the rice-field water were analysed following Michael, 1984; Eaton *et al*., 1995; Ramesh and Anbu, 1996; Gupta, 1999; Tripathi and Govil, 2001.

Biological parameter of the rice field: plankton and rice-stem periphyton communities

For quantitative estimation of plankton and rice-stem periphyton Lackey's drop method (Lackey, 1938) was followed. Both the plankton and periphyton were sorted out and identified to the lowest possible taxonomic level using light microscope (Magnus MLXi binocular microscope). Identification of phytoplankton and periphyton was done at magnification 40X and that of zooplankton at 10X following Needham and Needham, 1962; Pentecost, 1984; Battish, 1992; Anand, 1989, 1998; Bilgrami and Saha, 2004; John *et al*., 2011 and APHA, 2012 etc.

Feeding habit and food preferences of stocked fish

To find out the feed preference of the stocked fish in the rice-fish system fish samples were collected from the rice fields of the study area during three hours of the day (i.e. 8am-9am, 11am-12pm, and 2-3pm) and were preserved in 10% formalin. Later on the samples were brought to the laboratory and their respective lengths and weights were noted down. Intact stomach was separated from the fish and weighed using an electronic balance (Shimadzu, Ax200,No D440420098). Afterwards, the stomach was dissected and its contents were preserved with 4ml 10% formalin in test tubes. Later on the weight of empty stomach was also noted. The gut contents were examined following Lackey's drop method (Lackey,

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1938) using light microscope (Magnus MLXi binocular microscope). Identification of gut content of the fish was done following standard keys Ward and Whipple, 1959; Needham and Needham, 1972; Biswas, 1980; Ghosh and Sengupta, 1982; Michael, 1984; Vazirani, 1984; Gohan, 1988; Anand, 1989, 1998; Santhanam *et al.*, 1989; Battish, 1992; Santra, 1993 Calculation of different feeding indices were done following Levins,1968 and Hobson, 1974 as follows:

(1) Niche breath (Levins, 1968)

$B = 1/\sum (pj^2)$

Where,

B is Levin's diet/niche breadth,

pj is fraction of items in the diet that are of food category j.

B value ranges from 1.0, when the population under study uses one resource state exclusively and equal to R (i.e. the number of taxonomic identity or size category or anything categorizing resource or food) when the population uses all resource states.

(2) Ranking index (Hobson, 1974)

Ranking index of each prey item=

(Volumetric scale of prey item/ Volumetric scale of all prey items combined) x100

Growth of the stocked fish and its nutrient contents

In order to study the growth condition of the stocked fish in the rice field, fish samples were collected from the rice fields at monthly interval during the fish stocking stage (May to August) during 2014 by draining the water from the rice field through the outlet pipes. The fish samples were kept in ice box lined with ice cubes and brought to the laboratory. In the laboratory their respective length and weight were noted down in order to get information on their growth pattern. Total length of the fish samples was noted with the help of a measuring scale in centimetre. The weight of the fish was noted down using an

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electronic balance (Shimadzu, Ax200, No D440420098) after drying it with tissue paper. The growth pattern of the fish in terms of its body length and body weight was noted following Bhuiyan and Biswas, 1982.

Nutrient contents of the stocked fish

For determination of nutrient contents in the body of the stocked fish in the rice-fish system, fish samples were collected from the rice fields at monthly interval during the fish stocking stage (May to August) during 2014 by draining the water from the rice field through the outlet pipes. The fish samples were kept in ice box lined with ice cubes and brought to the laboratory. In the laboratory the fish samples were dried in an oven at 60°C for 24 hours after which these were transferred to desiccators and kept for another 24 hours. The samples were powdered with the help of mortar and pestle. Finally subsamples of the powdered form of the fish carcass after homogenization were used for determination of nutrient content of the fish samples. Determination of the body nutrient of the stocked fish in the rice-fish system comprised of proximate components like carbohydrate, protein, fat, and mineral components like sodium, potassium, calcium and phosphorous. Determination of carbohydrate was done by Anthrone method. Determination of protein was done by Kjeldahl method after acid hydrolysis (crude protein= total nitrogen x 6.25). Determination of fat (crude fat) was done by extracting it by petroleum ether in a Soxhlet apparatus. The macro elements like sodium (Na), potassium (K) and calcium (Ca) were determined by flame photometer method. Phosphorous (P) was determined by spectrophotometric method. Determination of all the above mentioned nutrients were done following standard references as per Raghuramulu *et al.* (1983), Okalebo *et al.* (1993), and Sadasivam and Manickam (1996).

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Formulation of low-cost fish feed

A. *Selection of raw materials*

For formulating the fish-feed, raw materials which are commonly available in the Apatani Plateau were selected as the ingredients. These are: (1) the leftover of processed and fermented rice after preparation of the local rice beer, '*Apong*', (2) algae which remain as clump near the rhizosphere of the rice plant in the paddy field, and (3) garlic (*Allium sativum*) as antioxidant.

B. *Formulation of fish-feed*

The raw materials i.e. leftover of processed and fermented rice and algae were dried separately in an oven at 70°C for 48 hrs. Followed by this, each of the components were separately grinded to a powdered form in a grinder. The powdered ingredients were then mixed in the proportions – (100 gm leftover of processed and fermented rice) + (50 gm clumped algae from the rice field) + (1 gm garlic paste). Soft dough was prepared using water at normal room temperature. This was followed by pelleting the dough using a pellet machine. Finally, the pellets were kept for drying in oven at 60°C for 24 hours.

C. *Determination of proximate composition of the raw materials and the prepared fish-feed*

The nutritional value of the raw materials used for the fish-feed formulation and of the final product, were analyzed for their proximate composition following standard methods of Raghuramulu *et al.* (1983), Okalebo *et al.* (1993), and Sadasivam and Manickam (1996).

D. *Efficacy test of the fish-feed under laboratory condition*

Aquaculture experiment was performed to test the efficacy of the formulated fish-feed on fish growth. For this, fish fries were collected from the nearest fish farm, and were acclimatized for 48 hours in an aquarium. The feeding trial was conducted for four weeks (December, 2014) in four experimental aquariums (30 L capacity) @ 12 individuals per aquarium. The fishes were fed twice per day at 08:30 hr and 17:30 hr with three feeding treatments (i. e. supplementation of the prepared fish feed @ 3%, 5%, and 7% of the initial

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body weight of the stocked fish in three different experimental aquaria) and one control (where no supplemental feed was given and it is presumed that the fish survived only on the available plankton in the experimental aquaria). At the end of each week the stocked fish (three replicates) in different experimental aquaria were tested for different growth parameters. The water in the experimental aquaria was changed once on the 15th day of the feeding trial. Growth response, feeding response and survival parameters of the stocked fish under different treatments were recorded following Fulton (1911), Bhuiyan and Biswas (1982), Faturoti and Akinbote (1986) and Lovell (1988).

Water quality parameters which are required for aquaculture experiments were also analyzed for two times- one set of analysis was done during the 14th day and the other on the 28th day of the experimental set up in different aquaria under different treatments following APHA (2012).

Chapter 4

WATER QUALITY OF RICE-FISH SYSTEM OF APATANI PLATEAU

Introduction

Rice today is grown in 113 countries in the world in a wide range of ecological conditions and water regimes. The cultivation of most rice crops in irrigated, rain fed and deepwater systems offers a suitable environment for fish and other aquatic organisms. Over 90% of the world's rice, equivalent to approximately 134 million hectares, is grown under these flooded conditions providing not only home to a wide range of aquatic organisms, but also offering opportunities for their enhancement and culture (Halwart and Gupta, 2004).

Fish culture in waterlogged rice fields have been known to be practiced in Asia for 5000-6000 years. The earliest record of rice fish culture was originated from China 2000 years ago (Li, 1988). An early review on rice-fish culture showed that by the mid-1900s it was practiced in 28 countries on six continents, namely, Africa, Asia, Australia, Europe, North America and South America (F.A.O., 1957). Countries with a recorded history of rice-fish culture are India, Indonesia, Malayasia, Thailand, Japan, Madagascar, Italy and Russia (Halwart, 1994).

Rearing of fish along with paddy is an old practice in India (Alikunhi, 1955) Rice and fish are immensely important to the livelihoods of the rural poor in India as both a source of nutrition and as a source of income. Rice and fish are considered to be the main sources of food in this region. It has been estimated that rice constitutes as much as 60% of the daily food intake of the majority of Asians.

However, in this regard, mention must be made that the fish production in rice fish system of Apatani Plateau, in fact, is far below the carrying capacity of the field in comparison to similar systems elsewhere. And, in order to increase the fish productivity research is needed to understand the pattern of nutrient dynamics in relation to fish

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production in the rice- fish system and based on the information of the field condition, the water quality parameters were analysed.

Results and discussion

Table 4.1 shows the physico-chemical properties of water in the rice-fish system of Apatani Plateau. In Bamin-michi, high values of pH, DO and least value free CO_2 and PO_4-P gives a general indication about the presence of less organic matter content in that station. Greater value of NO_3-N in Bamin-michi was perhaps due the less water depth and subsequently less water volume in the station and hence the concentrations of nitrates particularly due to faecal matters of the stocked fish. Least value of total alkalinity in Bamin-michi indicates very low buffering capacity of the water there and hence more stressed condition for the stocked fish. Greater values of BOD and PO_4-P in Bulla indicates presence of phosphorous-rich organic matters in more quantities and more microbial activities that lead to the release of PO_4-P in greater amount at that station. Hiza had highest value of water and sediment temperatures. This might be due to less water depth at this station and also might be due to the reason that sampling in this station was done when the solar intensity was high that also lead to increase in air temperature thereby reflecting the close interaction of air, water and sediment temperatures in the aquatic system. Hiza also had greater value of total alkalinity thereby reflecting relatively more buffering capacity of the water in this station. Low values of pH, DO and greater value of free CO_2 in Hong reveals a relatively stressed condition in this station. This might be due to more density of planktonic organisms (Figure 4) and also the stocked fish. However, BOD was less in Hong. This was perhaps due to more water depth and hence more water volume that lead to the dilution of organic matters in the water and less water temperature that lead to less microbial activities in that station. Least value of NO_3-N in Hong was perhaps due to greater photosynthetic activity of the phytoplankton which had a highest density at that station.

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Table 4.2 shows the Analysis of Variance for water properties in rice-fish system of Apatani Plateau. It showed that all the properties water in the rice-fish system varied significantly across stations, months and stations x months.

Table 4.3 shows the comparison of water properties in rice-fish system of Apatani Plateau with relevant standard of freshwater fisheries in warm water. It is observed that except for CO_2, all the parameters of the rice field water during the fish stocking stage were within the range for freshwater fishery.

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Table 4.1. Physico-chemical parameters of water in the rice fish system of Apatani Plateau

Stations	AT (°C)	WT (°C)	ST (°C)	WD (cm)	pH	TA (mgl⁻¹)	DO (mgl⁻¹)	BOD (mgl⁻¹)	Free CO_2 (mgl⁻¹)	Nitrate-N (mgl⁻¹)	Phosphate-P (mgl⁻¹)
Bamin-michi	24 ±1.30 (20-33)	26.08 ±0.85 (22-30)	25.7 8±0.7 (21-30)	10.19 ±0.83 (6.4-13.5)	7.38 ±0.12 (6.7-7.9)	20.45 ±1.45 (12.6-29.33)	8.73 ±0.7 (7.06-11.28)	3.41 ±0.48 (1.33-6.48)	11.63 ±1.21 (5.9-17.91)	3.66 ±1.09 (0.23-12.31)	0.04 ±0.01 (0.01-0.12)
Hari	24.08 ±1.08 (20-30)	26.45 ±1.03 (22-30)	25.42 ±0.72 (22-29)	12.6 ±0.83 (9.2-15.5)	7.22 ±0.15 (6.3-7.6)	24.47 ±2.31 (12.60-33.30)	7.83 ±0.13 (6.28-10.27)	2.19 ±0.19 (0.72-4.67)	12.77 ±1.10 (5.9-17.15)	5.01 ±1.00 (0.39-12.04)	0.06 ±0.03 (0.005-137)
Bulla	23.75 ±0.94 (19-32)	24.53 ±0.94 (20-29)	23.31 ±0.75 (19-28)	12.02 ±1.50 (6.2-20.6)	6.83 ±0.2 (5.02-7.9)	28.54 ±4.23 (13.2-54.66)	8.1 ±0.27 (6.48-10.54)	3.67 ±0.48 (0.94-4.91)	13.62 ±1.08 (4.59-19.2)	4.08 ±0.70 (0.52-9.04)	0.07 ±0.02 (0.01-0.29)
Hira	24.58 ±1.33 (20-33)	27.33 ±1.47 (21-35)	25.92 ±1.20 (20-32)	10.23 ±1.00 (5.0-15.9)	7.24 ±0.07 (6.7-7.9)	32.54 ±2.49 (20-44.66)	8.4 ±0.44 (6.34-11)	3.54 ±0.66 (0.72-8.44)	12.7 ±1.11 (6.59-18.57)	4.5 ±0.90 (0.34-8.21)	0.05 ±0.01 (0.004-0.114)
Hong	22.93 ±1.08 (19-32)	24.4 ±0.62 (20-28)	24.33 ±0.54 (22-29)	12.62 ±1.35 (6.0-21.7)	6.69 ±0.22 (4-7.7)	23.18 ±2.70 (12.6-35.33)	7.11 ±0.56 (5.12-9.84)	2.33 ±0.43 (0.24-7.01)	14.6 ±0.95 (7.98-19.9)	3.95 ±0.64 (0.11-7.07)	0.05 ±0.01 (0.003-0.075)

Mean ±SE, n=45; AT-Air temperature, WT-Water temperature, ST-Sediment temperature, WD-Water depth, TA-Total alkalinity, DO-Dissolved oxygen, BOD-Biological Oxygen Demand. Numbers in parenthesis designate range of mean values of the physico-chemical properties of water in different stations of the study area.

Table 4.2 Analysis of Variance for water properties in rice-fish system of Apatani Plateau

Physico-chemical properties of water	ANOVA		
	One-way		Two-ways
	Stations F-ratio	Months F-ratio	Stations x Months F-ratio
Air temperature	69.12*	857.1*	68.1*
Water temperature	142.42*	2463.91*	296.54*
Sediment temperature	177*	2759.7*	326.9*
Water depth	17.6*	70.908*	6.264*
pH	66.42*	987.12*	85.12*
Total alkalinity	18.4*	82.511*	2.748*
Dissolved oxygen	22.434*	155.682*	41.447*
Biological oxygen demand	7.5834*	31.8813*	7.6206*
Free carbon dioxide	7.6157*	25.4957*	6.3431*
Nitrate-nitrogen	3.12*	200.408*	5.895*
Phosphate-phosphorous	3.656*	18.5942*	2.1407*

*p<0.01

For one-way ANOVA degree of freedom=4

For two-ways ANOVA degree of freedom=16

Table 4.3. Comparison of water properties in rice-fish system of Apatani Plateau with relevant standard of freshwater fisheries in warm water

Parameters	Standards of water properties for freshwater fisheries in pond as per Das *et al.*, 2013	Standards of water properties for freshwater fisheries in pond as per Boyd, 1998	Range in water properties in rice-fish system of Apatani Plateau during fish stocking stage
Water temperature (°C)	25-32, *25-35	-	20-35
Water depth (cm)	>30; *5-25	-	2-21.7
pH	6.5-8.5	7-9	4-7.7
Total alkalinity ($mg\ l^{-1}$)	50-300	-	12.6-77.33
DO ($mg\ l^{-1}$)	5-10	5-15	5.12-11.28
BOD ($mg\ l^{-1}$)	<10	-	0.24-8.44
Free CO_2 ($mg\ l^{-1}$)	<3	1-10	4.59-19.9
Nitrate-N ($mg\ l^{-1}$)	0.1-3	0.2-10	0.11-12.31
Phosphate-P ($mg\ l^{-1}$)	0.05 to 2.0	0.005-0.2	0.003-0.137

*Standard of water temperature and water depth for fish culture in rice-fish system as per standard given by Tamilnadu Agricultural University, Coimbatore

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Chapter 5

NATURAL FISH FOOD IN RICE-FISH SYSTEM OF APATANI PLATEAU

Introduction

In rice rice-fish culture the presence and abundance of food organisms are very important factors. It harbours lots of phytoplankton and filamentous higher algae in its aquatic phase (Fernando, 1993). All these aquatic fauna and flora play important role on the overall ecology of rice field. Con The term "Plankton" refers to those minute aquatic forms which are non motile or insufficiently motile to overcome the transport by currents and living suspended in the open or pelagic water (Greek planktons, meaning wandering). They comprise of heterogeneous group of tiny plants and animals adapted to suspension in the sea and fresh water. Their intrinsic movements, if any, are so feeble that they remain essentially at mercy of every water current. The plankton belonging to plant origin are called phytoplankton (phyto =plant; plankton =floating) and those belonging to animal origin are called zooplankton (zoo = animal; plankton = floating) (Eaton *et al.*, 1985).

The plankton can further be divided on the basis of their size viz., megaplankton- more than 8cm, macroplankton-size vary from 1mm to 1cm, mesoplankton- 0.5-1mm, microplankton- 0.06-0.5mm, nanoplankton- 0.005 to 0.06mm, and ultraceston -0.0005 to 0.005mm (Battish, 1992).

Planktons are of immense value as food for fishes and play an important role in the natural purification of polluted waters. However some plankton form a harmful bloom and they cause high mortality among the aquatic organism and pose a serious hazard in the water supply for domestic and industrial use. Plankton also play important role as bio indicator of water quality

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Periphyton is a complex mixture of algae, cyanobacteria, heterotrophic microbes, and detritus that is attached to submerged surfaces in most aquatic ecosystems. It serves as an important food source for invertebrates, tadpoles, and some fish and it can be an important sorer of contaminants. Periphyton is also an important indicator of water quality; responses of this community to pollutants can be measured at a variety of times scales representing physiological to community-level changes.

Results and discussion

Table 5.1 shows the distribution of phytoplankton in the study area. It reveals the presence of 77 taxa of phytoplankton belonging to classes Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, Euglenophyceae, and Zygnemophyceae out of which 45 taxa belonged to Bacillariophyceae, 13 taxa to Chlorophyceae, 12 taxa to Cyanophyceae, 5 taxa to Zygnemophyceae and 1 each to Dinophyceae and Euglenophyceae. In all the stations Bacillariophyceae followed by Chlorophyceae was the most dominant phytoplankton class (Figure 5.1). The dominance of Bacillariophyceae in the rice-fish system was due to more silica content in the sediment and water which is the major nutrient required by the diatoms (Lukaw *et al.*, 2012). The second dominant phytoplankton class was Chlorophyceae which was perhaps due to low temperature of the rice field water, moderate nutrients like NO_3-N and PO_4-P (Mustapha, 2010) accompanied by better substrates, the paddy plants. Among all the stations, Hiza and Hong had the highest phytoplankton density (Figure 5.4A). However, phytoplankton taxa were relatively rich in Hiza and poor in Hong (Table 5.1). Therefore, different reasons can be ascribed for the greater density of phytoplankton in two different stations of the rice field systems. In Hiza the greater phytoplankton density with more phytoplankton taxa might be due favourable environmental condition (particularly due to more alkalinity) for diverse taxa at that station. In Hong the greater phytoplankton density

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with less phytoplankton taxa might be due favourable environmental condition for selected taxa at that station.

Table 5.2 represents the distribution of zooplankton in the rice -fish system of the study area. It shows the presence of a total of 15 taxa of zooplankton in the study area belonging to groups Cladocera, Rotifera, Decapoda, Copepoda, Calanoida and Diplostraca. A total of 8 taxa belonged to Cladocera, 2 each to Rotifera and Copepoda besides 1 each to Decapoda, Copepoda, Calanoida and Diplostraca. It was observed that in all the sampling stations Cladocera was dominant zooplankton group (Figure 5.2) thereby indicating the rice-fish system to be free from intense pollution which favoured their growth and reproduction (Ferdous and Muktadir, 2009). Besides, the abundance of Cladocera also indicates the presence of rich nutrients with weeds and shallow waters (Sharma *et al.*, 2012) in the rice-fish system. Zooplankton density as well as its taxonomic richness in the rice-fish system of Apatani Plateau was highest in Hari and lowest in Hiza (Figure5.4B and Table 5.2). This was perhaps due to greater variations in the water properties in both these station that favoured the growth of zooplankton community in one station (Hari) while in the other station (Hiza) the water properties were not that congenial for the growth of diverse zooplankton.

Table 5.3. shows the distribution of rice-stem periphyton in the rice-fish system of Apatani Plateau. It shows the presence of a total of 56 taxa of rice-stem periphyton in the study area belonging to classes Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, Euglenophyceae, Rhodophyceae, Xanthophyceae and Zygnemophyceae out of which 34 taxa belonged to Bacillariophyceae, 10 taxa to Chlorophyceae, 8 taxa to Cyanophyceae, and 1 each to Dinophyceae, Euglenophyceae, Rhodophyceae, Xanthophyceae and Zygnemophyceae. In all the stations Bacillariophyceae was the most dominant periphyton (Figure 5.3). Hari was found to have highest density of periphytic community which might be due maximum penetration of solar radiation into the system

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because of the shallowness of the system, which lead to periphytic growth. While the periphytic communities was lowest in Bamin-michi which may be due to deep water column which limits photosynthesis and retards periphytic growth (Figure 5.4C).

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Table 5.1. Distribution of phytoplankton in different stations of the rice-fish system of Apatani Plateau

Class	Taxa	Ramin-michi	Hari	Bulla	Hiza	Hong
Bacillariophyceae	*Achnanthes* sp1.	-	+	+	+	+
	Acnanthes sp2.	+	-	+	-	-
	Amphiplena pellucida	+	-	-	+	-
	Amphora	+	-	-	-	+
	Amphora ovalis	+	+	+	-	+
	Asterionella	-	-	-	+	-
	Cymbella sp1.	+	+	+	-	+
	Cymbella sp2.	-	+	-	+	+
	Diatoma sp1.	+	+	+	-	+
	Diatoma sp2.	-	-	+	+	+
	Diatoma vulgare	-	+	+	+	+
	Encyonema	+	+	+	+	+
	Epithemia	-	+	+	+	+
	Eunotia	+	+	+	+	+
	Fragellaria	-	+	+	+	-
	Frustulia	+	+	+	+	+
	Gomphonema	-	+	+	+	+
	Gomphonema angustrum	+	-	-	-	-
	Gyrosigma	-	+	-	-	-
	Gyrosigma valticum	-	-	-	+	-
	Himantidium	-	-	-	+	-
	Mastogloia	-	-	-	+	-
	Melosira	+	+	+	+	+
	Microcoleus vaginatus	+	+	-	+	-
	Pinnularia sp1.	-	+	+	+	-
	Pinnularia major	+	-	+	+	+
	Pinnularia sp2.	-	+	+	-	-
	Pleurosigma	-	-	-	+	-
	Navicula gracillis	-	+	+	+	+
	Navicula placenta	+	+	+	+	+
	Navicula rhynchocephala	+	+	+	+	+
	Navicula sp.	+	+	+	+	+
	Navicula viridis	+	+	+	+	+
	Nitzschia	+	-	+	+	-
	Nitzschia sigmoida	-	+	+	+	-
	Staurastrum	+	+	+	+	+
	Staurastrum magnum	-	-	-	-	+
	Stauroneis	+	-	+	+	+
	Staurastrum brachiatum	+	-	-	-	-
	Staurastrum magnum	-	-	-	-	-
	Surirella sp1.	+	+	+	+	+
	Surirella sp2.	+	+	+	+	+
	Synedra	+	+	+	+	+
	Synedra fumosa	-	-	+	+	+
	Synedra ulna	+	+	+	+	+
	Tabellaria	+	-	+	-	-
	Tabellaria flocculosa	-	-	-	-	+
	Rholophalodia gibba	+	+	+	+	+
Chlorophyceae	*Ankistrodesmus*	-	+	+	-	-
	Closterium	+	+	+	+	+
	Closterium striolatum	-	-	-	+	-
	Cosmarium	+	+	+	|	|
	Desmidium	-	+	-	+	+
	Docidium	+	+	+	-	+
	Euastrum	+	+	-	+	-

	Euastrum crassum	+	+	-	-	-
	Gonatozygon	+	+	+	+	+
	Scenedesmus	-	+	-	-	-
	Spirogyra sp1.	+	+	+	+	+
	Spirogyra sp2.	-	+	-	-	-
	Ulothrix	+	-	-	-	+
	Zygonema	+	+	-	-	-
Cyanophyceae	*Anabaena*	+	+	+	+	+
	Aphanizomenon	+	+	+	+	+
	Nostoc	-	-	+	+	-
	Oscilatoria sp.	-	+	+	+	-
	Phormidium	+	+	-	+	-
	Phormidium autumnale	-	-	-	+	-
	Pseudoanabaena	+	+	-	-	-
	Spirulina	-	+	+	-	-
Dinophyceae	*Massartia*	-	+	-	-	-
Zygnemophyceae	*Micrasterias* sp1.	+	+	-	-	-
	Micrasterias sp2.	-	+	-	-	+
	Micrasterias radiosa	-	+	-	+	-
	Miscrasterias foliacea	-	-	-	+	-
Euglenophyceae	*Euglena*	+	+	+	+	-
Total taxa	77	43	52	45	54	39

'+' indicates presence and '-' indicates absence of the taxa concerned

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Table 5.2. Distribution of zooplankton in different stations of the rice-fish system of Apatani Plateau

Groups	Taxa	Bamin-michi	Hari	Bulla	Hiza	Hong
Cladocera	*Alona*	-	-	+	-	-
	Bosmina	+	+	+	+	+
	Chydorus	+	-	-	-	-
	Daphnia	-	+	-	+	+
	Leydigiopsis	-	-	+	-	-
	Moina	+	-	-	-	-
	Pleuroxus	-	-	+	-	-
Copepoda	*Cyclops*	-	+	-	-	-
	Canthocamptus	+	-	-	-	-
Calanoida	*Diaptomus*	+	-	-	-	-
Decapoda	*Alonella*	-	+	+	+	+
	Palemonetes	-	-	+	-	-
Diplostraca	*Sida crystallina*	-	+	-	-	-
Rotifera	*Asplanchna*	-	+	-	-	-
	Brachionus	-	+	-	-	-
Total taxa	15	5	7	6	3	3

'+' indicates presence and '-' indicates absence of the taxa concerned

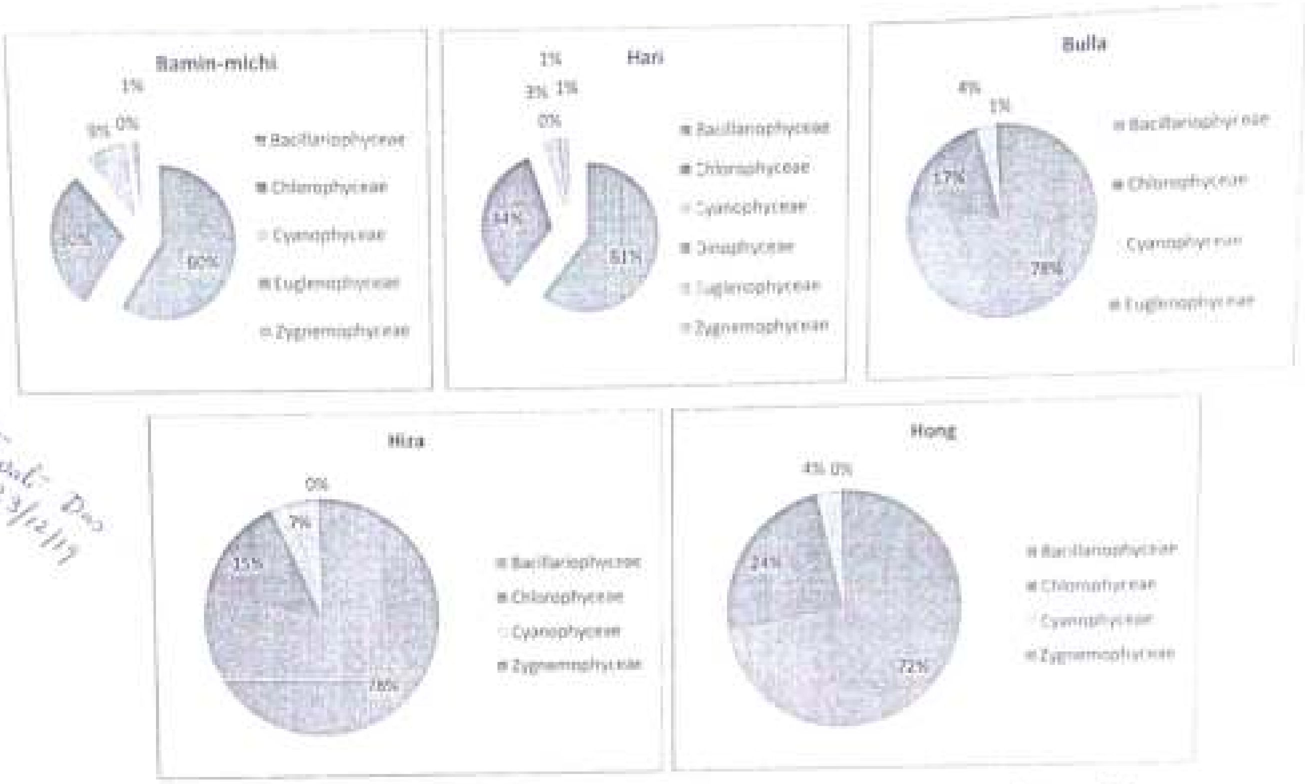

Figure 5.1. Class representation of phytoplankton in different stations of the rice-fish system of Apatani Plateau

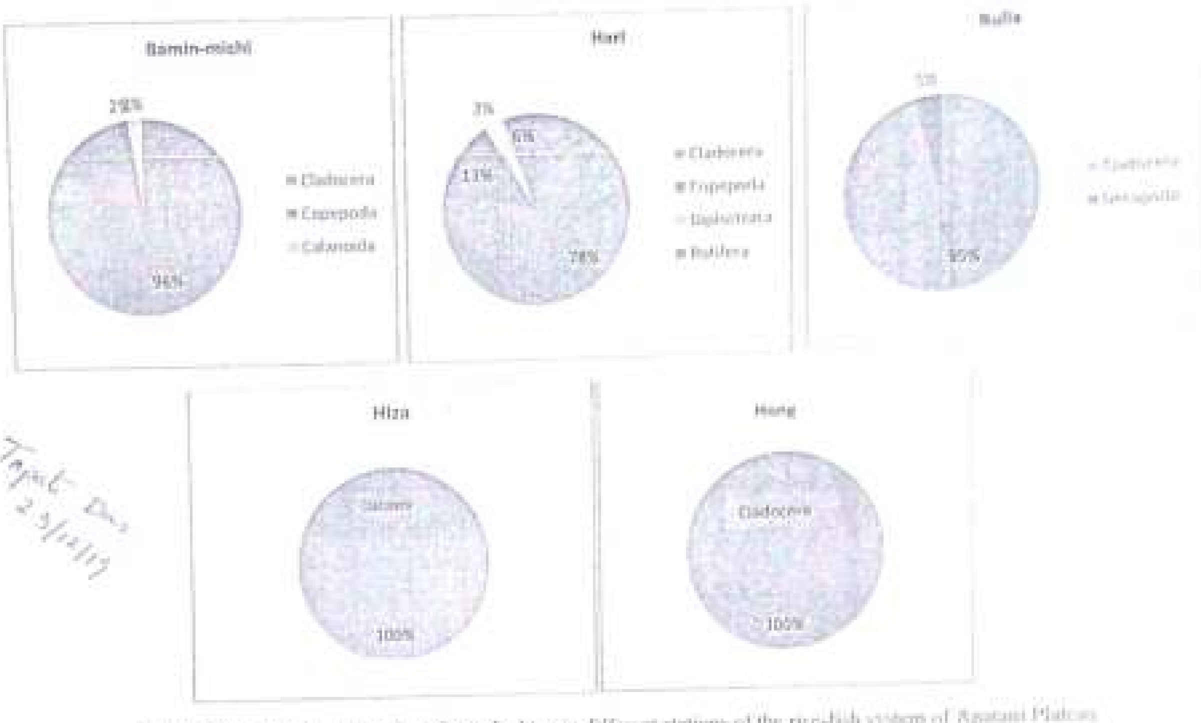

Figure 5.2. Order representation of zooplankton in different stations of the rice-fish system of Apatani Plateau

Table 5.3. Distribution of rice-stem periphyton in different stations of the rice-fish system of Apatani Plateau

Taxa	Bamin-michi	Hari	Bulla	Hiza	Hong
Achnanthes	+	+	+	+	+
Amphora ovalis	+	+	+	+	+
Amphidium	-	-	+	-	-
Asterionella	+	-	+	-	-
Cymbella	+	+	+	+	+
Cyclotella	-	-	-	+	-
Diatoma	-	-	+	+	+
Encyonema	-	-	+	+	+
Epithemia	+	+	+	+	+
Eunotia	+	+	+	-	+
Flagelleria	-	-	+	-	-
Frustulia	+	+	+	+	+
Gomphonema	+	+	+	+	+
Himantidium	-	-	-	+	+
Melosira	+	+	+	+	+
Navicul placenta	+	+	+	+	+
Navicula gracillis	-	+	+	-	-
Navicula radiosa	-	-	+	-	-
Navicula rhynchocephala	+	+	+	+	+
Navicula sp.	+	+	+	+	+
Navicula viridis	+	+	+	+	+
Nitzschia sigmoida	-	-	-	-	+
Oocystis	-	+	-	-	-
Pinnularia	+	+	+	+	+
Pinnularia major	+	+	+	+	+
Rophalodia gibba	+	+	+	-	+
Stauroneis	+	+	+	+	+
Staustrum	-	+	-	+	+
Surirella	-	-	+	+	+
Surirella elegans	+	+	+	+	+
Synedra	+	-	-	+	+
Synedra fumosa	+	+	-	+	+
Synura	-	+	-	-	-
Tabellaria	-	+	+	+	-
Closterium	-	+	+	+	+
Cosmarium	-	+	-	-	-
Docidium	-	+	+	-	+
Desmidium	+	+	-	+	-
Gonatozygon	-	+	-	-	+
Netrium	-	-	+	-	-
Scenedesmus	+	+	+	-	-
Spirogyra	-	+	-	-	-
Ulothrix	-	-	+	+	+
Zygonema		+	-		-
Anabaena	-	-	-	+	+
Aphanizemenon	+	+	+	-	-
Cylindospermum	-	+	+	-	-
Merismopedia	-	+	-	-	-
Microcoleus vaginatus	+	+	-	-	-
Oscillatoria	+	-	-	-	-
Phormidium	+	+	+	-	+
Spirulina	-	-	-	+	+
Xanthidium antilopaeum	-	+	-	-	-
Ceratum	-	+	+	-	-
Phacus	+	+	+	+	+

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Batrachospermum	+	+	+	+	+
Vaucheria	-	+	-	+	-
56	28	40	36	31	32

'+' indicates presence and '-' indicates absence of the taxa concerned

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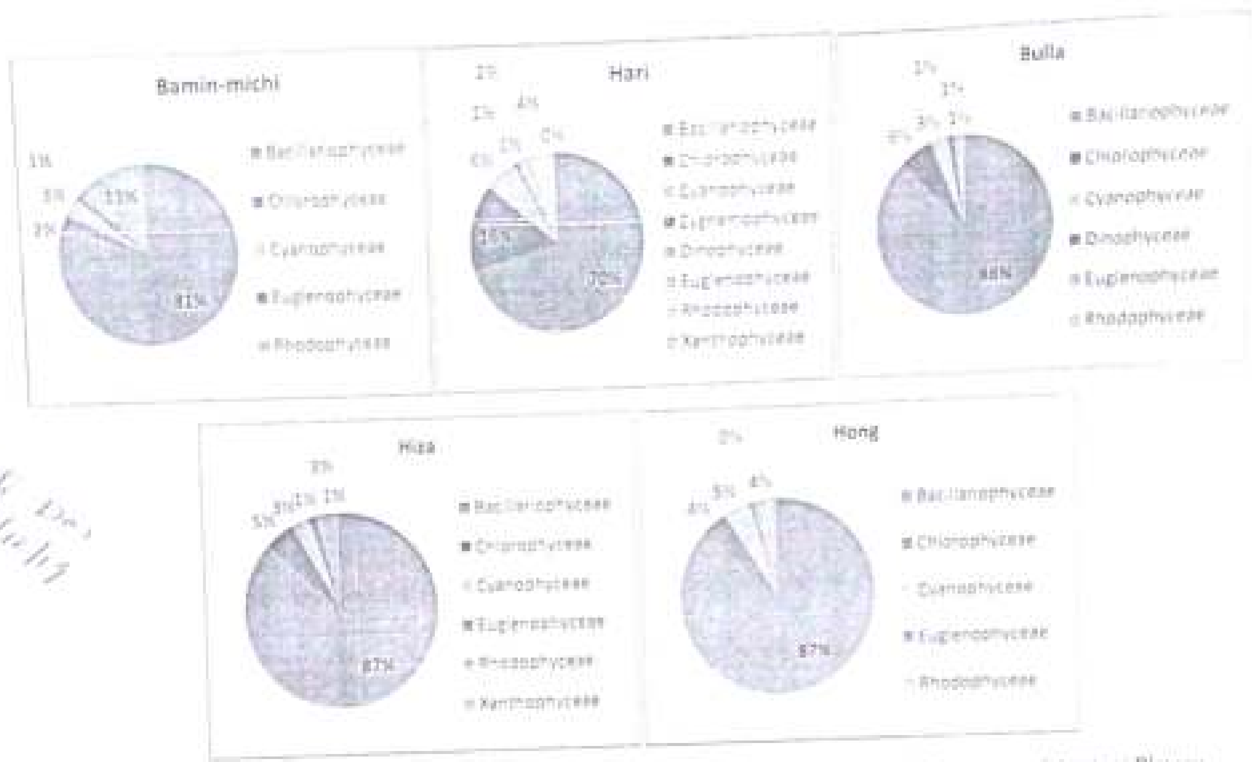

Figure 5.3. Class representation of rice-stem periphyton in different stations of the rice-fish system of Apatani Plateau

Figure 5.4. Total abundance of phytoplankton (A) and zooplankton (B) and rice-stem periphyton (C) in different stations of the rice-fish system of Apatani Plateau

Chapter 6

FEEDING HABIT AND FOOD PREFERENCES OF STOCKED FISH IN RICE-FISH SYSTEM OF APATANI PLATEAU

Introduction

Apatani tribe dwelling in Apatani Plateau, located in lower Subansiri district of Arunachal Pradesh, North East India, are involved in Integrated Agriculture Aquaculture in their wet rice fields since 50 years. This Integrated Agriculture Aquaculture is free from the use of agrochemicals and additional input of supplementary feed for fish and this unique practice is popularly termed as 'aji gnui assonii' (Saikia and Das, 2004). The cropping pattern of the area includes mono-cropping of wet rice once in a year accompanied by stocking the fish species, *Cyprinus carpio*. Being a simple production method, both fish and rice grow synergistically in rice fish system and harness the environmental resources only. About 1.5 to 2.5 t/ha of rice and 150 to 250 kg/ha of fish per season are harvested from such system (Saikia and Das, 2004). In this regard, mention must be made that the fish production in rice fish system of Apatani Plateau, in fact, is far below the carrying capacity of the field in comparison to similar systems elsewhere like China. And, in order to increase the fish productivity research is needed to get complete information on the food, feeding behaviour and growth parameters of the stocked fish in such systems. Based on the information of the field condition, appropriate management techniques can be adopted which will result in rapid growth and greater production of the stocked fish in the concurrent rice-fish culture.

Till now there is no detailed information on the food and feeding habit of fish stocked in this unique rice-fish system of Apatani Plateau located in the Indian Eastern Himalayan region of North East India.

With the above background information the present chapter tries to answer some question like:

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(i) What is the food preference of the stocked fish in the rice fish system?

(ii) What is the feeding behaviour of the stocked fish?

Results and discussion

After constant observation, *Cyprinus carpio* was found to consumed on plankton, periphyton, detritus, and some miscellaneous. The Phytoplankton/phyto-periphyton communities belong to classes Bacillariophyceae, Chlorophyceae, Cyanophyceae Euglenophyceae, Zygenemophyceae, Rhodophyceae, and zooplanktons belonging to groups Protozoa, Cladocera and Copepoda. Gut content analyses of the stocked fish comprised a total of 27 taxa belong to Bacillariophyceae,14 to Chlorophyceae, 5 to Cyanophyceae, 3 Euglenophyceae,1each to Zygenemophyceae, Rhodophyceae and Protozoa,7 Cladocera and 4 Copepoda .(Table6.1)

Niche breadth (Figure 6.1 A) was observed to be maximum during evening and morning hours of the day which reflected that the fish prefer to feed during these hours. Wider niche breadth reflects the fish to be an opportunistic feeder, while the narrow niche breadth reflects an increased specialization of the fish and this might be due to increased size and competitive ability of the species (Haroon & Pittman, 1998). When the niche breadth was considered month-wise, it was observed to be highest during May and lowest during the months June and July (Figure 6.1 B). The reason for highest niche breath during May might be due to maximum availability of food resource and also indicated good food preference and feeding activity by the young fish stocked in the rice-fish system, which feeds on the available food resource, which subsequently declines in the succeeding month. due to less availability of resource.

Ranking index of different food items is presented in Table 6.3. Amongst the phytoplankton/phyto-periphyton communities, Bacillariophyceae occupied the 1st rank followed by Chlorophyceae, Cyanophyceae, Rhodophyceae, Euglenophyceae, and

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Zygnemophyceae. Among zooplankton, Cladocera ranked 1st position followed by Copepoda and protozoa. Amongst the phytoplankton/phyto-periphyton class Bacillariophyceae, the preferred taxa found in the gut of the fish were *Melosira*>*Pinnularia*>*Navicula*>*Navicula placenta*>*Cymbella*. The preferred taxa for the class Chlorophyceae was *Docidium* >*Staurastrum*. The preferred food item of fish belonging to Cyanophyceae were *Phormidium*> *Anabaena*>*Nostoc* For the Class Rhodophyceae, the preferred food taxa of fish was *Batrachospermum*. For the class Euglenophyceae was *Euglena*>*Phacus*> *Trachelomonas* and the taxa preferred by the fish belonging to Zygnemophyceae was *Miscrasterias*. Amongst the zooplankton group, the preferred taxa of fish belonging to Cladocera was *Bosmina*>*Alona*> *Macrothrix*> *Chydororus*. For Copepoda the preferred taxa was *Cyclops* > *Mesocyclops*>*Diaptomus*. The preferred food belonging to group Protozoa was *Centropyxis*. The species which were ranked first, indicating to be the most preferred item for the fish.

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Table 6.1. Gut content (Number of individuals per gut) of *Cyprinus carpio* stocked in different stations of the rice-fish system in Apatani Plateau

Phytoplankton and /or phyto-periphyton class/ Zooplankton group	Taxa	Station 1	Station 2	Station 3	Pooled mean
Phytoplankton					
Bacillariophyceae	*Achnanthes*	58±56 (0-112)	51±72 (0-133)	75±33 (50-112)	62±12 (51-75)
	Amphora	6.94±12.03 (0-21)	-	7±12 (0-21)	5±4 (0-7)
	Amphora ovalis	8±14 (0-25)	-	25±27.32 (0-54)	11±13 (0-25)
	Cyclotella	89±81 (21-179)	58±74 (0-142)	67±47 (13-100)	71±16 (58-89)
	Cymbella	54±44 (25-104)	104±38 (63-138)	78±39 (46-121)	79±25 (54-104)
	Diatoma	8±140 (0-25)	4±7 (0-13)	13±22 (0-38)	8±4 (4-13)
	Diatoma vulgare	-	-	4±7 (0-13)	1±2 (0-4)
	Encyonema	47±41 (0-75)	18±4 (13-21)	7±12 (0-21)	24±21 (7-47)
	Eunotia	28±32 (0-66)	56±64 (0-125)	61±88 (0-163)	48±18 (28-61)
	Flagellaria	-	4±7 (0-13)	36±63 (0-108)	13±20 (0-36)
	Frustulia	13±13 (0-25)	8±7 (0-13)	4±7 (0-13)	8±4 (4-13)
	Gomphonema	8±7 (0-13)	8±14 (0-25)	13±22 (0-38)	10±2 (8-13)
	Melosira	499±152 (371-667)	106±119 (0-233)	976±411 (550-1371)	527±436 (106-976)
	Navicula	104±29 (88-138)	183±73 (129-267)	81±24 (54-100)	123±54 (81-183)
	Navicula placenta	86.±63 (25-150)	110±73 (54-192)	169±69 (104-242)	122±43 (86-169)
	Navicula rhyncocephala	49±43 (0-83)	4±7 (0-13)	-	18±27 (0-49)
	Nitzschia	-	13±13 (0-25)	8±7.22 (0-13)	7±6 (0-13)
	Pinnularia	208±99 (104-300)	825±207 (625-1037)	883±1118 (225-2175)	639±374 (208-883)
	Pinnularia major	-	-	4.17±7.22 (0-13)	1±2 (0-4)
	Rophalodia gibba	4±7 (0-13)	-	29±40 (0-75)	11±16 (0-29)
	Stauroneis	26±27 (0-54)	-	57±31 (25-87)	28±29 (0-57)
	Surirella	63±58 (21-129)	67±116 (0-200)	13±13 (0-25)	47±30 (13-67)
	Synedra	25±13 (13-38)	4±7 (0-13)	13±13 (0-25)	14±11 (4-25)
	Synedra ulna	8±14 (0-25)	4±7 (0-13)	31±43 (0-79)	14±14 (4-31)

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	Synedra fumosa	14±12 (0-21)	38±33 (13-75)	36±21 (13-50)	29±13 (14-38)
	Tabellaria	38±22 (13-50)	105±84 (13-175)	33±38 (0-75)	59±40 (33-105)
	Striatella	-	-	21±36 (0-63)	7±12 (0-21)
Chlorophyceae	*Ankistrodesmus*	4±7 (0-13)	4±7 (0-13)	-	3±2 (0-4)
	Aphanizomenon	21±36 (1-50)	-	-	7±12 (0-21)
	Closterium	21±19 (0-38)	4±7 (0-13)	25±25 (0-50)	17±11 (4-25)
	Cosmarium	33±30 (0-58)	42±42 (0-83)	22±28 (0-54)	32±10 (22-42)
	Desmidium	7±12 (0-21)	-	-	2±4 (0-7)
	Docidium	58±80 (0-150)	4.±7 (0-13)	17±19 (0-38)	26±28 (4-58)
	Gonatozygon	-	-	4.17±7.22 (0-13)	1±2 (0-4)
	Hydrodictyon	-	13±13 (0-25)	-	4±7 (0-13)
	Oocystis	4±7 (0-13)	4 ±7 (0-13)	-	3±2 (0-4)
	Scenedesmus	19±19 (0-38)	-	12.50±0 (13-13)	11±10 (0-19)
	Spirogyra	25±18 (13-38)	7±12 (0-21)	46±14 (38-63)	26±19 (7-46)
	Staurastrum	96±35 (71-121)	64±29 (33-92)	17±29 (0-50)	59±40 (17-96)
	Staurastrum bengalense	-	-	7±12 (0-21)	2±4 (0-7)
	Ulothrix	-	-	8±14 (0-25)	3±5 (0-8)
Cyanophyceae	*Anabaena*	21±7 (13-25)	25±25 0	42±38 (0-75)	29±11 (21-42)
	Microcystis	-	-	4±7 (0-13)	1±2 (0-4)
	Nostoc	21±0 (21-21)	26±24 (13-54)	4±7 (0-13)	17±12 (4-26)
	Oscilatoria	-	-	17±19 (0-38)	6±10 (0-17)
	Phormidium	79±56 (25-138)	29±19 (13-50)	96±81 (13-175)	68±35 (29-96)
Euglenophyceae	*Euglena*	-	4±7 (0-13)	13±13 (0-25)	6±6 (0-13)
	Phacus	-	-	8±14 (0-25)	3±5 (0-8)
	Trachelomonas	-	-	21±7 (13-25)	7±12 (0-21)
Zygnemophyceae	*Miscrasterias*	4±7 0	-	-	1±3 (0-4)
Rhodophyceae	*Batrachospermum*	26±15 (13-42)	24±23 (0-46)	100±109 (25-225)	50±43 (24-100)
Zooplankton					
Protozoa	*Centropyxis*	-	-	4±7 (0-13)	1±2 (0-4)
Cladocera	*Alona*	83. ±113	-	-	28±48

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					(0-83)
		0			1±2
	Biapertura affinis (Leydig)	4±7 0	-	-	(0-4)
	Bosmina	144±94 (71-250)	56±19 (38-75)	19±17 (0-33)	73±64 (19-144)
	Chydororus	17±19 (0-38)	13±13 (0-25)	-	10±9 (0-17)
	Daphnia	8±14 (0-25)	-	-	3±5 (0-8)
	Macrothrix	21±19 (0-38)	-	22±19 (0-33)	14±12 (0-22)
	Pleuroxus	28±24 (0-46)	-	-	9±16 (0-28)
Copepoda	*Cyclops*	21±7 (13-25)	4±7 (0-13)	9±16 (0-28)	11±9 (4-21)
	Diaptomus	-	-	8±14 (0-25)	3±5 (0-8)
	Leptodiaptomus	8±7 (0-13)	-	-	3±5 (0-8)
	Mesocyclops	7±12 (0-21)	-	13±13 (0-25)	7±6 (0-13)
Miscellaneous					
		4±7 (0-13)	-	-	1±2 (0-4)
		4±7 (0-13)	-	-	1±2 (0-4)

'-' indicates absence of the taxa concerned; mean±SD; n=36

Table 6.2. Diurnal and monthly variations in niche breadth of *Cyprinus carpio* stocked in different stations of the rice-fish system in Apatani Plateau

Niche breadth					Pooled mean
	Months	**Hours of day**			
		Morning	**Afternoon**	**Evening**	
Station 1	May	5.35	6.21	9.19	6.92±2.01
	June	11	5.56	9.15	8.57±2.76
	July	8.66	4.25	6.50	6.47±2.21
	August	9.82	2.88	10.71	7.80±4.29
Station 2	May	10.29	3.28	6.70	6.75±3.50
	June	2.78	1.36	2.27	2.14±0.72
	July	1.84	7.54	9.91	6.43±4.15
	August	2.92	6.76	6.25	5.31±2.08
Station 3	May	2.65	6.40	6.57	5.21±2.22
	June	3.44	4.78	7.35	5.19±1.99
	July	2.61	1.54	4.38	2.84±1.43
	August	5.68	1.86	3.84	3.79±1.91
Mean±SD and range		5.59±3.44 (1.84-11)	4.37±2.17 (1.36-7.54)	6.90±2.56 (2.27-10.71)	

mean±SD; n=36; Number within parenthesis represent range of the respective mean value

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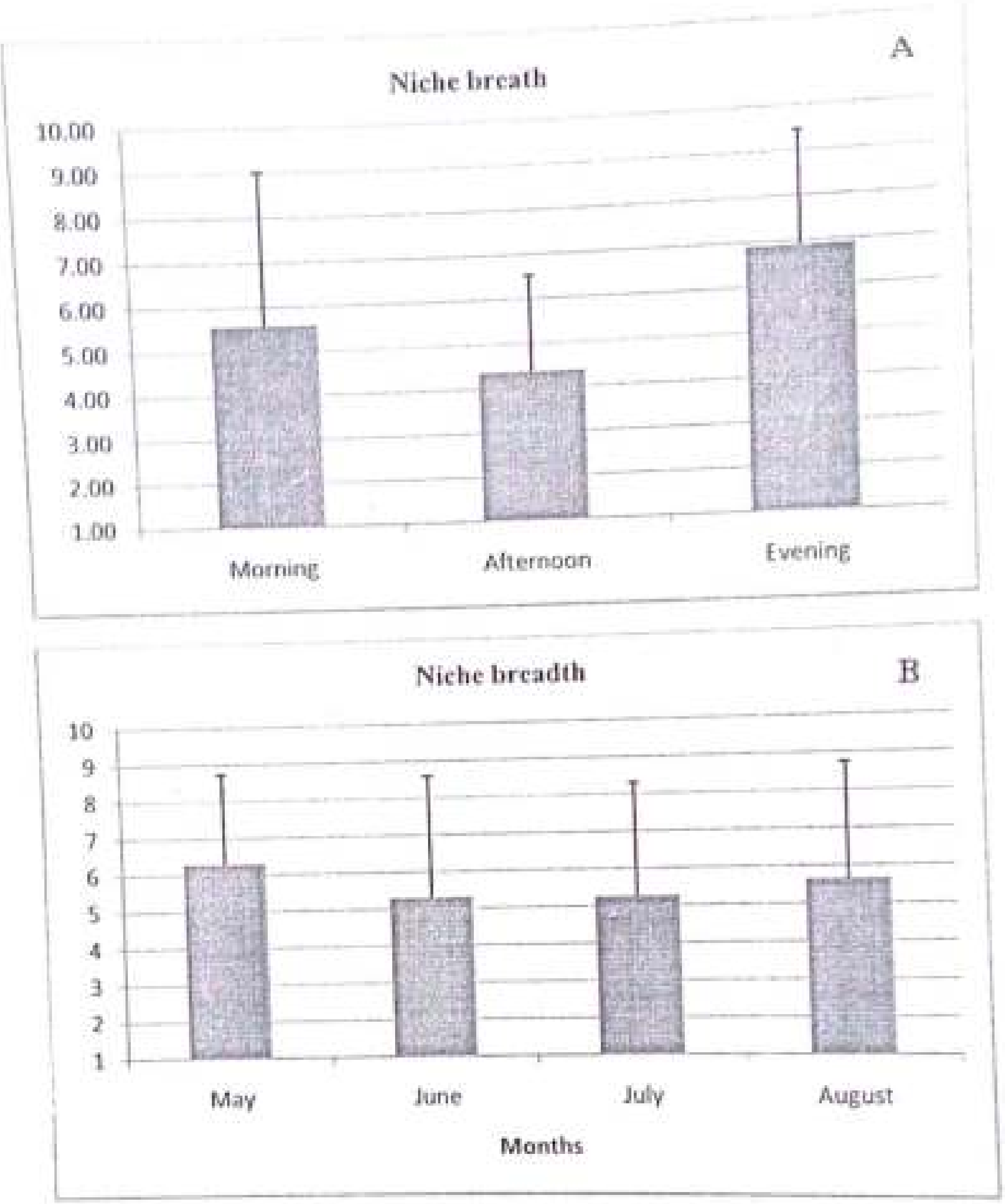

Figure 6.1. Diurnal (A) and monthly (B) variations in niche breadth of the stocked fish in the rice-fish system of Apatani Plateau

Table 6. 3. Variations in ranking index of food items of *Cyprinus carpio* stocked in different stations of the rice-fish system in Apatani Plateau

Phytoplankton/ Phyto-periphyton class And zooplankton groups	**Taxa**	**Station 1**	**Station 2**	**Station 3**	**Pooled mean**
Bacillariophyceae	*Achnanthes*	4±9 (0-33)	2±4 (0-9)	-	2±2 (0-4)
	Amphora	1±3 (0-11)	-	0.18±0.61 (0-2)	0.4±1 (0-1)
	Amphora ovalis	0.15±1 (0-2)	-	1±2 (0-6)	0.31±0.42 (0-1)
	Cyclotella	6±10 (0-30)	6±15 (0-53)	3±4 (0-11)	5±2 (3-6)
	Cymbella	3±5 (0-11)	6±6 (0-15)	2±2 (0-6)	4±2 (2-6)
	Diatoma	0.31±1.07 (0-4)	0.38±1 (0-5)	0.27±1 (0-3)	0.32±0.06 (0.3-0.4)
	Diatoma vulgare	-	-	0.09±0.31 (0-1)	0.03±0.05 (0-0.1)
	Encyonema	4±7 (0-22)	1±2 (0-4)	0.35±1 (0-4)	2±2 (0.4-4)
	Eunotia	3±9 (0-33)	2±7 (0-23)	2±4 (0-13)	2±1 (2-3)
	Flagellaria	-	0.42±1 (0-5)	1±2 (0-8)	0.41±0.40 (0-1)
	Frustulia	1±2.75 (0-8)	1±3 (0-8)	0.13±0.44 (0-2)	1±1 (0.13-1)
	Gomphonema	1±2 (0-6)	1±2 (0-5)	0.16±1 (0-2)	1±0.34 (0.16-0.8)
	Melosira	21±13 (6-46)	11±17 (0-57)	35±22 (3-66)	23±12 (11-35.)
	Navicula	7±10 (0-33)	11±9 (0-27)	2±3 (0-8)	7±4 (2-11)
	Navicula placenta	7±13 (0-44)	4±7 (0-23)	4±5 (0-17)	5±2 (4-7)
	Navicula rhyncocephala	4±13 (0-44)	-	-	1±2 (0-4)
	Nitzschia	-	1±2 (0-6)	0.14±0.4 (0-1)	0.3±0.4 (0-1)
	Pinnularia	15±16 (0-56)	23±33 (0-87)	15±25 (0-80)	18±5 (15-23)
	Pinnularia major	-	-	0.1±0.3 (0-1)	0.03±0.1 (0-0.1)
	Rophalodia gibba	0.11±0.4 (0-1)	-	0.40±1 (0-4)	0.17±0.21 (0-0.4)
	Stauroneis	3±6 (0-22)	-	2±3 (0-9)	1±1 (0-2)
	Striatella	-	-	1±3 (0-9)	0.3±0.4 (0-1)
	Surirella	4±6 (0-18)	2±6 (0-21)	1±1 (0-4)	2±2 (1-4)
	Sydera	1±2 (0-6)	1±2 (0-7)	0.33±1 (0-3)	1±1 (0.33-1)
	Sydera ulna	0.4±1 (0-3)	1±2 (0-7)	1±2 (0-4)	1±0.20 (0.4-1)
	Synedra fumosa	1±3.15	4±7	1±1	2±2

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		(0-11)	(0-21)	(0-7)	(1-4)
	Tabellaria	3±5 (0-17)	2±5 (0-18)	1±2 (0-6)	2±1 (1-3)
Chlorophyceae	*Akistodesmus*	1±2 (0-6)	0.42±1 (0-5)	-	0.30±0.3 (0-1)
	Aphanizomenon	1±3 (0-11)	-	-	0.30±1 (0-1)
	Closterium	1±2 (0-6)	0.29±1 (0-4)	0.10±0.36 (0-1)	1±1 (0.1-1)
	Cosmarium	3±6 (0-22)	1±3 (0-9)	0.28±1 (0-2)	1±1 (0.3-3)
	Desmidium	1±3 (0-11)	-	-	0.30±1 (0-1)
	Docidium	5±8 (0-25)	0.29±1 (0-4)	3±6 (0-14)	3±2 (0.3-5)
	Gonatozygon	-	-	0.1±0.31 (0-1)	0.03±0.05 (0-0.1)
	Hydrodictyon	-	1±3 (0-8)	-	0.42±1 (0-1)
	Microcystis	-	-	0.13±0.44 (0-2)	0.04±0.08 (0-0.13)
	Oocystis	0.25±1 (0-3)	0.1±0.30 (0-1)	-	0.11±0.13 (0-0.25)
	Scenedesmus	1±1 (0-4)	-	0.4±1 (0-3)	0.33±0.31 (0-1)
	Spirogyra	1±4 (0-12)	0.23±1 (0-3)	1±1.94 (0-5)	1±1 (0.23-1)
	Staurastrum	5±7 (0-18)	4±4 (0-15)	1±2 (0-5)	3±2 (1-5)
	Staurastrum bengalense	-	-	0.18±1 (0-2)	0.06±0.10 (0-0.18)
Cyanophyceae	*Anabaena*	2.43±4.15	2.56±7.14	0.95±1.71	1.98±0.89 (0.95-2.56)
	Nostoc	1.10±3.15	2.31±3.49	0.05±0.18	1.15±1.13 (0.05-2.31)
	Oscilatoria	-	-	0.57±1.13	0.19±0.33 (0-0.57)
	Phormidium	5±5 (0-13)	1±3 (0-9)	3±5 (0-18)	3±2.04 (1-5)
Zygnemophyceae	*Miscrasterias*	1±1 (0-6)	-	-	0.17±0.30 (0-0.52)
Rhodophyceae	*Batrachospermum*	2±3 (0-8)	1±2 (0-7)	5±8 (0-23)	3±2 (1-5)
Euglenophyceae	*Euglena*	-	0.1±0.30 (0-1)	0.4±1 (0-3)	0.16±0.20 (0-0.4)
	Phacus	-	-	0.10±0.36 (0-1)	0.03±0.1 (0-0.1)
	Trachelomonas	-	-	1±1 (0-3)	0.21±0.4 (0-1)
Protozoa	*Centropyxis*	-	-	0.1±0.31 (0-1.08)	0.03±0.1 (0-0.1)
Cladocera	*Alona*	10±12 (0-31)	-	-	3.35±6 (0-10)
	Biapertura affinis	1±3 (0-10)	-	-	0.28±1 (0-1)
	Bosmina	41±58	49±55	13±31	34±19

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		(0-200)	(0-150)	(0-100)	(13-49)
	Chydorus	3±5 (0-11)	4±14 (0-59)	-	2.33±7.15 (0-4)
	Daphnia	2±5 (0-17)	-	-	1±1 (0-2)
	Macrothrix	3±7 (0-29)	-	7±15 (0-59)	3±3 (0-7)
	Pleuroxus	6±13 (0-33)	-	-	2±4 (0-6)
Copepoda	*Cyclops*	7±19 (0-67)	8±29 (0-100)	0.03±0.10 (0-0.33)	5±4 (0.05-8)
	Diaptomus	1	1	8±29 (0-100)	3±5 (0-8)
	Leptodiaptomus	2.78±9.62	-	-	0.93±1.63 (0-2.78)
	Mesocyclops	-	-	21±49 (0-100)	7±17 (0-23)
Miscellaneous		2±5 (0-17)	-	-	1±1 (0-2)

mean±SD; n=36; Number within parenthesis represent range of the respective mean value

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Chapter 7

GROWTH OF THE STOCKED FISH AND ITS NUTRIENT CONTENTS

Introduction

Knowledge of nutrient composition of any food item is an important aspect in understanding the links between food production, access and nutrient intake and in devising policies and programmes such as development of improved production technologies (Thilsted and Wahab, 2014a) to ensure that the food production fulfils the nutrient requirement of the population and to enhance their health and socio-economic condition. Fish has an important role in food security and poverty alleviation in both rural and urban areas. Analyses of proximate composition of a fish species helps to assess its nutritional and edible value (Prapasri, 1999; Hei and Sarojnalini, 2012). The nutrient analysis of reared fish can give an assessment of its food composition, its physiological condition and can serve as guide for any future feed formulations for fish in captivity (Dempson *et al.*, 2004).

In the present study attempt has been made to determine the month-wise variations in the growth of *C. carpio* stocked in the rice-fish system. Attempt has also been made to determine the month-wise variations in body nutrient contents of *C. carpio* stocked in the rice-fish system of Apatani Plateau.

Results and discussion

Growth parameters of *Cyprinus carpio* stocked in the rice-fish system

Monthly variations in body length and body weight of *Cyprinus carpio* stocked in the rice-fish system of Apatani Plateau are shown in Figure 7.1. The figure showed that both the body length (Figure 7.1.A) and body weight (Figure 7.1.B) of the stocked fish increased consistently from May to August. Highest values for body length and body weight of the stocked fish in the rice-fish system during August indicates the stocked fish attained maximum maturity during August.

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Nutrient contents of *Cyprinus carpio* stocked in the rice-fish system

Month-wise variations in body nutrient contents (%) of *Cyprinus carpio* stocked in the rice-fish system of the study area during the study period are shown in the Figure 7.2.

Carbohydrate content in the body of the stocked fish was highest in the month of May and dropped down in June and again increased in July which again dropped during August (Figure 7.2.A). This is due to the fact that due to sufficient food material in the rice field during May the stocked fish did not have to invest much energy for feeding which lead to greater reserves of energy in the form of carbohydrate in their body in the month of May. However during June and August the carbohydrate content dropped down which indicates investment of more energy for survival and gathering food from the rice field during those months.

Protein content in the body of the stocked *Cyprinus carpio* was lowest in May and highest in August (Figure 7.2.B). This implies that there was scarcity of protein-rich food items in the rice field during May. However during August there was an increase in protein-rich food item in the rice field may be in the form of detrital matters which deposited in greater amount in the rice field during August.

Fat content in the body of the stocked fish in the rice field was lowest in May and highest in July (Figure 7.2.C). This is due to the fact that with maturity of the stocked fish there is greater deposition of fat in its body.

Month-wise variations in sodium content of the stocked fish in the rice fish system showed the lowest value in May and the highest value in July and August (Figure 7.2.D). This indicates greater concentration of Na in the rice field water in the successive months of fish stocking from which the stocked fish assimilate this mineral nutrient

Month-wise variations in potassium content of the stocked fish in the rice fish system showed its lowest value in May and the highest value in June (Figure 7.2.E). This indicates

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lower concentration of K in the rice field water during May and its greater value in June, July and August which entered in the rice field with the runoff water.

Month-wise variations in calcium content of the stocked fish in the rice-fish system showed that the value was same all throughout the months (Figure 7.2.F).

Month-wise variations in phosphorous content of the stocked fish in the rice fish system showed the highest value in August and the lowest value in July (Figure 7.2.G). This indicates greater concentration of P in the rice field water in June due to the effect of entry of silt-rich runoff water because of intense rainfall during June.

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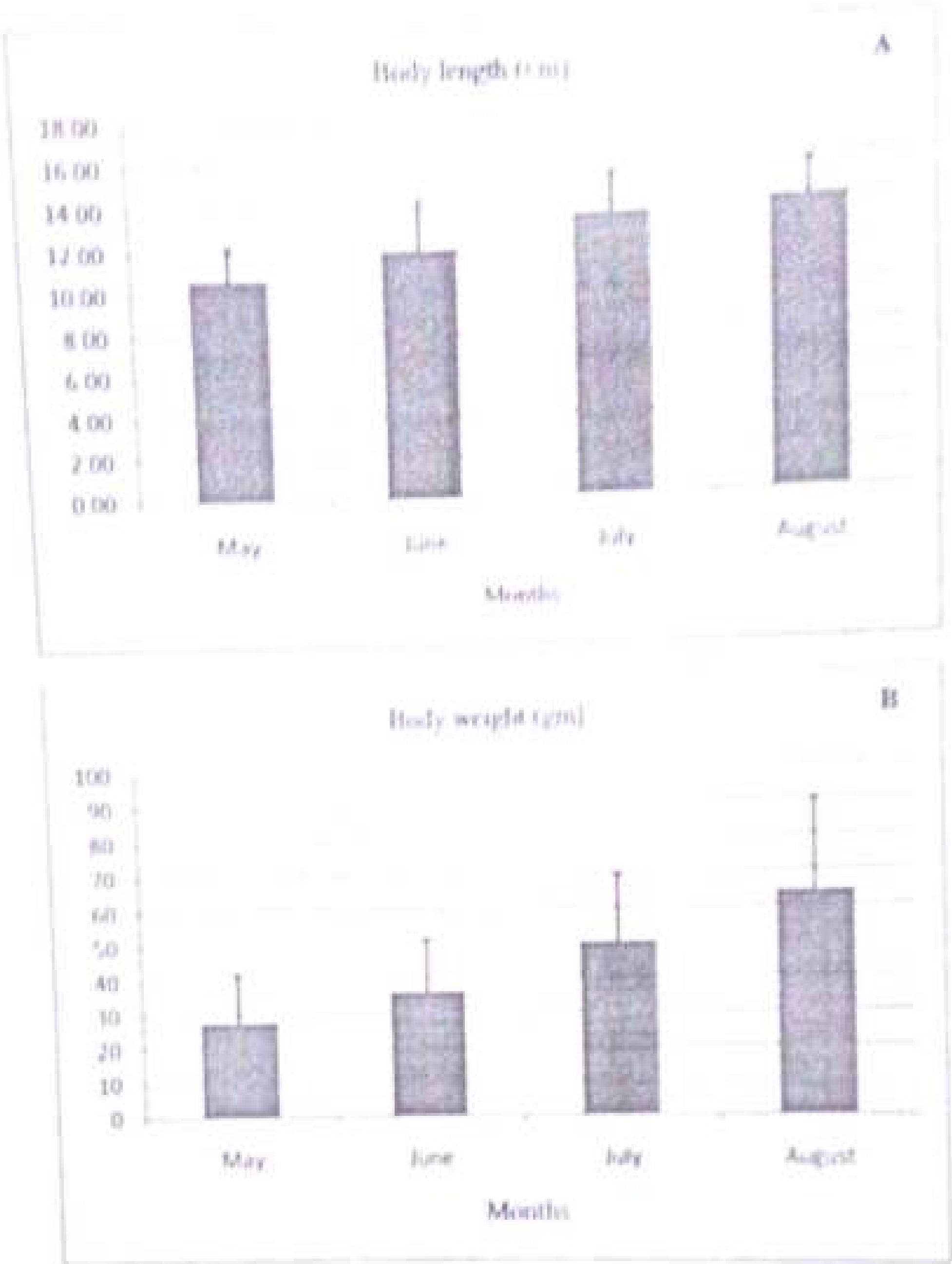

Figure 7.1. Monthly variations in body length and body weight of *Cyprinus carpio* stocked in the rice-fish system of Apatani Plateau.

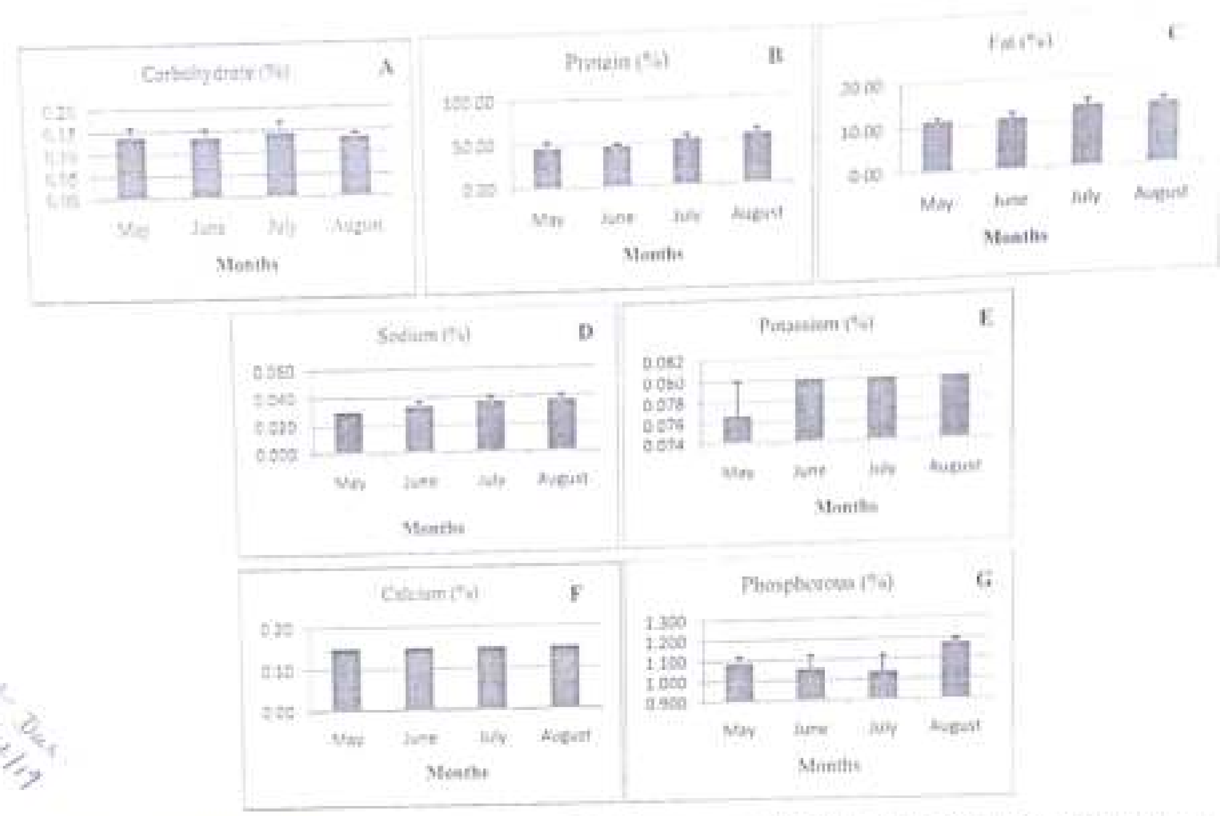

Figure 7.2. Month-wise variations in body nutrient contents (%) of *Cyprinus carpio* stocked in the rice-fish system of the study area during the study period

Chapter 8

FORMULATION OF LOW-COST FISH FEED USING LOCAL INGREDIENTS AND ITS EFFICACY TEST ON GROWTH PERFORMANCE OF *Cyprinus carpio*

Introduction

Fish is an important source of food and income in the developing countries. Fish requires high quality nutritionally balanced diet for growth and attainment of market size within the shortest possible time. Therefore, local production of fish-feed is very crucial to the development and sustainability of aquaculture. Paddy-cum-fish culture is practiced in many parts of the world e.g. China, Egypt, India, Indonesia, Thailand, Vietnam, Philippines, Bangladesh, Malaysia etc (Fernando, 1993; Halwart and Gupta, 2004). In India, the agrarian *Apatani* hill tribe in the lower Subansiri district of Arunachal Pradesh also traditionally practice integrated agriculture aquaculture in the wet rice fields, which is the only prevalent system amongst the Indian tribal farmers. Energy subsidies in the form of agro-chemicals or feed are not administered in the agro-ecosystem during the culture period, which makes it very unique in the context of production. The fishes are cultured along with the rice plant in the paddy fields. The fishes depend on the natural feed such as plankton, benthic algae, and other feeding materials available in the rice fields. However, limited availability of natural feed and short duration of the rearing period do not allow the fish to gain much biomass (Halwart and Gupta, 2004). As a result, only 150 to 250 kg ha^{-1} of fish (*Cyprinus carpio*) per season are harvested from the system (Saikia and Das, 2004), which is much lower comparing to similar systems in China (Zhang, 1995; Halwart, 1998).

Administering supplementary feeding material to the fish in the paddy fields may increase the secondary productivity (Halwart and Gupta, 2004). Locally available ingredients such as agro-based by-products and other organic wastes may be used as feed input in the system, which may be a promising solution from the perspective of the rural economy and sustainability.

In the present study, fish-feed formulation was done using locally available raw materials in the Apatani Plateau. This was followed by the analyses of the proximate composition of the fish-feed formulation and an aquaculture experiment to test the effectiveness of the prepared fish-feed on the overall growth and health performance of the stocked fish, *Cyprinus carpio*. Efficacy test was performed also to quantify the proportion of feed to be supplemented in the rice-fish system that would be appropriate for optimal growth without disrupting the natural ecological balance within the rice-fish system.

Results and discussion

The formulated feed contains higher dietary protein (22.92%) and less carbohydrate (2.39%) and lipids (3.35%) (Table 8.1). Higher dietary protein has often been associated with better growth rate in many fish species (Mohapatra and Patra, 2014). Although not essential, carbohydrates are included in aquaculture diets for their binding activity during feed manufacturing (Hassan, 2015). A recent trend in fish feeds is to use higher level of lipids/fats in the diet (Hassan, 2015). Vitamins are organic compounds which are not synthesized by fish, and must be supplied in the diet. Amongst all the vitamins, vitamin C is probably the most important, because it is a powerful antioxidant and helps in maintaining the immune system in fish (Hassan, 2015). In the prepared fish feed, vitamin C was also available in trace (0.04%). However, if we compare the proximate composition of the prepared fish-feed with the general fish-feed standard (as per Hassan, 2015), we can see that the quantity of lipid is relatively less, and that of phosphorous is more. So, care has to be taken regarding too much input of P into the culture system if the feed is supplemented in greater quantity.

Efficacy test revealed hundred percent survival of the fries in the different aquaria with various treatments (Table 8.2). Body weight, body length, standard length and body

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depth of the fries showed better performance in treatment 2 (i.e., when the fish were fed with the prepared feed @ 5% of their initial body weight) where the feed conversion ratio was lowest. Weight gain was highest in Treatment 3 (i.e., when the fish were fed with the prepared feed @ 7% of their initial body weight) where the feed conversion was highest. However, specific growth rate and condition factor showed significantly greater value in treatment 1 (i.e., when the fish were fed with the prepared feed @ 3% of their initial body weight) where the feed conversion ratio was slightly greater than the lowest value (in treatment 2).

Different feeding treatments in the experimental aquaria showed that body length and body depth increased with increase in the supplementary feed till treatment 2. However, further increase in the supplementary feed decreased both the body length and body depth (Figure 8.1.A and 8.1.B). SGR showed better performance when the feed supplementation was less (Figure 8.1.C). Condition factor slightly declined when the fish were not given any feed or when the feed supplementation was greater (Figure 8.1.D). All these therefore show that fish can grow in a better way when they are provided with optimum quantity of feed.

Therefore, considering all the parameters of growth, feeding and survival conditions, it may be concluded that the fries of *Cyprinus carpio* would grow in a better and healthier way if they are fed with the prepared feed @ 3% of initial their body weight while stocking in aquaculture system.

Water quality was monitored before and after supplementation of the prepared fish-feed for four weeks in the experimental aquaria, and it varied between different treatments (Table 8.3). However, when compared with the relevant standard required for fresh- and warm water fishery (Boyd, 1998 and Das *et al.*, 2013; Table 8.3), the water quality in all the aquaria were within the standards except the water temperature. This was due to the seasonal effect, as the experiment was conducted during the month of December, 2014.

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Table 8.1: Proximate composition (%) of raw materials used as fish-feed ingredients and the formulated fish-feed using these ingredients, and comparison of the proximate composition of the fish feed with standard fish-feed

Parameters	Raw materials		Fish –feed formulated using these raw materials	Proximate composition of standard fish-feed as per Hassan, 2015
	Leftover of processed and fermented rice after preparation of local rice beer, '*Apong*'	Algae which remained clumped in water of the rice-fish system of Apatani Plateau		
Carbohydrate	0.001	0.017	2.78	Not very essential but may contain 15-20%
Protein	30.3	3.25	22.92	18-50%
Fat	0.1	0.01	1.35	10-25%
Calcium	0.01	0.06	1.15	Trace amount
Phosphorus	3.9	1.40	7.96	~1.5%
Sodium	0.03	0.10	0.30	Trace amount
Potassium	0.3	0.63	1.27	Trace amount
Vitamin C	0.06	0.08	0.04	Trace amount

Table 8.2. Feeding response, growth response, nutrient utilization and survival parameters of *Cyprinus carpio* fry fed with varying quantities of the prepared fish-feed in experimental aquaria

Parameters		Control	Treatment1 (feeding @ 3% of the initial body weight of the stocked fish)	Treatment2 (feeding @ 5% of the initial body weight of the stocked fish)	Treatment3 (feeding @ 7% of the initial body weight of the stocked fish)	F-ratio
Feeding response		-	Excellent	Good	Good	-
Growth response	Body weight (gm)	4.96 ±0.25	5.68 ±0.08	5.78 ±0.07	5.16 ±0.33	2.13
	Body length (cm)	7.11 ±0.20	7.33 ±0.11	7.60 ±0.09	7.28 ±0.15	7.64**
	Standard length (cm)	5.83 ±0.10	6.01 ±0.03	6.33 ±0.06	5.74 ±0.13	1.06
	Body depth (cm)	2.06 ±0.05	2.08 ±0.03	2.14 ±0.05	2.07 ±0.03	6.74**
	Specific growth rate (% day^{-1})	2.07 ±0.77	5.18 ±1.34	1.54 ±0.37	4.11 ±0.84	3.619*
Nutrient utilization	Feed conversion ratio for 1 gm increase in body weight	-	0.26 ±0.02	0.19 ±0.05	0.69 ±0.25	3.39
	Feed conversion ratio for 1 kg increase in body weight	-	260.69 ±22.54	187.20 ±49.09	687.44 ±248.04	3.39
Survival parameters	Survival rate	100%	100%	100%	100%	-
	Condition factor	1.39 ±0.08	1.45 ±0.07	1.32 ±0.05	1.34 ±0.03	6.69**

Mean ±SE; n=16; **$p<0.01$; * $p<0.05$

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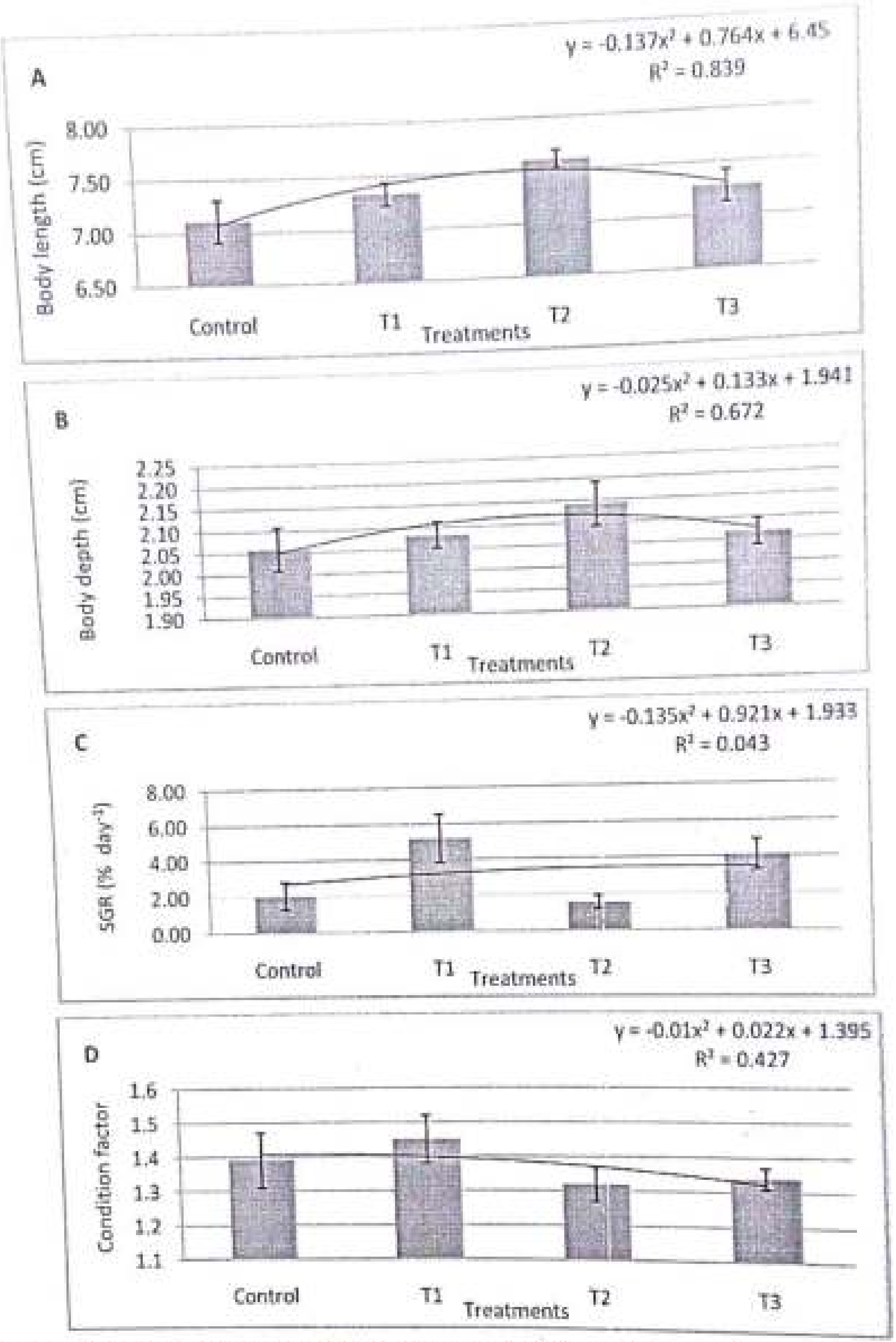

Figure 8.1. Changes in body length (A), body depth (B), specific growth rate (C) and condition factor (D) of *Cyprinus carpio* after four weeks of feeding with the prepared fish-feed under different feeding treatments in experimental aquaria

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Table 8.3. Water quality parameters before and after supplementing the prepared fish-feed for four weeks in the experimental aquaria and comparison with water standard for freshwater fisheries

Parameters	Quality of water which was used for the experiment before stocking the fish and giving different treatments	*Water quality in experimental aquaria after four weeks of supplementation of the prepared fish-feed				Standards of water properties for warm freshwater fisheries in pond as per	
		Control	Treatment 1	Treatment 2	Treatment 3	Boyd, 1998	Das *et al.*, 2013
Water temperature (°C)	20	17±1.0	19±1.0	18.5±0.5	15.50±0.5	-	25.0-32.0
pH	6.5	7.33±0.08	7.44±0.17	8.02±0.37	7.84±0.07	7.0-9.0	6.5-8.5
Dissolved oxygen ($mg\,l^{-1}$)	6.12	9.97±1.11	9.39±0.20	8.68±0.98	9.49±1.25	5.0-15.0	5.0-10.0
Biological oxygen demand ($mg\,l^{-1}$)	0.88	6.49±3.78	6.08±2.50	4.09±1.52	4.80±0.61	-	<10.0
Free carbon dioxide ($mg\,l^{-1}$)	10.09	9.99±1.35	7.99±1.33	8.65±1.33	8.99±0.33	1.0-10.0	<3.0
Nitrate-N ($mg\,l^{-1}$)	0.2	2.81±1.97	4.22±1.63	2.45±0.74	4.43±2.78	0.2-10.0	0.1-3.0
Phosphate-P ($mg\,l^{-1}$)	0.29	0.15±0	0.09±0.05	0.18±0.03	0.19±0.06	0.005-0.2	0.05 – 2.0

*Mean ±SE; n=2

Chapter 9

GENERAL DISCUSSION AND CONCLUSION

The present study was undertaken to formulate low-cost fish feed using locally available agro-based wastes. The study was done in context of increasing fish production through supplementation of low cost fish feed in the rice-fish system of Apatani landscape in Arunachal Pradesh, North-east India.

In the present study attempt was made to know the habitat condition, food availability, feeding, and growth and nutrient assimilation of the stocked fish in the rice-fish system of Apatani Plateau. Fish feed formulation was prepared using locally available agro-based raw materials in different proportions. This was followed by nutrient analyses of the feed formulation and an efficacy test of the formulated feed on growth performance of the stocked fish under laboratory condition.

In order to know the habitat condition and food availability of the stocked fish, a total of five stations (villages) were selected. For gut content analysis and analyses of different feeding activities of the stocked fish besides analysis of its growth performances and nutrient assimilation from its habitat, a total of 3 stations (villages) were selected. In the entire field study sampling was done at monthly interval during the fish stocking stage. For detailed analysis of the feeding activities of the stocked fish sampling was done 3 times a day covering morning, noon and evening hours.

The physico-chemical properties of water of rice fish systems (Tables 4.1 and 4.2) showed significant variations with respect to stations, months and stations x months. These significant variations indicate the system to be highly dynamic in nature both, spatially and temporally. Physico-chemical properties showed that the pH of rice field water in the rice-fish system of Apatani Plateau slightly fluctuated from slightly acidic to slightly alkaline range (4-7.7). Besides, it may be mentioned here that the value of water depth in the rice-fish

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system ranged from (2 to 21.7 cm) indicating it to be a shallow system. When the physico-chemical properties of rice field water in the rice-fish system was compared with the standard water properties for fresh water fishery (Table 4.3), it was observed that the value for CO_2 was high during some months of fish stocking period which reveals that the stocked fish can survive under the unfavourable condition which might be partially due to the hardy nature of *Cyprinus carpio* (Singh *et al.*, 2015) and/or partially due to presence of refuge trenches in the rice-fields that facilitate the movement of the stocked fish from adverse circumstance in the rice field.

Investigation of planktonic (Tables 5.1 to 5.2) and rice stem periphytic communities (Table 5.3) present in the rice-fish system of the Apatani Plateau revealed that the phytoplankton and phyto-periphytic algae were more diverse communities than the zooplankton communities. Bacillariophyceae was the most dominant phytoplankton and rice-stem phyto-periphyton class in the rice-fish system (Figures 5.1 and 5.3). Cladocera was the most dominant zooplankton group in the rice-fish system (Figure 5.2).

Gut content analyses (Table 6.1) revealed that the stocked fish in the rice-fish system consumed plankton, periphyton, and some miscellaneous items including detritus. The phytoplankton/periphyton communities present in the gut belonged to classes Bacillariophyceae, Chlorophyceae, Cyanophyceae, Euglenophyceae, Zygnemophyceae, and Rhodophyceae. The zooplankton communities present in the gut belonged to the groups Protozoa, Cladocera, and Copepoda. Gut content analyses of the stocked fish comprised a total of 27 taxa belonging to Bacillariophyceae, 14 to Chlorophyceae, 5 to Cyanophyceae, 3 to Euglenophyceae, 1 each to Zygnemophyceae, Rhodophyceae and Protozoa, 7 to Cladocera and 4 to Copepoda. The gut content study revealed a close relationship of food intake/preference with the available food items in the rice-fish system. The gut content analysis of the stocked fish revealed it to be omnivorous in nature.

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The niche breadth of the stocked fish was maximum during evening and morning hours of the day (Figure 6.1.A) which reflected that the fish prefer to feed on different items during morning and evening hours of the day. While during afternoon the decrease in niche breadth is perhaps due to extreme environmental condition due to intense sunlight and increased water temperature which inhibit the stocked fish for free movement in the rice field and most of them take refuge in the refuge trenches of the rice field. When the niche breadth was considered month-wise, it was observed to be highest during May and lowest during the months June and July (Figure 6.1.B). The reason for highest niche breath during May might be due to maximum availability of food resource with the onset of fingerling stocking. This indicates greater food preference and feeding activity by the young fish stocked in the rice-fish system, which feeds on the available food resource, which subsequently declines in the succeeding month due to less availability of the food resource. The wider niche breadth during May also reflects the stocked fish to be opportunistic feeder.

The ranking index of the food items of the stocked fish (Table 6.3) showed that amongst phytoplankton/phyto-periphyton classes available in the rice field, the fish fed more on Bacillariophyceae followed by Chlorophyceae, Cyanophyceae, Rhodophyceae, Euglenophyceae and Zygnemophyceae. Amongst the phytoplankton/phyto-periphyton belonging to class Bacillariophyceae, the preferred taxa found in the gut of the fish were *Melosira* > *Pinnularia* > *Navicula* > *Navicula placenta* > *Cymbella*. The preferred food item of fish belonging to Chlorophyceae were *Docidium* > *Staurastrum* > *Spirogyra*. The preferred food item of fish belonging to Cyanophyceae were *Phormidium*> *Anabaena* >*Nostoc*. For the Class Rhodophyceae, the preferred food taxon of fish was *Batrachospermum*. For the class Euglenophyceae the preferred food item was *Euglena* > *Phacus* > *Trachelomonas* and the taxa preferred by the fish belonging to Zygnemophyceae was *Miscrasterias*. Amongst zooplankton/zoo-periphyton groups available in the rice field the fish fed more on Cladocera

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followed by Copepoda. The preferred taxa of fish belonging to Cladocera was *Bosmina* > *Alona* > *Macrothrix* > *Chydororus*. Under the group, Copepoda the preferred taxa was *Cyclops* > *Mesocyclops* > *Diaptomus*. The preferred food belonging to group Protozoa was *Centropyxis*. The preferred food items of the stocked *C. carpio* was more for phytoplankton/phyto-periphyton communities belonging to class Bacillariophyceae and zooplankton communities belonging to group Cladocera.

When the growth parameters of the fish were observed, it was found that both the body weight and body length of the stocked fish increased consistently from May to August (Figure 7.1). Highest values for body weight and total length of the stocked fish in the rice-fish system during August indicate the stocked fish attained maximum maturity during August.

Body nutrient content of the stocked fish revealed variations in the proximate and mineral nutrient compositions in the body of the stocked fish with respect to months (Figure 7.2). This indicates variations in the availability and type of food across different months leading to monthly variations in the body nutrient content of the stocked fish.

Earlier study by Saikia and Das (2004) revealed that the production rate of *C. carpio* in the rice-fish system of Apatani Plateau is far below the carrying capacity of the field in comparison to similar systems elsewhere. This therefore, indicated the necessity of supplementary feed for the stocked fish to increase their production within a short period of time. In this regard, the fish feed formulation was performed using locally available resources in order to reduce the cost of feed production on one hand and to increase the fish production within limited time on the other.

Nutrient content analyses of the formulated fish feed showed it to be comparable with the standard fish feed material (Table 8.1). Efficacy test was performed with formulated feed under laboratory condition (Table 8.2 and Figure 8.1). The study suggests that, the stocked

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fish would grow much faster if the prepared fish-feed is supplemented into the rice-fish system of Apatani Plateau @ 3% of their initial body weight while stocking in the rice field. However, further studies following on-farm feeding trials would enhance our understanding on the growth behaviour of the fishes in this system.

Overall, the study highlights the possibility of increasing the production of fish in the rice-fish system of Apatani Plateau by exploiting the existing agro-based wastes which would definitely result in more per capita fish-protein consumption and better economic returns to the local people of the Apatani landscape in sustainable and eco-friendly ways.

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Photographs

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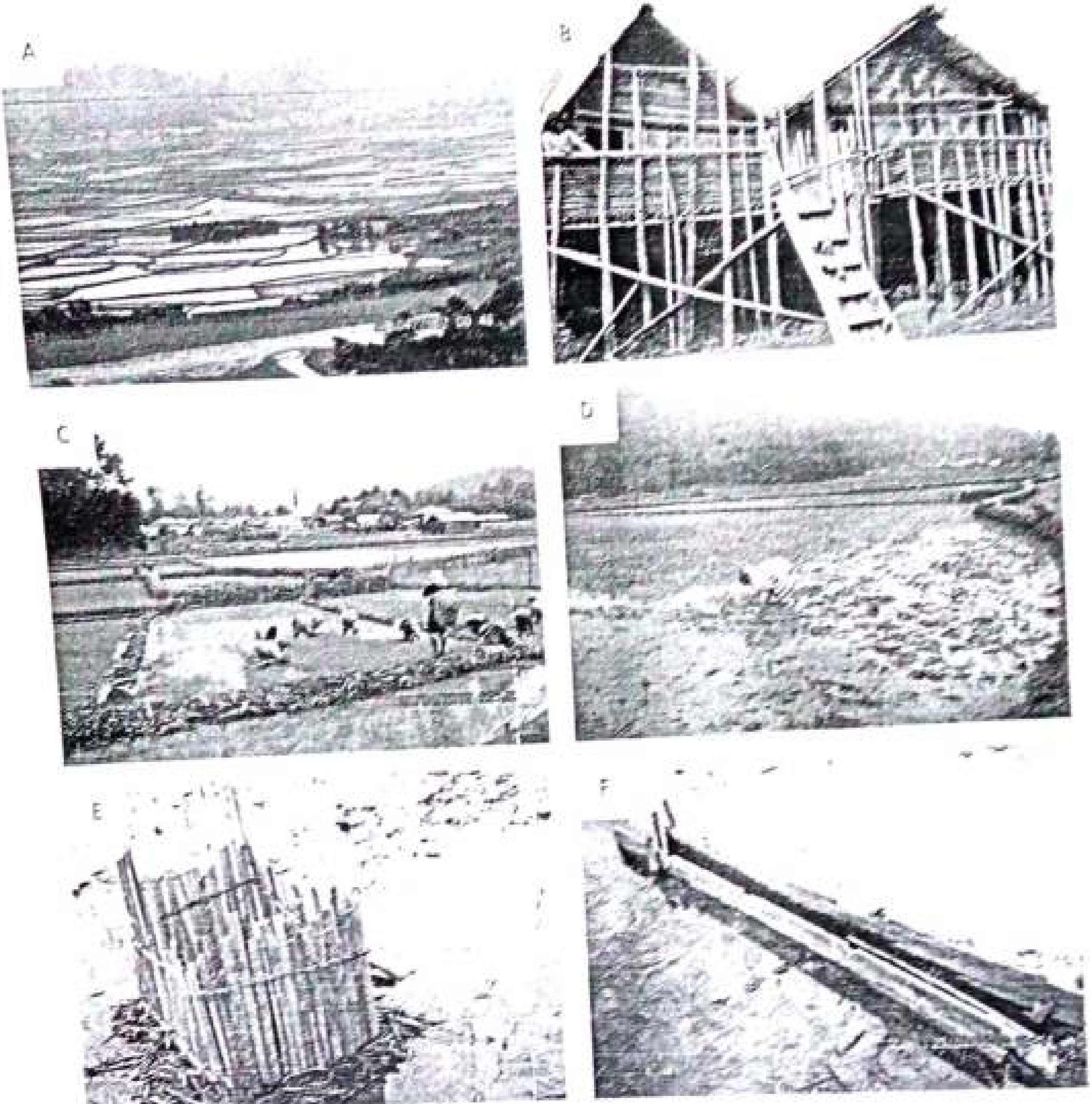

Plate 1. (A) Apatani agricultural fields with human settlements in the background, (B) A typical Apatani house in Ziro, (C) Collecting paddy plants from the nursery for transplantation, (D) Planting paddy plants in the prepared plot, (E) Agricultural plots marked after transplantation and introduction of fingerling of common carp, (F) Wooden channels made to maintain flow of water and for fish movement between different plots.

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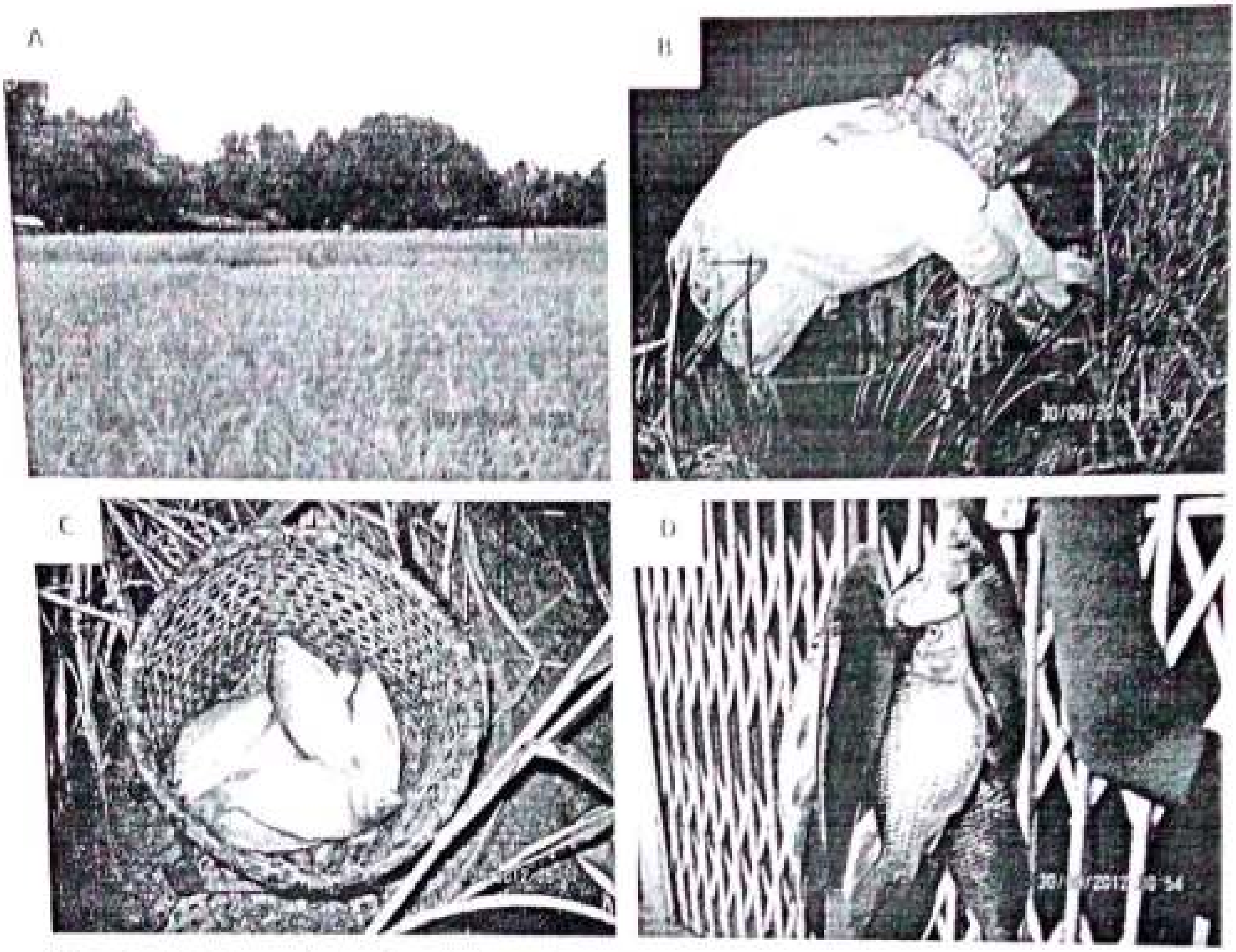

Plate 2. (A) Matured rice plant during the month of September, (B) Harvesting of fish being done before paddy harvest, (C) Harvested fishes in traditional basket, (D) Harvested fish brought to the market for sale.

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Raw materials locally available in the *Apatani* Plateau for preparation of low-cost fish-feed

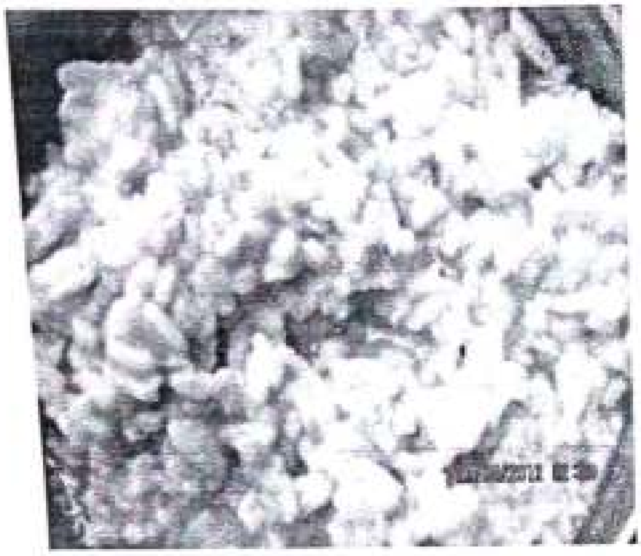

Plate 3. Leftover of processed and fermented rice after preparation of the traditional rice beer, '*Apong*'

Plate 4. Filamentous algae clumped near the rhizosphere of the rice plant in the rice-fish system

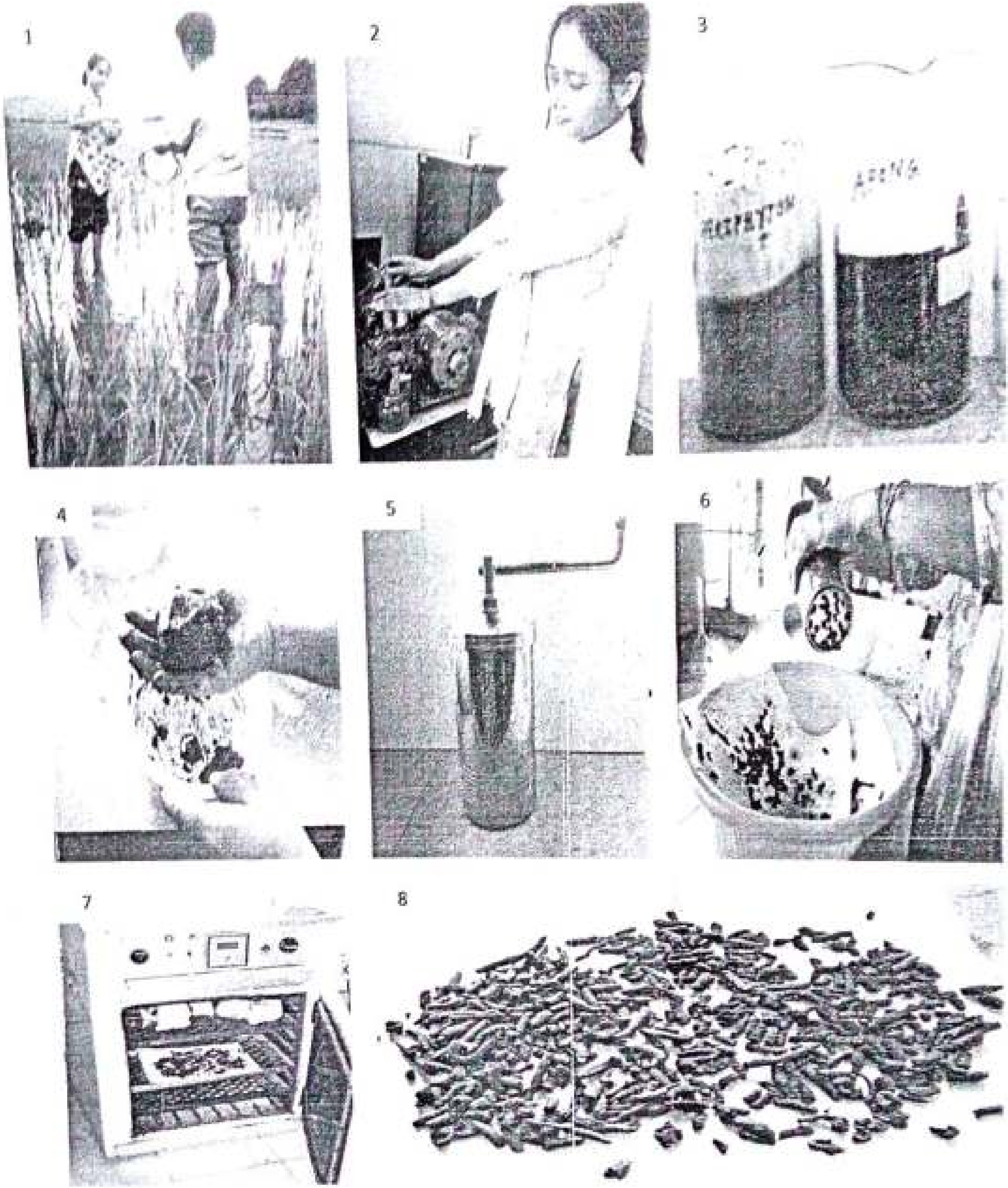

Plate 5. Steps involved in formulation of fish feed. (1) Collection of periphyton, (2) Grinding of raw materials, (3) Raw materials in powdered form, (4) Doughing the raw materials, (5) Put the dough in a palletizer, (6) Fish-feed pelleting, (7) Oven drying of the fish-feed, (8) Fish-feed ready to be supplemented in the rice-fish system

Plate 6. Conducting meeting and discussion with the villagers related to fish feed formulation and its application in the rice-fish system

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Extension bulletin

PROCESSING AND FORMULATION OF ECONOMICAL FISH-FEED FOR SUPPLEMENTATION IN RICE-FISH SYSTEM OF APATANI PLATEAU

CONTENTS	PAGE NUMBER

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INTRODUCTION

Growing fish in water bodies is an important source of protein food as well as a well-known means of family income in the developing countries. The activity termed simply as 'fish culture' always requires high quality nutritionally balanced fish diet for attaining a good growth of cultured fishes within a short duration. Localized production of fish-feed is therefore very important for the development and sustainability of such aquaculture.

In this context, mention may be made of an agrarian hill tribe known as Apatani in lower Subansiri district of Arunachal Pradesh, North East India. The Apatanis are habituated in integrated agriculture aquaculture traditionally in their wet rice fields since a long time. Their practice, locally termed 'ajingui assonii,' is free from the use of agro-chemicals and additional input of supplementary feed for the reared fish. So, the fish production in Apatani rice-fish system is less compared to similar systems around the world. Therefore, formulating a fish diet within the least possible cost using locally available resources to increase the fish production and maximize profit has been conceptualized for the welfare of the farm families of the area. The ingredients of feed that are cheap but rich in nutrients for optimum growth performance of the stocked fish have been selected very carefully to design such a compatible quality of fish feed.

The method of feed formulation involved blending of feed ingredients into nutritionally balanced diet, which should be economically rational, and could be used as per requirement to increase fish production in rice-fish system within the duration of culture period. The processing methods which included sourcing, mixing, pelleting, drying and storing was also very crucial as it determined bioavailability of the nutrients, feed acceptability, palatability and durability, which often depicted effect on growth performance of fish.

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FORMULATION OF FISH-FEED

(I) Raw materials

For formulating fish-feed for stocked fishes in Apatani rice-fish system, ingredients readily available in the household and rice-fish system of Apatani Plateau have been taken as raw materials. These ingredients are: (1) the leftover of processed and fermented rice after preparation of the rice beer, *Apong*, a traditional drink for the locals, (2) filamentous algal mass forming clump near rice rhizosphere in the rice-fish system, and (3) garlic (*Allium sativum*) an widely used spice to act as antioxidant.

(II) Nutrient composition of ingredients

In order to determine the nutritional values of above mentioned raw materials of the fish-feed, analysis of nutrient content was done (Raghuramulu *et al.*, 1983; Okalebo *et al.*, 1993 and Sadasivam and Manickam, 1996). Major nutrient contents of the locally available raw materials are shown below:

Nutrient contents	Locally available raw materials for fish-feed formulation	
	Leftover of processed and fermented rice after preparation of the rice beer, *Apong*	Filamentous algal mass forming clump in rice rhizosphere under the rice-fish system
Carbohydrate (%)	0.001	0.017
Protein (%)	30.3	3.25
Fat (%)	0.1	0.01
Calcium (%)	0.01	0.06
Phosphorus (%)	3.9	3.40
Sodium (%)	0.03	0.10
Potassium (%)	0.3	0.63
Vitamin C (%)	0.06	0.05

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(III) Techniques used for fish-feed formulation :

Following steps were followed for the purpose:

Step 1: Drying of the residues of *Apong* (leftover of processed and fermented rice residue), algal mass collected from the rice fields and garlic separately either in an oven at 70°C for 48 hrs or using the indigenous 'chulas'.

Step 2: Grinding of the dried materials into fine powder using a grinding machine or indigenous mortar and pestle.

Step 3: Mixing of the powdered raw materials in the following proportion:

(i) Residue of the *Apong* :100 gm

(ii) Algae powder : 50 gm

(iii) Garlic (*Allium sativum*): 1 gm

Step 4: Preparing soft dough using water (at normal room temperature)

Step 5: Making pellets of the dough with the help of pellet machine

Step 6: Drying pellets in oven at 60°C for 24 hours. At farmers level these may be sun dried /or by using 'chula'

(IV) Nutrient contents of the feed

The following table shows the nutrient contents of the prepared fish-feed

Carbohydrate (%)	2.39
Protein (%)	22.92
Fat (%)	3.35
Calcium (%)	1.15
Phosphorus (%)	7.36
Sodium (%)	0.30
Potassium (%)	1.27
Vitamin C (%)	0.04

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FLOW CHART OF THE FISH-FEED FORMULATION

Selection of locally available raw materials from Apatani Plateau for preparation of the fish-feed

↓

These ingredients are: (1) the leftover of processed and fermented rice after preparation of the rice beer, *Apong*, a traditional drink for the locals, (2) filamentous algal mass forming clump near rice rhizosphere in the rice-fish system, and (3) garlic (*Allium sativum*), to act as antioxidant.

↓

Fish-feed is prepared by maintaining a proper ratio of the selected raw materials after proper drying, powdering and mixing them properly in the following proportion:
100gm *Apong* residue: 50gm algae powder: 1 gm garlic powder

↓

Preparing a soft dough using water

↓

Making pellets of the dough

↓

Drying the pellets

(V) Efficacy test of the formulated fish-feed under laboratory condition

Aquaculture experiment was performed in order to carry out the efficacy test of the formulated fish-feed on fish growth . For this,*Cyprinus carpio* at fry stage were collected from the nearest fish farm. These were acclimatized for 48 hours in an aquarium and then feeding trial was conducted for a period of four weeks in four experimental aquaria (30 L capacity) @ 12 individuals per aquarium. Three feeding rates (3%, 5%, and 7% of initial body weight of the stocked fish) with three replicates per treatment were tested. The fishes were fed twice per day respectively at 08:30 hr and 17: 30 hr. The fishes were harvested after every seven days and their morphometrics and growth parameters were recorded following Fulton (1911), Bhuiyan and Biswas (1982), Faturoti and Akinbote (1986), Lovell (1988).

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RESULTS

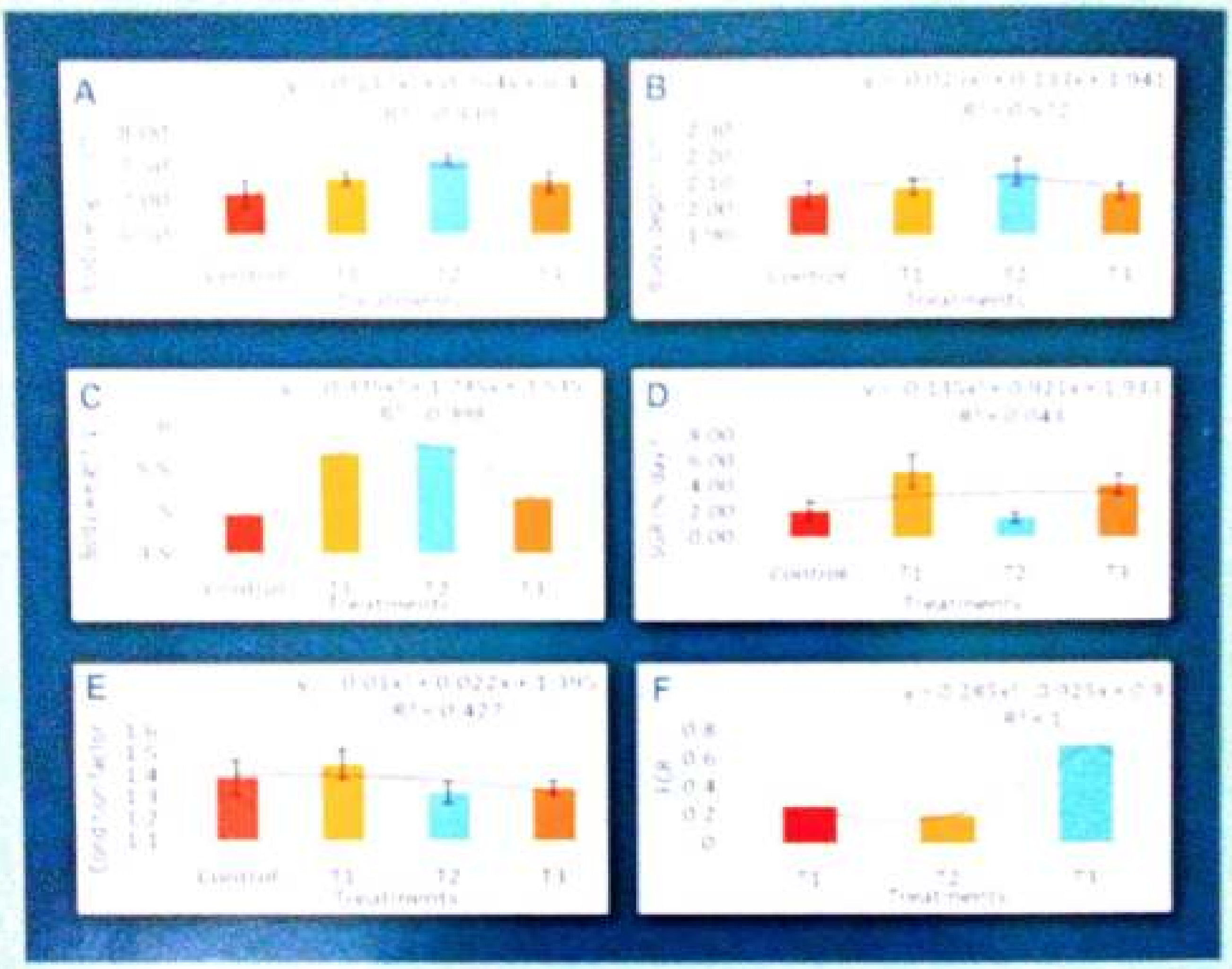

Figure 1. Changes in body length (A), body depth (B), body weight (C) specific growth rate (SGR;D), condition factor (E) and feed conversion ratio (FCR;F) of *Cyprinus carpio* after four weeks of feeding with the prepared fish-feed under different feeding treatments in experimental aquaria.

Treatments T1, T2 and T3 represent feeding @ 3%, 5% and 7% of the initial body weight of the stocked fish respectively in different experimental aquaria.

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DISCUSSION AND CONCLUSION

The experiment revealed that body length, body depth and body weight of *Cyprinus carpio* showed better performance in treatment 2 where the feed conversion ratio and condition factor had the lowest value. However, specific growth rate and condition factor showed significantly greater value in treatment 1 where the feed conversion ratio was slightly greater than treatment 2.

Considering all the growth parameters of the stocked fish in the experimental aquaria, it can be concluded that the fry stages of *Cyprinus carpio* would grow in a better and healthier way in the rice-fish system if they are fed with the prepared feed @ 3% of their initial body weight while stocking. This practice of using the agro-based waste matter as fish food would be a means of converting waste to useful commodities for the benefit of traditional rice-fish farmers of Apatani plateau, Arunachal Pradesh.

PHOTOGRAPHIC PANORAMA

Raw materials locally available in the Apatani Plateau for preparation of low-cost fish-feed

Plate 1. Leftover of processed and fermented rice after preparation of the traditional rice beer, Apong

Plate 2. Filamentous algae clumped near the rhizosphere of the rice plant in the rice-fish system

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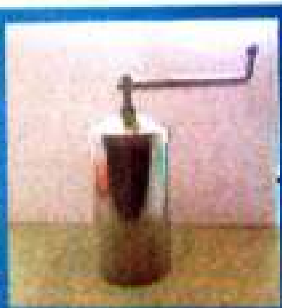
RESEARCH ACTIVITIES

Collection of periphyton

Grinding of raw materials

Raw materials in powdered form

Doughing the raw materials



Palletizer

Fish-feed pelleting

Oven drying of the fish-feed

Fish-feed ready to be supplemented in the rice-fish system

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This bulletin is an outcome of a major research project entitled, '*Formulation and evaluation of low cost fish feed for supplementation in rice-fish system of Apatani Plateau, Arunachal Pradesh*' sponsored by University Grants Commission, New Delhi.

This publication is not a priced one but an extension bulletin only for the rice-fish farmers and extension workers. This may exclusively be used for dissemination of information on the protocol for formulating fish-feed using locally available resources, which could judiciously be used as a feed supplement in the rice-fish system of Apatani Plateau, Arunachal Pradesh. The output of the above mentioned project endeavor has ultimately been published with the major aim towards popularizing this particular farming concept and also for farmers' welfare living elsewhere in India under similar agro ecosystems.

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'Formulation and evaluation of low cost fish feed for supplementation in rice-fish system of Apatani Plateau, Arunachal Pradesh'

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<u>ANNEXURE-C</u>

Summary of the findings

The study was undertaken to formulate low-cost fish feed using locally available agro-based wastes in the *Apatani* landscape of Arunachal Pradesh, North-east India. The study was done with the overall goal of improving fish production through supplementation of low-cost fish feed in the rice-fish system of the *Apatani* landscape. We studied the habitat condition, food availability, feeding, growth, and nutrient assimilation of the stocked fish in the rice-fish system of *Apatani* Plateau. The fish feed was formulated using locally available agro-based raw materials. This was followed by nutrient analyses and efficacy test of the formulated feed on growth performance of the stocked fish under laboratory condition.

The physicochemical properties of rice field water revealed the rice-fish system to be a shallow water system. Investigation of planktonic and rice stem periphytic communities present in the rice-fish system of the *Apatani* Plateau revealed that the phytoplankton and phyto-periphytic algae were more diverse communities than the zooplankton communities. Bacillariophyceae was the most dominant phytoplankton class in the rice field water as well as the most dominant phyto-periphyton class on the rice stem while Cladocera was the most dominant zooplankton group in the rice-fish system.

Gut content analyses revealed the stocked fish in the rice-fish system to be omnivorous in nature. Body nutrient content of the stocked fish revealed variations in the proximate and mineral nutrient compositions in the body of the stocked fish with respect to months. This indicates variations in the availability and type of food in the rice-fish system across different months leading to monthly variations in the body nutrient content of the stocked fish.

The fish-feed formulation was done using locally available raw materials in the *Apatani* Plateau. This was followed by the analyses of the proximate composition of the fish-feed formulation and an aquaculture experiment to test the effectiveness of the prepared fish-feed on the overall growth and health performance of the stocked fish, *Cyprinus carpio*. Efficacy test was performed also to quantify the proportion of feed to be supplemented in the rice-fish system that would be appropriate for optimal growth of the stocked fish without disrupting the natural ecological balance within the rice-fish system.

Efficacy test performed with formulated feed under laboratory condition suggests that the stocked fish would grow much faster if the prepared fish-feed were supplemented into the rice-fish system of *Apatani* Plateau @ 3% of their initial body weight while stocking in the rice field. However, further studies following on-farm feeding trials would enhance a better understanding of the growth behavior of the fishes in this system.

Overall, the study highlights the possibility of increasing the production of fish in the rice-fish system of *Apatani* Plateau by exploiting the existing agro-based wastes in the study area as supplementary fish feed which would definitely result in more per capita fish-protein consumption and better economic returns to the local people of the *Apatani* landscape in sustainable and eco-friendly ways.

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ANNEXURE-B

Achievements from the project

(1) *List of publications*

(a) Research articles

Dev Gupta, B., Das, T. and Das, D.N. (2015). A preliminary investigation on habitat condition and natural food of *Cyprinus carpio* stocked in the rice-fish system of Apatani Plateau, Arunachal Pradesh. *ECOBIOS*8:(1and 2): 1-23.(ISSN:0972-6446).

Das,T., Dev Gupta, B. and Das, D.N.(2016). Formulation of low-cost fish feed using locally available agro-based wastes and its efficacy on growth performance of common carp (*Cyprinus carpio* L.) - A case study from Apatani landscape of Arunachal Pradesh in Northeast India. *International research Journal of Biological Sciences* 5 (3): 61-67 (E-ISSN 2278-3202).

(b) Chapter in edited volume

Dev Gupta, B., Das, T. and Das, D. N. (2013) A preliminary investigation on planktonic communities in the rice-fish system of Apatani Plateau, Arunachal Pradesh, In: Bioresources and Traditional Knowledge of Northeast India (Eds). K.K. Singh, K.C. Das and H. Lalruatsanga. Mizo Post Graduate Science Society and Pachunga University College, Aizawl, India. pp 143- 152.ISBN: 987-81-924321- 4-7

(c) Communicated in edited volume

Bipasha Dev Gupta, Tapati Das and D. N. Das. 2018. Food preference and feeding of *Cyprinus carpio* stocked in high altitude rice-fish system: A case study from Apatani landscape of Arunachal Pradesh. In: Research and Development on mountain fisheries of Arunachal Himalayas. In Press.

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A preliminary investigation on habitat condition and natural food of *Cyprinus carpio* stocked in the rice-fish system of Apatani Plateau, Arunachal Pradesh

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ABSTRACT

The present study gives preliminary information on the habitat conditions and natural food availability of *Cyprinus carpio* stocked in the rice-fish system of Apatani Plateau, Arunachal Pradesh, North East India. For the present study sampling was done during the fish stocking stage in the rice-fish system of the Apatani Plateau i.e., from May to August, 2012. Besides analysis of water samples of the rice-fish system, analyses of plankton in the rice field water, epiphyton on rice-stems, and gut content analyses of *Cyprinus carpio* stocked in the rice-fish system were also done. Physico-chemical parameters of water in the rice-fish systems of the Apatani Plateau revealed it as moderately nutrient-rich shallow system where the pH of the rice field water fluctuated from slightly acidic to slightly alkaline condition. The phytoplankton in rice field water and epiphytic algae on the rice stem were more diverse communities than the zooplankton and zoo-epiphytic communities. Bacillariophyceae was the most dominant class of phytoplankton and phyto-epiphyton and Cladocera was the most dominant group of zooplankton and zoo-epiphyton in the rice-fish system. The gut content of *Cyprinus carpio* showed a direct relationship of the available plankton/epiphyton communities in the rice-fish system with the fish feeding. The study further revealed that all the natural live organisms present in the rice-fish system are not used as feeding materials by the stocked fish in the rice-fish system. Amongst phytoplankton and/or phyto-epiphyton diverse taxa belonging to Bacillariophyceae and amongst zooplankton and/or zoo-epiphyton taxa belonging to Cladocera were the more preferred food items.

Key words: Rice-fish system, Apatani Plateau, *Cyprinus carpio*, habitat condition, natural food

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INTRODUCTION

Rice-fish culture is practiced in many parts of India, viz., Kerala, West Bengal, Arunachal Pradesh and Tripura [1, 2, 3]. In India, the agrarian *Apatani* hill tribe, settled in the lower Subansiri district of Arunachal Pradesh are the only Indian tribal farmers who traditionally practice rice-fish culture since past 50 years. No agro-chemicals and fish-feed are administered in the system during the culture period, which makes it unique in the context of production. The fishes (*Cyprinus carpio*) are cultured along with the local rice cultivars viz., *Amo, Mypia* and *Pyapee* in the paddy fields. The fish depend on the natural food available in the rice-fish system which comprises phytoplankton, zooplankton, different periphytic organisms, detrital matters etc. In the present study attempt has been made to investigate the habitat condition and available natural food items of *Cyprinus carpio* stocked in the rice-fish system.

MATERIALS AND METHODS

For the present a total of five villages of the Apatani landscape were selected. These were Bamin-michi (Station 1), Bulla (Station 2), Hong (Station 3), Hiza (Station 4) and Hari (Station 5) (Figure 1).

Field sampling

In order to assess the natural habitat condition of the stocked fish in the rice-fish system of the study area, water samples from the different sampling stations were collected at monthly intervals during the fish stocking stage (i.e., for a period of 4 months from May to August, 2012). During each sampling temperatures of air, water and sediment were recorded with a mercury bulb thermometer (0-50°C); and water depth was recorded using a wooden pole and a measuring tape. Samples for dissolved oxygen was collected in BOD bottles and were fixed immediately in the field using alkaline iodide and manganous sulphate. For analysis of other parameters of the rice field water, water samples were taken in PVC bottles and were brought to the laboratory.

During sampling of rice field water (May to August, 2012) simultaneously plankton samples were also collected by passing 25 litres of rice-field water through plankton net of 40 µm screen size, and was immediately preserved in glass vials using 2ml formalin (4%) which was later on

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brought to the laboratory for identification.

Sampling of epiphytes on the rice stem was also done for 2 months from July to August, 2012. The epiphytic communities on the rice stem were collected by scrapping gently few representative rice stems (from 1cm^2 surface area) within the rice-fish system using a fine scalpel and preserved in glass vial using 2ml formalin (4%) which were later on brought to the laboratory.

In order to know the food preferences of the stocked fish in the rice-fish system, fish samples from the rice-fish system were collected for a period of two months from July to August, 2012 which were immediately preserved in 10% formalin solution. Later on the samples were brought to the laboratory.

Laboratory analysis

In the laboratory pH of the water samples were recorded using pH meter (make: Systronics; model: 103621). Estimations of dissolved oxygen, biological oxygen demand (for 3 days at 20°C), total alkalinity, free carbon dioxide, nitrate-nitrogen, and phosphate-phosphorous of the rice field water were done following standard methods [4,5]

The final volume of all the samples of plankton and epiphyton collected from the rice field were made to 10 ml in the laboratory. For gut content analysis of the stocked fish in the rice-fish system stomach of each fish sample was dissected out and its contents were removed very carefully on petri dish. Contents of the gut were diluted to 10 ml by adding distilled water.

Identifications of plankton, epiphyton and the gut content of the stocked fish were done drop wise on glass slides and looking through binocular microscope (make: Magnus; model: MLXi). Micro-scopic identifications at lowest possible taxonomic level of phytoplankton and epiphytic algae were done at 40X and that of zooplankton and zoo-epiphyton were done at 10X magnifications respectively following standard references viz., [4-22].

For quantitative estimation of both the plankton in the rice field water, and epiphyton on the rice stem Lacky's drop method[23] was followed and the results were finally converted to percent relative abundance. However, the gut contents of the stocked fish was analysed for only the presence or absence of different taxa in the gut of the fish.

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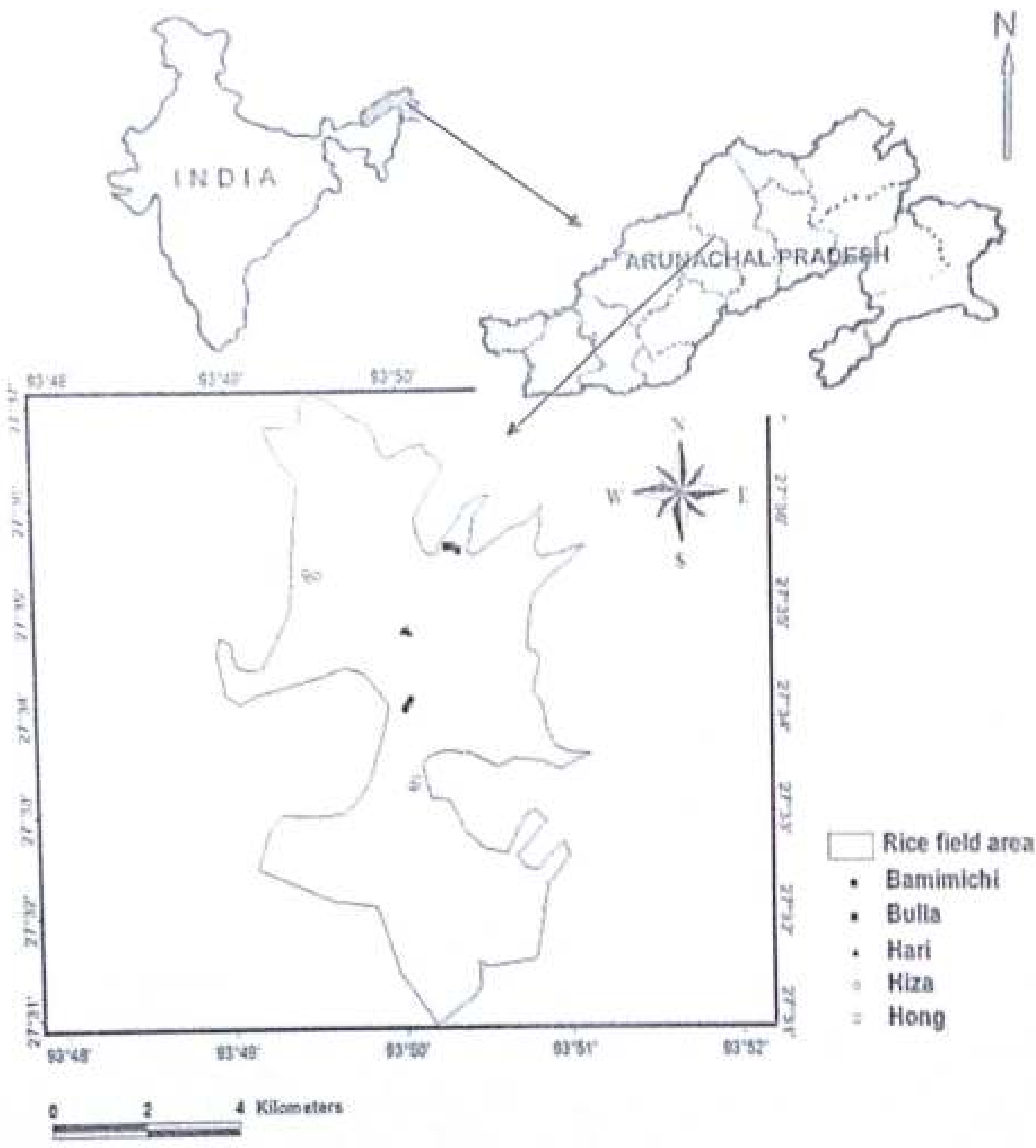

Figure 1. Map showing the sampling stations

RESULTS

Table 1 shows the physico-chemical properties of water in the rice-fish system of Apatani Plateau. It shows that Station 1 had greater values of pH, dissolved oxygen (DO) and nitrate-N, and lowest values of water depth, total alkalinity; free carbon dioxide (CO_2) and Phosphate-P.

Station 2 had greater values of biological oxygen demand (BOD) and Phosphate-P. Station 3 had lowest value of water temperature, pH, DO, BOD, nitrate-N and greater value for water depth and CO_2. Station 4 had greater value of water and sediment temperatures and total alkalinity.

Table 1. Physico-chemical parameters of water in the rice-fish system of Apatani Plateau

Stations	AT (°C)	WT (°C)	ST (°C)	WD (cm)	pH	TA (mgl^{-1})	DO (mgl^{-1})	BOD (mgl^{-1})	CO_2 (mgl^{-1})	Nitrate-N (mgl^{-1})	Phosphate-P (mgl^{-1})
Station 1	24	26.06	25.7	10.19	7.38	20.45	8.71	3.41	11.63	5.66	0.04
	±1.30	±0.85	8±0.7	±0.83	±0.12	±1.45	±0.7	±0.48	±1.21	±1.09	±0.01
	(20-33)	(22-30)	(21-30)	(6.4-13.5)	(6.7-7.9)	(12.6-29.33)	(7.06-11.28)	(1.33-6.48)	(5.9-17.91)	(0.23-12.31)	(0.01-0.12)
Station 2	23.73	24.51	23.33	12.02	6.83	28.54	8.30	3.67	13.62	4.08	0.07
	±0.94	±0.94	±0.75	±1.50	±0.2	±4.25	±0.27	±0.48	±1.08	±0.70	±0.02
	(19-32)	(20-29)	(19-28)	(6.2-20.6)	(5.02-7.5)	(13.2-34-66)	(6.48-10.54)	(0.94-4.91)	(4.59-19.2)	(0.52-9.04)	(0.01-0.29)
Station 3	22.93	24.4	24.33	12.62	6.69	23.18	7.11	2.15	14.6	3.95	0.05
	±1.08	±0.62	±0.54	±1.35	±0.27	±2.70	±0.36	±0.43	±0.95	±0.64	±0.01
	(19-32)	(20-28)	(22-29)	(6.0-21.7)	(4-7.7)	(12.6-35.33)	(5.12-9.04)	(0.24-7.01)	(7.98-19.9)	(0.11-7.07)	(0.003-0.075)
Station 4	24.58	27.33	25.92	10.23	7.24	32.54	8.40	3.54	12.7	4.5	0.05
	±1.33	±1.47	±1.20	±1.09	±0.07	±2.49	±0.44	±0.66	±1.11	±0.90	±0.01
	(20-33)	(21-35)	(20-32)	(5.0-15.0)	(6.3-7.5)	(20-44.66)	(6.34-11)	(0.72-8.44)	(6.59-18.57)	(0.34-8.21)	(0.004-0.114)
Station 5	24.08	26.45	25.42	12.6	7.22	24.47	7.85	2.19	12.77	5.03	0.06
	±1.08	±1.03	±0.72	±0.83	±0.15	±2.31	±0.33	±0.39	±1.10	±1.00	±0.01
	(20-30)	(22-30)	(22-29)	(9.2-15.5)	(6.3-7.6)	(12.60-33.30)	(6.28-10.27)	(0.72-4.67)	(5.9-17.15)	(0.39-12.04)	(0.005-137)

Mean±SE; n=45; AT-Air temperature; WT-Water temperature; ST-Sediment temperature; WD-Water depth; TA-Total alkalinity; DO-Dissolved oxygen; BOD-Biological Oxygen Demand.

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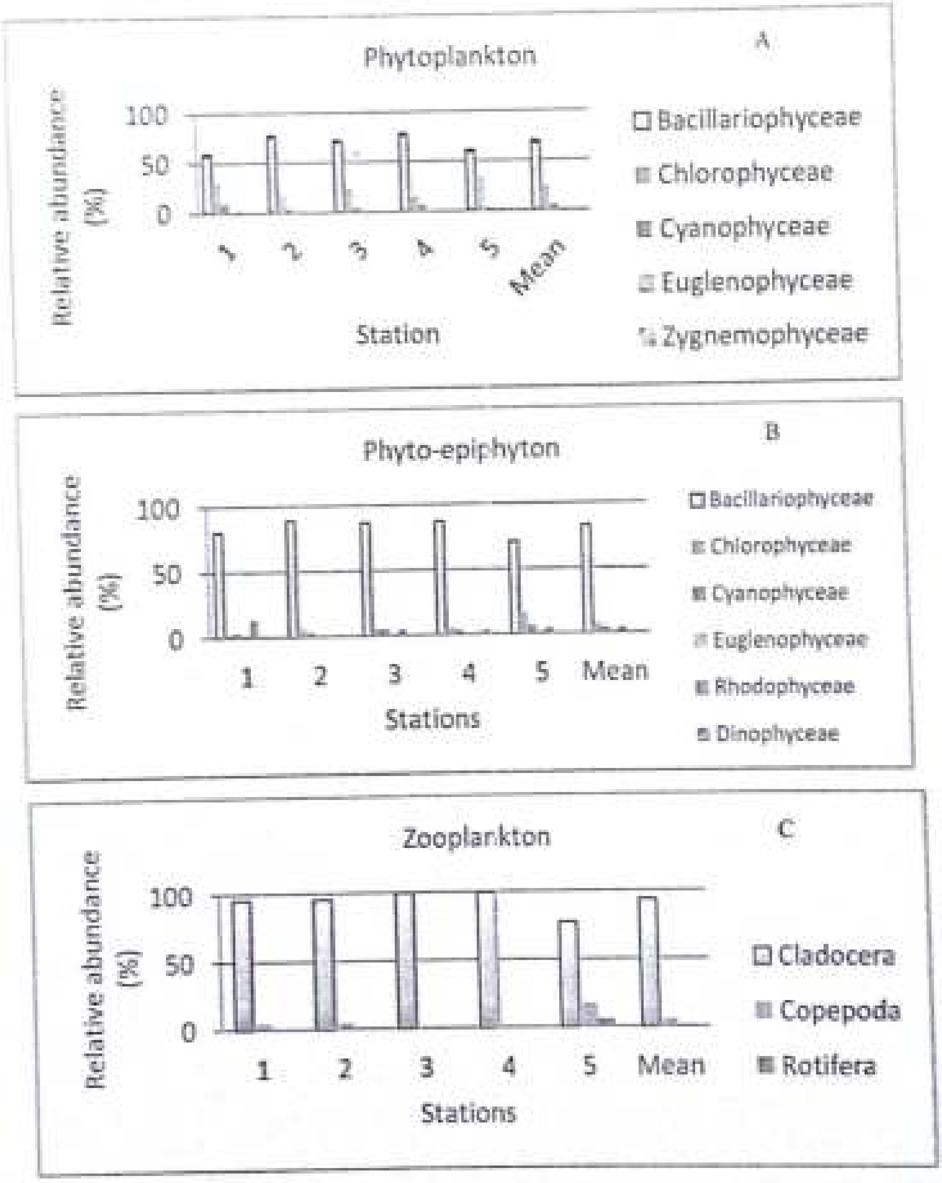
Numbers in parenthesis designate range of mean values of the physico-chemical properties of water in different stations of the study area

Table 2 represents the taxonomic richness and distribution of phytoplankton in the rice-fish system of Apatani Plateau. It reveals the presence of 76 taxa of phytoplankton belonging to classes Bacillariophyceae,Chlorophyceae, Cyanophyceae, Dinophyceae, Euglenophyceae, and Zygnemophyceae. In all the stations Bacillariophyceae followed by Chlorophyceae was the most dominant phytoplankton class (Figure 2A).



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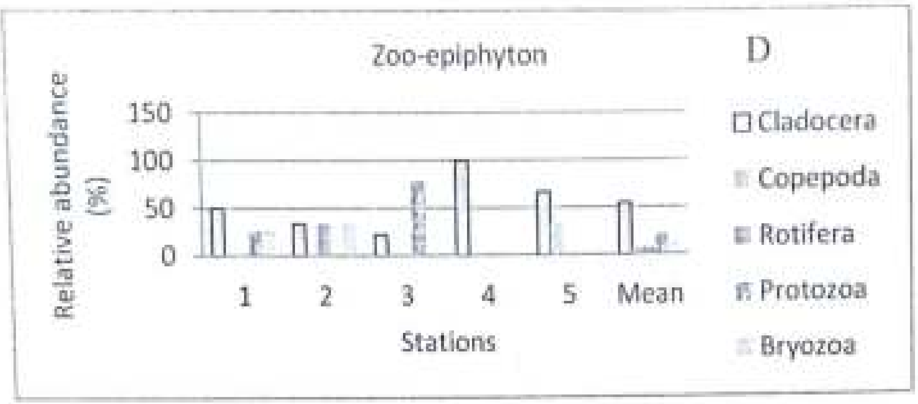

Figure 2: Relative abundance (%) of classes of phytoplankton in the rice field water (A) and phyto-epiphyton on rice stems (B), groups of zooplankton in the rice field water (C), and zoo-epiphyton on the rice stems (D) in the rice-fish system of Apatani Plateau

Table 2. Taxonomic richness and distribution of phytoplankton in the rice-fish system of Apatani Plateau

Class	Taxa	Stations				
		1	2	3	4	5
Bacillariophyceae	*Achnanthes*	-	+	+	+	+
	Acnanthes biasolettiana	-	+	-	-	-
	Amphipleura pellucida	+	-	-	-	-
	Amphora	+	-	+	+	+
	Amphora ovalis	+	+	+	+	+
	Asterionella	-	-	-	+	-
	Cymbella	+	+	+	+	+
	Cymbella neocistula	-	-	-	-	+
	Diatoma sp1	+	+	+	+	+
	Diatoma sp2	-	+	+	+	-
	Diatoma vulgare	-	+	-	-	+
	Encyonema	+	+	+	+	+
	Epithemia	+	+	+	+	+
	Eunotia	+	+	+	+	+
	Fragilaria	-	+	-	+	+
	Frustulia	+	+	+	+	+
	Gomphonema	+	+	+	+	+
	Gomphonema angustrum	-	-	-	+	-
	Gyrosigma sp1	-	-	-	-	+
	Gyrosigma sp2	-	-	-	+	-
	Himantidium	-	-	-	+	-

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	Mastogloia	-	-	-	+	-
	Melosira	+	+	+	+	+
	Pinnularia	+	+	+	+	+
	Pinnularia major	+	+	+	+	+
	Pinnularia acrosphaeria	-	+	-	-	+
	Pleurosigma	-	-	-	+	-
	Navicula gracilis	-	+	+	+	+
	Navicula placenta	+	+	+	+	+
	Navicula rhynchocephala	+	+	+	+	+
	Navicula mutica	+	+	+	+	+
	Navicula viridis	+	+	+	+	+
	Nitzschia	+	+	-	+	-
	Nitzschia sigmoidea	-	+	-	+	+
	Stauroneis	+	+	+	+	+
	Surirella	+	+	+	+	+
	Surirella elegans	+	+	+	+	+
	Synedra	+	+	+	+	+
	Synedra fumosa	-	+	+	+	-
	Synedra ulna	+	+	+	+	+
	Tabellaria	+	+	-	-	-
	Tabellaria flocculosa	-	-	+	-	-
	Rhopalodia gibba	+	+	+	+	+
Total taxa :	**43**	**25**	**32**	**27**	**35**	**30**
Chlorophyceae	*Ankistrodesmus*	-	+	-	-	+
	Closterium	+	+	+	+	+
	Closterium striolatum	-	-	-	+	-
	Cosmarium	+	+	+	+	+
	Desmidium	-	-	+	+	+
	Docidium	+	+	+	+	+
	Euastrum	+	-	-	+	+
	Euastrum crassum	+	-	-	-	+
	Gonatozygon	+	+	+	+	+
	Scenedesmus	-	-	-	-	+
	Spirogyra	+	+	+	+	+
	Spirogyra longata	-	-	-	-	+
	Staurastrum	+	+	+	+	+
	Staurastrum magnum	-	-	+	-	-
	Staurastrum brachiatum	+	-	-	-	-
	Ulothrix	+	-	+	-	-

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	Zygnema	+	-	-	-	+
Total taxa:	17	11	7	9	9	13
Cyanophyceae	*Anabaena*	+	+	+	+	+
	Aphanizomenon	+	+	+	+	+
	Microcoleus vaginatus	+	-	+	+	+
	Nostoc	-	+	-	+	-
	Oscillatoria	-	+	-	+	+
	Oscillatoria anguina	-	+			+
	Phormidium	+	-	-	+	+
	Phormidium autummale	-	-	-	+	-
	Pseudanabaena	+	-	-	-	+
	Spirulina	-	+	-	-	+
Total taxa:	10	5	6	3	7	8
Dinophyceae	*Massartia*	-	-	-	-	+
Total taxa:	1	0	0	0	0	1
Zygnemophycea	*Micrasterias alata*	+	-	+	-	+
	Micrasterias mahabuleshwarensis	-	-	-	-	+
	Micrasterias radiosa	-	-	-	+	+
	Miscrasterias foliacea	-	-	-	+	-
Total taxa:	4	1	0	1	2	3
Euglenophyceae	*Euglena*	+	+	-	+	+
Total taxa:	1	1	1	0	1	1
Grand total taxa:	76	42	44	39	54	55

'-' indicates absence of the taxa concerned

Table 3 represents the taxonomic richness and distribution of zooplankton in the rice-fish system of the Apatani Plateau. It shows the presence of a total of 15 taxa belonging to groups Cladocera, Copepoda and Rotifera. Cladocera was the most dominant zooplankton group (Figure 2C).

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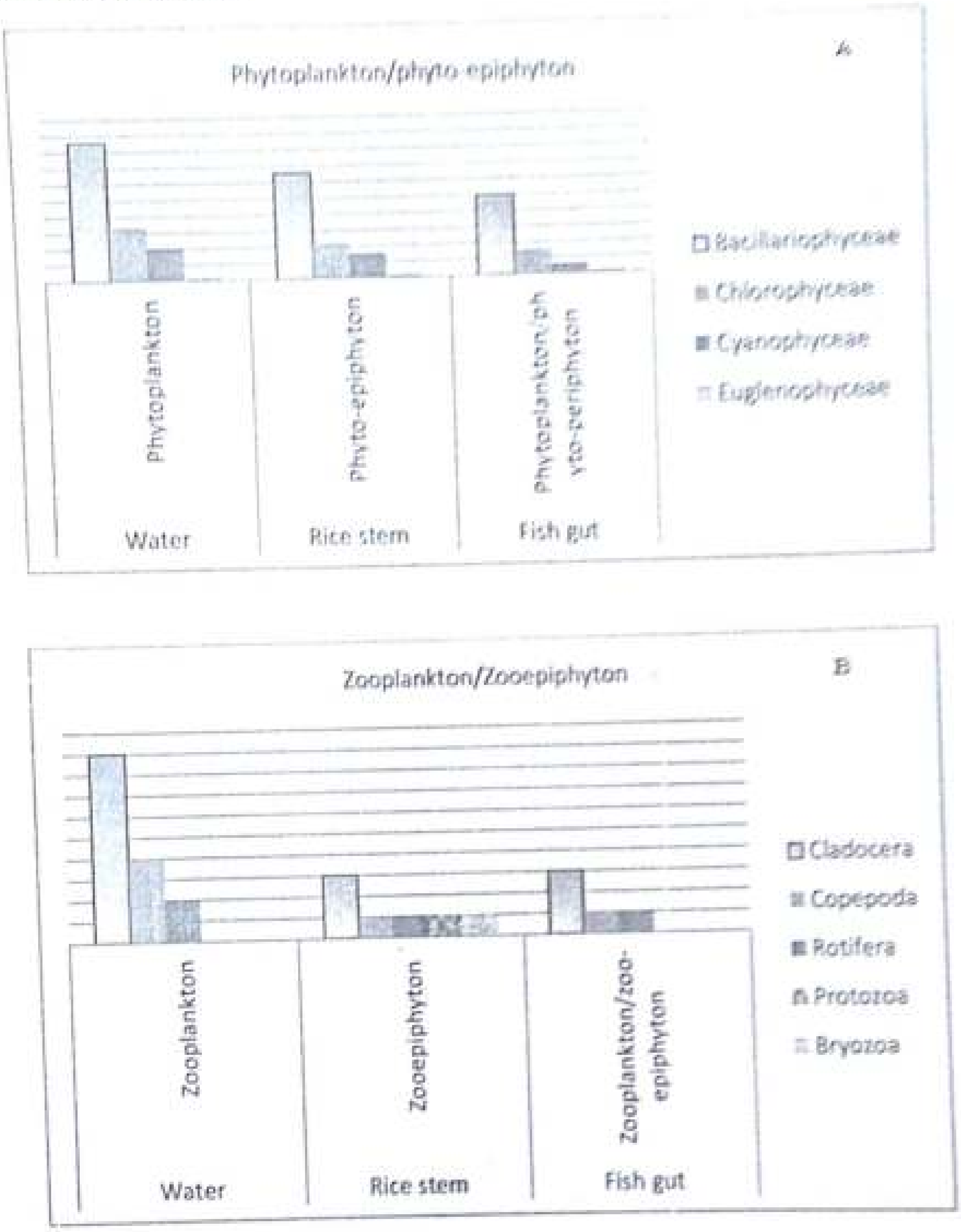

Figure 3: Taxonomic richness of different classes of phytoplankton in water and phyto-epiphyton on rice stems and phytoplankton/phyto-epiphyton present in the fish gut (A), and taxonomic richness of different groups of zooplankton in water and zoo- epiphyton on rice stems and zooplankton/zoo-epiphyton present in the fish gut (B) in the rice-fish system of Apatani Plateau

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Table 3. Taxonomic richness and distribution of zooplankton in the rice -fish system of Apatani Plateau

Group	Taxa	Stations				
		1	2	3	4	5
Cladocera	*Alona*	-	+	-	-	-
	Bosmina	+	+	+	+	+
	Chydorus	+	-	-	-	-
	Daphnia	-	-	-	+	+
	Leydigiopsis	-	+	-	-	-
	Moina	+	-	-	-	-
	Pleuroxus	-	+	-	-	-
	Alonella	-	+	+	+	+
	Sidacrystalina	-	-	-	-	+
Total taxa:	9	3	5	2	3	4
Copepoda	*Cyclops*	-	-	-	-	+
	Canthocamptus	+	-	-	-	-
	Diaptomus	+	-	-	-	-
	Palaemonetes	-	+	-	-	-
Total taxa:	4	2	1	0	0	1
Rotifera	*Asplanchna*	-	-	-	-	+
	Brachionus	-	-	-	-	+
Total taxa:	2	0	0	0	0	2
Grand total taxa: 15		5	6	2	3	7

'-' indicates absence of the taxa concerned

Table 4 represents the phyto-epiphyton (or epiphytic algae) presents on rice stems in rice-fish system of the Apatani Plateau. It reveals the presence of 56 taxa belonging to classes Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, Euglenophyceae, Zygnemophyceae, Rhodophyceae, and Xanthophyceae. Bacillariophyceae was the most dominant epiphytic algae (Figure 2 B).

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Table 4. Taxonomic richness and distribution of phyto-epiphyton on rice stems in different stations of the rice-fish system of Apatani Plateau

Class	Taxa	Stations				
		1	2	3	4	5
Bacillariophyceae	*Achnanthes*	+	+	+	+	+
	Amphora ovalis	+	+	+	+	+
	Amphipleura	-	+	-	-	-
	Asterionella	|	+	-	-	-
	Cymbella	+	+	+	+	+
	Cyclotella	-	-	-	+	-
	Diatoma	-	+	+	+	-
	Encyonema	-	+	+	+	-
	Epithemia	+	+	+	+	+
	Eunotia	+	+	+	-	+
	Flagelleria	-	+	-	-	-
	Frustulia	+	+	+	+	+
	Gomphonema	+	+	+	+	+
	Himantidium	-	-	+	+	-
	Melosira	+	+	+	+	+
	Navicula placenta	+	+	+	+	+
	Navicula gracilis	-	+	-	-	+
	Navicula radiosa	-	+	-	-	-
	Navicula rhynchocephala	+	+	+	+	+
	Navicula sp.	+	+	+	+	+
	Navicula viridis	+	+	+	+	+
	Nitzschia sigmoidea	-	-	+	-	-
	Oocystis	-	-	-	-	+
	Pinnularia	+	+	+	+	+
	Pinnularia major	+	+	+	+	+
	Rhopalodia gibba	+	+	+	-	+
	Stauroneis	+	+	+	+	+
	Surirella	-	+	+	+	-
	Surirella elegans	+	+	+	+	+
	Synedra	+	-	+	+	-
	Synedra fumosa	+	-	+	+	+
	Synura	-	-	-	-	+
	Tabellaria	-	+	-	+	+

Total taxa:	33	20	26	24	23	22
Chlorophyceae	*Closterium*	-	+	+	+	+
	Cosmarium	-	-	-	-	+
	Docidium	-	+	+	-	+
	Desmidium	+	-	-	+	+
	Gonatozygon	-	-	+	-	+
	Netrium	-	+	-	-	-
	Scenedesmus	+	+	-	-	+
	Staustrum	-	-	+	+	+
	Spirogyra	-	-	-	-	+
	Ulothrix	-	+	+	+	-
	Zygnema	-	-	-		+
Total taxa:	**11**	**2**	**5**	**5**	**4**	**8**
Cyanophyceae	*Anabaena*	-	-	+	+	-
	Aphanizemenon	+	+	-	-	+
	Cylindospermum	-	+	-	-	+
	Merismopedia	-	-	-	-	+
	Microcoleus vaginatus	+	-	-	-	+
	Oscillatoria	+	-	-	-	-
	Phormidium	+	+	+	-	+
	Spirulina	-	-	+	+	-
Total taxa:	**8**	**4**	**2**	**3**	**2**	**5**
Zygnemophyceae	*Xanthidium antilopaeum*	-	-	-	-	+
Total taxa:	**1**	**0**	**0**	**0**	**0**	**1**
Dinophyceae	*Ceratum*	-	+	-	-	+
Total taxa:	**1**	**0**	**1**	**0**	**0**	**1**
Euglenophyceae	*Phacus*	+	+	+	+	+
Total taxa:	**1**	**1**	**1**	**1**	**1**	**1**
Rhodophyceae	*Batrachospermum*	+	+	+	+	+
Total taxa:	**1**	**1**	**1**	**1**	**1**	**1**
Xanthophyceae	*Vaucheria*	-	-	-	+	+
Total taxa:	**1**	**0**	**0**	**0**	**1**	**1**
Grand total taxa: 56		**28**	**36**	**32**	**31**	**40**

'-' indicates absence of the taxa concerned

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Table 5 shows the taxonomic richness and distribution of zoo-epiphyton in the rice-fish system of Apatani Plateau. It shows the presence of 7 taxa belonging to groups Protozoa, Bryozoa, Cladocera, Copepoda, and Rotifera. Amongst all the taxa Cladocera was the most dominant group of zoo-epiphyton in the rice fish system (Figure 2D).

Table 5. Taxonomic richness and distribution of zoo-epiphyton on rice stems in the rice-fish system of Apatani Plateau

Group	Taxa	Stations				
		1	2	3	4	5
Protozoa	*Centropyxis*	+	-	+	-	-
Total taxa:	*1*	1	0	1	0	0
Bryozoa	*Plumatella*	+	+	-	-	-
Total taxa:	*1*	1	1	0	0	0
Cladocera	*Bosmina*	-	+	+	+	-
	Chydorus	+	+	-	+	+
	Pleuroxus	+	-	-	-	-
Total taxa	*3*	2	2	1	2	1
Copepoda	*Cyclops*	-	-	-	-	+
Total taxa	*1*	0	0	0	0	1
Rotifera	*Lecane inopinata*	-	+	-	-	-
Total taxa	1	0	1	0	0	0
Grand total taxa: 7		**4**	**4**	**2**	**2**	**2**

Table 6 represents the gut content of *Cyprinus carpio* stocked in the rice-fish system of Apatani Plateau. It reveals that the fishes feed on phytoplankton/ phyto-epiphyton and zooplankton/ zoo-epiphyton present in the rice field water and rice stems in the rice-fish system. The phytoplankton/ phytoepiphyton communities found in the fish gut belonged to classes Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae. Zooplankton/ zooepiphyton communities found in the fish gut belonged to groups Cladocera, Copepoda and Rotifera. Amongst the different classes of phytoplankton/phytoepiphyton communities, Bacillariophyceae followed by Chlorophyceae was the most abundant

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gut contents of *C. carpio*. Amongst zooplankton, Cladocera was the most abundant group in the gut of the fish.

Table 6. Gut content of *Cyprinus carpio* stocked in the rice-fish system of Apatani Plateau

Phytoplankton /phyto-epiphyton class/ Zooplankton/ zoo-epiphyton group	Taxa	Stations					Gut content of *C. carpio* which are available in the rice-fish system either as planktonic or epiphytic or both planktonic and epiphytic forms
		1	2	3	4	5	
Phytoplankton /Phyto-epiphyton							
Class: Bacillariophyceae	*Achnanthes*	-	+	-	+	-	Both
	Amphora ovalis	-	+	+	-	+	Both
	Cymbella	+	+	+	+	+	Both
	Diatoma	-	-	+	-	-	Both
	Encyonema	-	+	+	+	+	Both
	Epithemia	-	+	-	+	-	Both
	Eunotia	+	-	-	+	-	Both
	Flagellaria	-	-	-	-	-	Both
	Frustulia	-	+	-	+	-	Both
	Gomphonema	-	+	-	-	-	Both
	Himantidium	-	-	-	+	-	Both
	Melosira	+	+	+	+	-	Both
	Navicula placenta	-	+	+	+	+	Both
	Navicula rhynchocephala	-	+	-	+	+	Both
	Navicula sp.	+	-	-	+	-	Both
	Navicula viridis	+	+	-	+	-	Both
	Nitzschia	+	+	-	+	-	Both
	Pinnularia	+	+	+	+	-	Both
	Pinnularia major	-	+	+	-	+	Both
	Pinnularia sp.	-	-	-	-	+	Both

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	Rhopalodia gibba	+	+	+	+	+	Both
	Stauroneis	+	+	+	+	+	Both
	Surirella	+	+	+	+	+	Both
	Synedra ulna	-	+	-	+	+	Both
	Tabellaria	-	-	+	-	-	Both
Total taxa:	**25**	**10**	**18**	**12**	**18**	**11**	
Class: Chlorophyceae	*Closterium*	+	+	+	+	+	Both
	Cosmarium	+	-	+	+	+	Both
	Desmidium	-	+	-	+	+	Both
	Docidium	+	+	+	+	+	Both
	Scenedesmus	-	-	-	-	+	Both
	Staurastrum	-	+	-	+	-	Both
	Spirogyra	+	+	+	+	+	Both
	Gonatozygon	+	-	+	-	+	Both
Total taxa:	**8**	**5**	**5**	**5**	**6**	**7**	
Class: Cyanophyceae	*Oscillatoria*	-	+	-	+	+	Both
	Phormidium	+	-	-	+	-	Both
	Anabaena	+	+	+	-	+	Both
Total taxa:	**3**	**2**	**2**	**1**	**2**	**2**	
Class: Euglenophyceae	*Euglena*	+	+	-	-	+	Both
Total taxa:	**1**	**1**	**1**	**0**	**0**	**1**	
Grand total taxa: 37		**18**	**26**	**18**	**26**	**21**	
	Zooplankton/zoo-epiphyton						
Group: Cladocera	*Alonella*	-	+	-	+	+	Planktonic
	Bosmina	+	-	+	+	+	Both
	Daphnia	-	-	-	+	-	Planktonic
Total taxa:	**3**	**1**	**1**	**1**	**3**	**2**	
Group: Copepoda	*Cyclops*	-	-	-	-	+	Both
Total taxa:	**1**	**0**	**0**	**0**	**0**	**1**	
Group: Rotifera	*Brachionus*	-	-	-	-	+	Planktonic
Total taxa:	**1**	**0**	**0**	**0**	**0**	**1**	
Grand total taxa: 5		**1**	**1**	**1**	**3**	**4**	

'-' indicates absence of the taxa concerned

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Figure 3A represents the taxonomic richness of different classes of phytoplankton and phyto-epiphyton in the rice-fish system and gut content of fish stocked in the rice-fish system. It shows that amongst all the classes of phytoplankton and phyto-epiphyton, Bacillariophyceae was the most dominant in the system as well as in the fish gut.

Figure 3B represents the taxonomic richness of different groups of zooplankton and zoo-epiphyton in the rice-fish system and gut content of fish stocked in the rice-fish system. It shows that amongst zooplankton/zoo-epiphyton group, Cladocera was the most dominant in the system as well as in the fish gut.

DISCUSSION

Physico-chemical properties of water in the rice-fish system of Apatani Plateau (Table 1) reveals that Station 1 had highest values of pH, DO and lowest values of free CO_2 and PO_4-P which gives a general indication about the presence of less organic matter content in that station. Greater value of NO_3-N in Station 1 was perhaps due to less water depth and subsequently less water volume in the station resulting in greater concentrations of nitrate-N perhaps due to faecal matters of the stocked fish. Least value of total alkalinity in Station 1 indicates very low buffering capacity of the water there and hence more stressed condition for the stocked fish. Greater values of BOD and PO_4-P in Station 2 indicates presence of phosphorous-rich organic matters in greater quantities and more microbial activities that lead to the release of PO_4-P in greater amount at that station. Station 4 had highest value of water and sediment temperatures. This might be due to less water depth at that station and also might be due to the reason that sampling in that station was done when the solar intensity was high that also lead to increase in air temperature thereby reflecting the close interaction of air, water and sediment temperatures in the rice field like any other aquatic systems. Station 4 also had greater value of total alkalinity thereby reflecting relatively more buffering capacity of the water in that station. Low values of pH and DO and greater value of free CO_2 in Station 3 reveals a relatively stressed condition for the stocked fish in that station. Besides, least value of BOD in Station 3 was perhaps due to more water depth and hence more water volume that lead to the dilution of organic matters in the rice field water. In addition, less water temperature in Station 3 might have

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lead to less microbial activities resulting in the lowest value of BOD in the rice field water.

Taxonomic richness and distribution of phytoplankton in the rice-fish system of Apatani Plateau (Table 2) reveals the presence of 76 taxa of phytoplankton belonging to classes Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, Euglenophyceae, and Zygnemophyceae out of which 43 taxa belonged to Bacillariophyceae, 17 taxa to Chlorophyceae, 10 taxa to Cyanophyceae, 4 taxa to Zygnemophyceae and 1 each to Dinophyceae and Euglenophyceae. Taxonomic richness of phytoplankton was more in Station 5 perhaps due to favourable environmental condition in terms of its various water parameters. On the other hand, taxonomic richness of phytoplankton were less in Station 3 which was perhaps due to acidic water and less nutrients like nitrate and phosphate in the rice field water at this station. In all the stations Bacillariophyceae followed by Chlorophyceae was the most dominant phytoplankton class (Figure 2.A). The dominance of Bacillariophyceae in the rice-fish system was perhaps due to more silica content in the sediment and water which is the major nutrient required by the diatoms[24]. The second dominant phytoplankton class was Chlorophyceae which was perhaps due to low temperature of the rice field water and presence of moderate nutrients like NO_3-N and PO_4-P[25].

Taxonomic richness and distribution of zooplankton in the rice-fish system of the Apatani Plateau (Table 3) shows the presence of a total of 15 taxa belonging to groups Cladocera, Copepoda and Rotifera. A total of 9 taxa belonged to Cladocera, 4 taxa to Copepoda and 2 to Rotifera. Taxonomic richness of zooplankton was highest in Station 5 and lowest in Station 3 which indicates that the habitat conditions in terms of various water parameters were more congenial for diverse zooplankton to grow and survive in rice field water at Station 5 and the reverse condition in Station 3. In all the sampling stations Cladocera was the dominant zooplankton group (Figure 2C) thereby indicating the rice-fish system of the study area to be free from intense pollution which favoured their growth and reproduction[26]. Besides, the abundance of Cladocera also indicates the presence of rich nutrients and shallow water condition [27] with moderate water temperature[28] of the rice-fish system. Similar results were

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also observed in the rice field of Chatla wetland of Assam [29].

Phyto-epiphyton (or epiphytic algae) present on rice stems in different stations of the rice-fish system of the Apatani Plateau (Table 4) reveals the presence of 56 taxa belonging to classes Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, Eugleno-phyceae, Zygnemophyceae, Rhodo-phyceae, and Xanthophyceae. Amongst all the taxa, 33 taxa belonged to Bacillariophyceae, 11 taxa to Chlorophyceae, 8 taxa to Cyanophyceae, and 1 each to Dinophyceae, Euglenophyceae, Zygnemophyceae, Rhodophyceae and Xanthophyceae. Amongst all the stations, Station 5 had greater taxonomic richness of the phyto-epiphyton on the rice stem which might be due to favourable nutrient concentration particularly nitrate-N in the rice field water with favourable water depth. On the other hand, Station 1 had lowest taxonomic richness of phyto-epiphyton which might be due to relatively shallow water depth with less phosphate-P concentration in the rice field water. Bacillariophyceae was the most dominant epiphytic algae in all the stations (Figure 2 B). This was due to presence of silica in the rice plant since rice plant is an accumulator of silicon [30].

Taxonomic richness and distribution of zoo-epiphyton in the rice-fish system of Apatani Plateau (Table 5) shows the presence of 7 taxa belonging to groups Protozoa, Bryozoa, Cladocera, Copepoda, and Rotifera. Amongst all the taxa Cladocera was the most dominant group of zoo-epiphyton in the rice fish system (Figure 2D). The dominance of Cladocera indicated shallow nature of the rice-fish ecosystem.

Gut content of *Cyprinus carpio* stocked in the rice-fish system of Apatani Plateau (Table 6) revealed that the fish fed on phytoplankton/ phyto-epiphyton and zooplankton/ zoo-epiphyton present in the rice field water and rice stems in the rice-fish system. The phytoplankton/ periphyton communities found in the fish gut belonged to classes Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae. Zooplankton/ zoo-epiphyton communities found in the fish gut belonged to groups Cladocera, Copepoda and Rotifera. A total of 25 taxa of phytoplankton/phyto-epiphyton belonging to Bacillariophyceae, 8 to Chlorophyceae, 3 to Cyanophyceae, 1 to Euglenophyceae and, 7 to Cladocera and

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1 each to Copepoda and Rotifera were observed in the gut of the stocked fish. Amongst phytoplankton/phyto-epiphyton classes Bacillariophyceae followed by Chlorophyceae remained dominant gut contents of *C. carpio* thereby indicating that Bacillariophyceae is the most preferred food item (whether it is in free floating form or it is in attached form) of the *C. carpio* stocked in the rice-fish system of Apatani Plateau. This finding is in conformity with the findings of Mondal *et al.*, 2013 [11] who observed Bacillariophyceae as the dominant food items in the gut of *C. carpio* stocked in the rice-fish system in Bangladesh. Amongst zooplankton, Cladocera was the most dominant group in the gut of the fish which indicates Cladocera group as the most preferred zooplankton food of *C. carpio* stocked in the rice-fish system of the Apatani Plateau. Gut content analysis also showed that few taxa such as *Alonella*, *Daphnia* (belonging to Cladocera) and *Brachionus* (belonging to Rotifera) were exclusively found as planktonic form in the rice-fish system and the rest were present either as planktonic or epiphytic form.

Taxonomic richness of different classes/groups of phytoplankton/zooplankton in water and phyto-epiphyton/zoo-epiphyton on rice stems and all the taxa present in the fish gut in the rice-fish system of Apatani Plateau (Figures 3A and 3B) show that amongst phytoplankton, and phyto-epiphyton, Bacillariophyceae class was most dominant in the system as well as in the fish gut and amongst zooplankton/zoo-epiphyton group, Cladocera was most dominant in the system as well as in the fish gut. All these indicate that food intake/preference of *C. carpio* stocked in the rice-fish system also depends on the availability of food in its habitat.

CONCLUSION

The study revealed that the rice-fish system of the Apatani Plateau is a moderately nutrient-rich shallow system where the pH of the rice field water fluctuated from slightly acidic to slightly alkaline condition. The phytoplankton and epiphytic algae were more diverse communities than the zooplankton/zoo-epiphytic communities. Bacillariophyceae was the most dominant phytoplankton and phyto-epiphyton class in the rice-fish system. Cladocera was the most dominant zooplankton and zoo-epiphyton group in the rice-fish system. The gut content analyses of *C. carpio* stocked in the rice-

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fish system showed a close relationship of food intake/preference with the available plankton/epiphyton communities in the rice-fish system. However, taxa under Cyanophyceae are less preferred food of the stocked *C. carpio* in the rice-fish system. The preference was more for phytoplankton/phyto-epiphyton communities belonging to class Bacillariophyceae and zooplankton/zoo-epiphytic communities belonging to group Cladocera. The gut content analysis revealed that although *C. carpio* is considered as an omnivore never the less it has its own preference for feed present in the system.

However, the present study is only a preliminary investigation on the habitat ecology and natural food of *C. carpio* stocked in the rice-fish system of Apatani Plateau. In order to get more detailed information there is a need for further investigation on the overall feeding habit and food selectivity in relation to growth pattern of *C. carpio* stocked in the rice-fish system.

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Formulation of low-cost Fish feed using locally available agro-based wastes and its efficacy on growth performance of common Carp (*Cyprinus carpio* L.) - A case study from Apatani landscape of Arunachal Pradesh in Northeast India

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Abstract

The present study was done to formulate a low-cost fish feed using locally available agro-based waste, and to test its efficacy on growth of common carp (Cyprinus carpio). The study was done in context of increasing fish production in the rice-fish system of the Apatani landscape of Arunachal Pradesh in Northeast India. Nutrient content analyses of the formulated fish-feed showed it to be comparable with the standard feed material. Efficacy test of the formulated feed under laboratory condition showed that specific growth rate and condition factor of the stocked fish were significantly more when it was fed with a low dose of the formulated feed (i.e., @ 3% of the initial body weight). Overall, the study highlighted the possibility of increasing fish production in the rice-fish system of Apatani Plateau by exploiting the existing agro-based wastes. This may help in upliftment of the rural economy and sustainability of the region.

Keywords: Low cost fish-feed, Agricultural waste product, Growth performance, *Cyprinus carpio*, Rice-fish system, Apatani Plateau.

Introduction

Paddy-cum-fish culture is practiced in many parts of India, viz., Kerala, West Bengal Arunachal Pradesh and Tripura[1-3]. In India, the agrarian *Apatani* hill tribes settled in the lower Subansiri district of Arunachal Pradesh (Figure-1) are the only Indian tribal farmers who traditionally practice paddy-cum-fish culture since past 50 years. Agro-chemicals and fish-feed are not administered in the agro-ecosystem during the culture period, which makes it unique in the context of production. The fishes (*Cyprinus carpio*) are cultured along with the local rice cultivars viz., *Amo, Mypia* and *Pyapee* in the paddy fields. The fish depend on the natural feed such as plankton, periphyton, and other feeding materials available in the rice field. However, short duration of the rearing period and perhaps limited nutrition in the rice-fish system do not allow greater fish production during the rice-fish culture period. As a result, only 150 to 250 kg ha^{-1} of fish (*C. carpio*) per season are harvested from the system[2], which is much below the fish yield per hectare in similar systems in China[4,5]. Therefore, it calls for formulation of a suitable fish diet that can be administered in the rice-fish system as supplementary feeding material that would increase fish production.

In the present study, we prepared a fish-feed formulation using locally available agro-based wastes from the Apatani Plateau. This was followed by nutrient analyses of the feed formulation and an efficacy test of the formulated feed on growth performance of the stocked fish, *C. carpio*. Efficacy test was performed to optimize the proportion of feed for supplementation in the rice-fish system that might be appropriate for optimal fish growth without disrupting the natural ecological balance within the rice-fish system.

Materials and Methods

Selection of raw materials: For formulating the low cost fish-feed, commonly available agro-based wastes in the Apatani landscape were selected viz., (1) fermented residual rice after preparation of *Apong* - a local rice beer, (2) periphytic algal clumps formed in rice-field water near the rice rhizosphere. Besides, small quantity of garlic (*Allium sativum*) was also used, as it has antioxidant property[6]. It may be mentioned here that garlic is not locally grown by the *Apatani* people but is commonly used by them as spice and is purchased from the local market.

Analysis of nutrient content of the locally available ingredients used for fish-feed formulation: The nutrient contents of the rice residues of '*Apong*' and the rice field algal mass were assessed on dry weight basis (oven dried at 70°C for 48 hours) following standard methods[7-9].

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Figure-1
Map showing the location of the Apatani Plateau

Fish-feed formulation: The steps involved in the process are mentioned below: Step 1: Drying the fish-feed ingredients i.e., the rice residues, algal mass and garlic in an oven at 70°C for 48 hrs. Step 2: Grinding the dried ingredients separately into powder form using a grinder. Step 3: Mixing the powdered ingredients in the proportion 1(rice residue): 0.5 (algal mass): 0.01 (garlic). Step 4: Preparing soft dough of the powdered mixture following the proportion as mentioned above by adding appropriate quantity of clean water (at normal room temperature). Step 5: Making pellets of suitable sizes from the fresh dough using a pelletizer. Step 6: Drying the pellets in an oven at 60°C for 24 hours.

Analysis of nutrient content of the feed pellets: The nutritional value of the fish-feed formulation was analyzed for their nutrient content at dry phase (oven dried at 60°C for 24 hours)[7-9].

Efficacy test of the feed pellets under laboratory condition: In order to carry out the efficacy test of the formulated feed, fish growth experiment using candidate species in aquarium condition was performed in the laboratory during December, 2014. The feeding trial was carried out for a period of four weeks in four experimental aquaria (30 L capacity). Fries of *Cyprinus carpio* of sizes ranging from 2.5-3.5 cm were collected from the nearest fish farm, and were acclimatized for 48 hours in the aquaria. This was followed by stocking the fries in the experimental aquaria under different treatments @ 12 individuals per aquarium. Three feeding treatments using pelleted feed respectively @ 3% (Treatment 1), 5% (Treatment 2), and 7% (Treatment 3) of initial body weight of the stocked fishes were tested simultaneously. The fishes were fed twice with the fixed daily ration respectively at 08:30 hr and 17: 30 hr. One aquarium with no supplementation of feed was used as control. It is assumed that in the control aquarium, the stocked fish survived only on the available plankton communities present in the aquarium water. At the end of each week, the treated fishes (each group with three replicates) from different experimental aquaria were measured for various morphometric and growth parameters[10-14]. The water in all the experimental aquaria was changed once during 15[th] day of stocking.

Assessment of water quality in the aquaria: Water quality parameters, which are generally considered for fish culture, were analyzed for three times following standard methodologies[15]. The first set of water analysis was done before stocking the fish in the aquaria to find out suitability of the water for the aquarium experiment. Second set of analysis was

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done on 14th day of stocking and the 3rd set on 28th day of stocking.

Statistical analysis: One-way ANOVA was performed to test the growth response, nutrient utilization capacity and survival parameters of the stocked fish under different feeding treatments. Regression model was run to explore the relationship of growth and survival parameters of the stocked fish with different feeding treatments. All the statistical analysis was performed using MS Excel and PAST 3.04[16].

Results and Discussion

Nutrient contents of both the locally available agro-based wastes used as fish-feed ingredients and the formulated fish-feed using the agro-based wastes and comparison of nutrient contents of the formulated fish-feed with standard fish-feed is represented in Table-1. The formulated feed contained high dietary protein (22.92%) which is considered suitable for better growth rate in fish[17]. Carbohydrate, although not so essential in fish feed[18], is included in aquaculture diets for their binding activity during feed manufacturing. In this regard, less carbohydrate content (2.39%) in the prepared feed is also considered suitable. Lipids content was less (3.35%) as compared to the general fish-feed standard. Besides, trace amounts of minerals like sodium and potassium, and traces of Vitamin C were also detected in the formulated fish-feed. However, greater concentration of phosphorous (7.36%) in the formulated feed cautions us against too much supplementation of the formulated fish-feed into the rice-fish culture system, which otherwise, might decrease the existing N: P ratio of the rice field water and would facilitate the dominance of nuisance Cyanophyceae algae[19] by replacing the palatable algal species from the rice-fish system.

Table-2 shows the feeding response, growth response, nutrient utilization and survival parameters of *Cyprinus carpio* fry fed with varying quantities of the prepared fish-feed in experimental aquaria. It revealed satisfactory feeding and 100% survival under all the treatments. Body weight, body length, standard length and body depth of the fries showed better performance under Treatment 2 beyond which feed supplementation (Treatment 3) had a negative effect on fish growth particularly on body length and body depth as shown in Figures-2A and 2B respectively. However, highest value of feed conversion ratio (FCR) and lowest values of condition factor (K) and specific growth rate (SGR) under Treatment 2 indicates less assimilation capacity and less suitable habitat condition for the stocked fish and a low fish growth rate in this treatment. SGR and K of the stocked fish were significantly more under Treatment 1 which also had lowest FCR and excellent feeding response as shown in Table-2 and Figures- 2C and 2D thereby showing better growth rate due to better nutrient assimilation accompanied by better habitat condition of the stocked fish in Treatment 1.

Table-1
Nutrient contents (%) of locally available agro-based wastes used as fish-feed ingredients and the formulated fish-feed using the agro-based wastes and comparison of nutrient contents of the formulated fish-feed with standard fish-feed

Nutrient content (%)	Agro-based wastes		Formulated fish-feed using the agro-based wastes	Nutrient contents of standard fish-feed as per Hassan, 2015
	Fermented residual rice after preparation of '*Apong*'	Periphytic algal clumps formed in rice-field water near the rice rhizosphere		
Carbohydrate	0.001	0.017	2. 39	Not very essential but may contain 15-20%
Protein	30.3	3.25	22.92	18-50%
Fat	0.1	0.01	3.35	10-25%
Calcium	0.01	0.06	1.15	Trace amount
Phosphorus	3.9	3.40	7.36	< 1.5%
Sodium	0.03	0.10	0.30	Trace amount
Potassium	0.3	0.63	1.27	Trace amount
Vitamin C	0.06	0.05	0.04	Trace amount

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The aquaculture experiment revealed that the stocked fish would perform better in terms of their feeding response, daily growth rate, nourishment and habitat condition when they are fed with minimum dose (i.e., @ 3% of their initial body weight; Treatment 1). It may also be mentioned here that as the feed had greater concentration of P, lower dose of the feed supplementation would also help in maintaining the existing ratio of N and P in the rice field water and the diversity of existing algal and zooplankton communities in the rice-fish system, that act as natural live feed for the stocked fish. Minimum supplementation of the formulated feed would help the stocked fish to grow better by feeding not only on the supplementary feed but also on the existing diverse natural live feed from the rice-fish system. This would help in sustainable utilization of the natural resources from both within (algal clumps in the water-logged rice field) and outside (left over of fermented rice after preparation of the '*Apong*') the rice-fish system by the stocked fish leading to increased fish production.

Table-3 shows water quality parameters before and after supplementing the prepared fish-feed for four weeks in the experimental aquaria and its comparison with water standards for freshwater fisheries. Efficacy test of the formulated fish-feed on the water quality parameters showed variations under different treatments, though no clear-cut trend was observed. However except the water temperature, the water quality of all the experimental aquaria was within the fishery standards[20, 21]. This was due to the seasonal effect as the experiment was conducted during the cold month of December, 2014.

Table-2
Feeding response, growth response, nutrient utilization and survival parameters of *Cyprinus carpio* fry fed with varying quantities of the formulated fish-feed in experimental aquaria

Parameters		Control	Treatment1 (feeding @ 3% of the initial body weight of the stocked fish)	Treatment2 (feeding @ 5% of the initial body weight of the stocked fish)	Treatment3 (feeding @ 7% of the initial body weight of the stocked fish)	F-ratio
Feeding response		-	Excellent	Good	Good	-
Growth response	Body weight (gm)	4.96 ±0.25	5.68 ±0.08	5.78 ±0.07	5.16 ±0.33	2.13
	Body length (cm)	7.11 ±0.20	7.33 ±0.11	7.60 ±0.09	7.28 ±0.15	7.64**
	Standard length (cm)	5.83 ±0.10	6.01 ±0.03	6.33 ±0.06	5.74 ±0.13	1.06
	Body depth (cm)	2.06 ±0.05	2.08 ±0.03	2.14 ±0.05	2.07 ±0.03	6.74**
	Specific growth rate (SGR) (% day^{-1})	2.07 ±0.77	5.18 ±1.34	1.54 ±0.37	4.11 ±0.84	3.62*
Nutrient utilization	Feed conversion ratio (FCR)	-	2.76 ±0.24	26.35 ±14.75	9.96 ±2.76	2.82
Survival parameters	Survival rate (%)	100	100	100	100	-
	Condition factor (K)	1.39 ±0.08	1.45 ±0.07	1.32 ±0.05	1.34 ±0.03	6.69**

Mean ±SE; n=12; **p<0.01; * p<0.05

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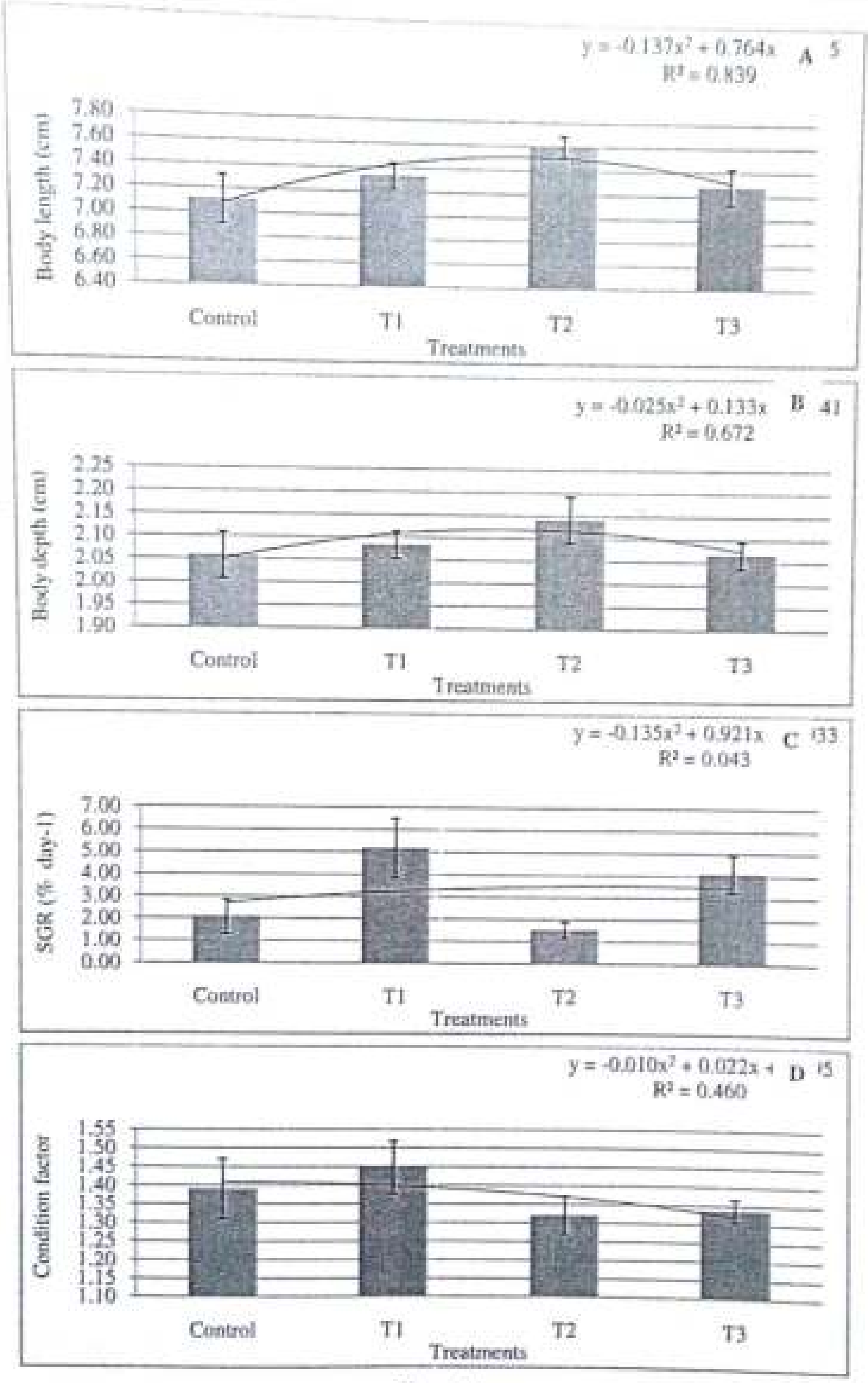

Figure-2
Changes in body length (A), body depth (B), specific growth rate (C) and condition factor (D) of *Cyprinus carpio* after four weeks of feeding with the formulated fish-feed under different feeding treatments in experimental aquaria

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Table-3
Water quality parameters before and after supplementing the formulated fish-feed for four weeks in the experimental aquaria and its comparison with water standards for freshwater fisheries

Parameters	*Quality of water which was used for the aquaria experiment before stocking the fish in the experimental aquaria	**Water quality in experimental aquaria after four weeks of supplementation of the prepared fish-feed				Standards of water properties for warm freshwater fisheries in pond as per	
		Control	Treatment 1	Treatment 2	Treatment 3	Boyd, 1998	Das *et al.*, 2015
Water temperature (°C)	20	17±1.0	19±1.0	18.5±0.5	15.5±0.5	-	25.0-32.0
pH	6.5	7.33±0.08	7.44±0.17	8.02±0.37	7.84±0.07	7.0-9.0	6.5-8.5
Dissolved oxygen (mgl^{-1})	6.12	9.97±1.11	9.40±0.20	8.68±0.98	9.49±1.25	5.0-15.0	5.0-10.0
Biological oxygen demand at 20°C for 3 days ($mg\ l^{-1}$)	0.88	6.49±0.78	6.08±2.50	4.09±1.52	4.80±0.61	-	<10.0
Free carbon dioxide ($mg\ l^{-1}$)	10.09	9.99±1.33	7.99±1.33	8.65±1.33	8.99±0.33	1.0-10.0	<3.0
Nitrate-N ($mg\ l^{-1}$)	0.2	2.51±0.66	4.22±1.63	2.45±0.74	4.43±0.87	0.2-10.0	0.1-3.0
Phosphate-P ($mg\ l^{-1}$)	0.29	0.14±0.0001	0.15±0.002	0.18±0.026	0.19±0.06	0.005-0.2	0.05 – 2.0

Mean ±SE; *n=1(Analyses of water quality from the water source before stocking the fish in the experimental aquaria); ** n=2 (Analyses of water quality of the experimental aquaria at 14th and 28th day of stocking the fish)

Conclusion

Overall, the study highlighted the possibility of increasing the secondary productivity of fish in the rice-fish system of Apatani Plateau by exploiting the existing agro-based wastes which would definitely result in more per capita fish-protein consumption and better economic returns to the local people of the Apatani landscape in sustainable and environmental friendly ways. However, further studies following on-farm feeding trials would enable us towards better understanding of the growth performance and habitat condition of the stocked fish, in addition to the overall ecology and economy of the Apatani rice-fish system.

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Bioresources and Traditional Knowledge of Northeast India

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A preliminary investigation on planktonic communities in the rice-fish system of Apatani Plateau, Arunachal Pradesh

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ABSTRACT

A study was undertaken to assess the planktonic communities and the water properties in the rice-fish system of Apatani Plateau of Arunachal Pradesh. Sampling was done during the aquatic phase of the system from May to September 2012. Water quality parameters like water temperature, pH, dissolved oxygen, free carbon dioxide, biological oxygen demand, total alkalinity, phosphate-P and nitrate-N were analyzed. Besides, qualitative and quantitative estimation of plankton were also done. The present investigation revealed the rice-fish systems of Apatani Plateau to be moderately nutrient rich and shallow systems. The study revealed a total of 77 taxa of phytoplankton belonging to classes Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, Euglenophyceae, and Zygonemophyceae. Besides, a total of 15 taxa of zooplankton were identified belonging to groups Cladocera, Rotifera, Decapoda, Copepoda, Calanoida, and Diplostraca. Among the phytoplankton community Bacillariophyceae was found to be the dominant class and among the zooplankton, Cladocera was the dominant group.

Key words: Plankton, rice-fish system, Apatani Plateau

INTRODUCTION

The term "Plankton" refers to those minute aquatic forms which are non motile or insufficiently motile to overcome the transport by currents and living suspended in the open or pelagic water (Greek planktons, meaning wandering). They comprise of heterogeneous group of tiny plants and animals adapted to suspension in the sea and fresh water. Their intrinsic movements, if any, are so feeble that they remain essentially at mercy of every water current. The plankton belonging to plant origin are called phytoplankton (phyto =plant; plankton =floating) and those belonging to animal origin are called zooplankton (zoo = animal; plankton = floating) (Eaton *et al.*, 1985).

The plankton can further be divided on the basis of their size viz., megaplankton- more than 8cm, macroplankton-size vary from 1mm to 1cm, mesoplankton- 0.5-1mm, microplankton- 0.06-0.5mm, nanoplankton- 0.005 to 0.06mm, and ultraceston -0.0005 to 0.005mm (Battish, 1992).

Planktons are of immense value as food for fishes and play an important role in the natural purification of polluted waters. However some plankton form a harmful bloom and they cause high mortality among the aquatic organism and pose a serious hazard in the water supply for domestic and industrial use. Plankton also play im-

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portant role as bio indicator of water quality.

Apatani Plateau of lower Subansiri district of Arunachal Pradesh (26° 55' to 28°21' N and 92° 40' to 94° 21' E) dominated by Apatani tribe who are involved in Integrated Agriculture Aquaculture in their wet rice fields since many years. This Integrated Agriculture Aquaculture is free from the use of agrochemicals and additional input of supplementary feed for fish and this unique practice is popularly termed as 'aji ngui assonii' (Saikia and Das, 2004). The cropping pattern of the area includes mono-cropping of wet rice once in a year in their wet plots and it is unique in context of production and also its sustainability as revealed by earlier researchers (Das *et al.*, 2007). However, till now there is no detailed information on the phytoplankton and zooplankton communities in this unique rice-fish system. Based on this above background information the present study was taken into consideration.

Study site

For the present study five stations from Apatani plateau were selected (Long. 27°33'-27°35'E and Lat. 093°49' to 093°50'N). These were Bamin-michi, Hari, Bulla, Hiza and Hong

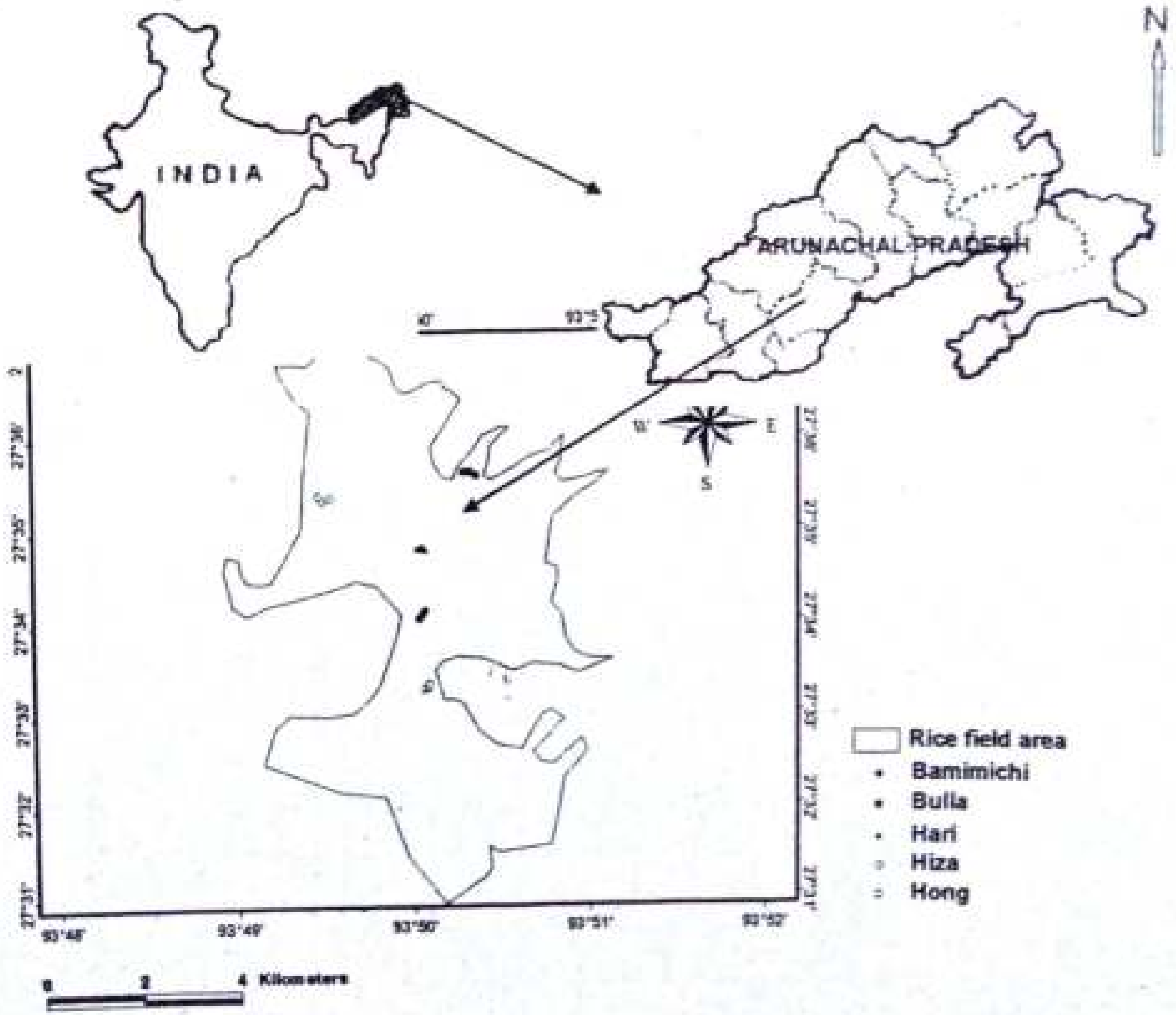

Figure 1. Study site

(Figure 1). The study was undertaken to look into the planktonic communities in relation to the water properties of the rice-fish system of Apatani plateau.

MATERIALS AND METHODS

Analysis of the physico-chemical properties of rice field water was done, following standard methods of Michael, 1984; Eaton *et al.*, 2005; Ramesh and Anbu, 1996; Gupta, 1999; Tripathi and Govil, 2001 and Rice *et al.*, 2012. For quantitative estimation of plankton Lackey's drop method (Lackey, 1938) was followed. Both the phyto- and zooplankton were sorted out and identified to the lowest possible taxonomic level using light microscope (Magnus MLXi binocular microscope). Identification of phytoplankton was done at magnification 40X and that of zooplankton at 10X following Needham and Needham, 1962; Pentecost, 1984; Battish, 1992; Anand, 1989, 1998; Bilgrami and Saha, 2004; John *et al.*, 2011 and Rice *et al.*, 2012.

RESULTS AND DISCUSSION

Table 1 shows the physico-chemical properties of water in the rice-fish system of Apatani Plateau. In Bamin-michi, high values of pH, DO and least value free CO_2 and PO_4-P gives a general indication about the presence of less organic matter content in that station. Greater value of NO_3-N in Bamin-michi was perhaps due the less water depth and subsequently less water volume in the station and hence the concentrations of nitrates particularly due to faecal matters of the stocked fish. Least value of total alkalinity in Bamin-michi indicates very low buffering capacity of the water there and hence more stressed condition for the stocked fish. Greater values of BOD and PO_4-P in Bulla indicates presence of phosphorous-rich organic matters in more quantities and more microbial activities that lead to the release of PO_4-P in greater amount at that station. Hiza had highest value of water and sediment temperatures. This might be due to less water depth at this station and also might be due to the reason that sampling in this station was done when the solar intensity was high that also lead to increase in air temperature thereby reflecting the close interaction of air, water and sediment temperatures in the aquatic system. Hiza also had greater value of total alkalinity thereby reflecting relatively more buffering capacity of the water in this station. Low values of pH, DO and greater value of free CO_2 in Hong reveals a relatively stressed condition in this station. This might be due to more density of planktonic organisms (Figure 4) and also the stocked fish. However, BOD was less in Hong. This was perhaps due to more water depth and hence more water volume that lead to the dilution of organic matters in the water and less water temperature that lead to less microbial activities in that station. Least value of NO_3-N in Hong was perhaps due to greater photosynthetic activity of the phytoplankton which had a highest density at that station (Figure 4A).

Table 2 shows the distribution of phytoplankton in the study area. It reveals the presence of 77 taxa of phytoplankton belonging to classes Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, Euglenophyceae, and Zygnemophyceae out of which 45 taxa belonged to Bacillariophyceae, 13 taxa to Chlorophyceae, 12 taxa to Cyanophyceae, 5 taxa to Zygnemophyceae and 1 each to Dinophyceae and Euglenophyceae. In all the stations Bacillariophyceae followed by Chlorophyceae was the most dominant phytoplankton class (Figure 2). The dominance of Bacillariophyceae in the rice-fish system was due to more silica content in the sediment and water which is the major nutrient required by the diatoms (Lukaw *et al.*, 2012). The second dominant phytoplankton class was Chlorophyceae which was perhaps due to low temperature of the rice field water, moderate nutrients like NO_3-N and PO_4-P (Mustapha, 2010) accompanied by better substrates, the paddy plants. Among all the stations, Hiza and Hong had the highest phytoplankton density

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Table 1. Physico chemical parameters of water in the rice fish system of Apatani Plateau

Stations	AT (°C)	WT (°C)	ST (°C)	WD (cm)	pH	TA (mgl^{-1})	DO (mgl^{-1})	BOD (mgl^{-1})	Free CO_2 (mgl^{-1})	Nitrate-N (mgl^{-1})	Phosphate P (mgl^{-1})
Ramin-michi	24	26.08	25.7	10.19	7.18	20.45	8.71	3.41	11.61	5.66	0.04
	±1.30	±0.85	8±0.7	±0.81	±0.12	±1.45	±0.7	±0.48	±1.21	±1.09	±0.01
	(20-33)	(22-30)	(21-30)	(6.4-13.5)	(6.7-7.9)	(12.6-29.33)	(7.06-11.28)	(1.33-6.48)	(5.9-17.91)	(0.23-12.34)	(0.03-0.12)
Hari	24.08	26.45	25.42	12.6	7.22	24.47	7.85	2.19	12.77	5.03	0.06
	±1.08	±1.01	±0.72	±0.83	±0.15	±2.31	±0.33	±0.39	±1.16	±1.00	±0.01
	(20-30)	(22-30)	(22-29)	(9.2-15.5)	(6.3-7.6)	(12.60-3.80)	(6.28-10.27)	(0.72-4.47)	(5.9-17.25)	(0.39-12.04)	(0.009-.127)
Bulla	23.73	24.51	23.33	12.02	6.83	28.54	8.3	3.67	13.62	4.08	0.07
	±0.94	±0.94	±0.75	±1.50	±0.2	±4.25	±0.27	±0.48	±1.08	±0.76	±0.02
	(19-32)	(20-29)	(19-28)	(6.2-20.6)	(5.02-7.5)	(13.2-34-6)	(6.48-10.54)	(0.94-4.91)	(4.98-19.2)	(0.52-9.04)	(0.01-0.29)
Hiza	24.58	27.33	25.92	10.23	7.24	32.54	8.4	3.54	12.1	[illegible]	0.15
	±1.33	±1.47	±1.20	±1.09	±0.07	±2.49	±0.44	±0.66	±1.11	±0.91	±0.01
	(20-33)	(21-35)	(20-32)	(5.0-15.0)	(6.7-7.5)	(20-44.66)	(6.34-11)	(0.72-8.44)	(6.59-18.57)	(0.34-8.23)	(0.004-.114)
Hong	22.93	24.4	24.33	12.62	6.69	23.18	7.11	2.15	18.6	3.95	0.05
	±1.08	±0.62	±0.54	±1.35	±0.27	±2.70	±0.36	±0.43	±0.95	±0.64	±0.01
	(19-32)	(20-28)	(22-29)	(6.8-21.7)	(4-7.7)	(12.6-35.33)	(5.12-9.04)	(0.24-7.03)	(7.98-19.9)	(0.11-7.87)	(0.003-.079)

Mean±SE, n=45; AT-Air temperature;WT-Water temperature, ST-Sediment temperature, WD-Water depth, TA-Total alkalinity, DO-Dissolved oxygen, BOD-Biological Oxygen Demand. Numbers in parenthesis designate range of mean values of the physico-chemical properties of water in different stations of the study area)

Table 2: Distribution of phytoplankton in the rice-fish system of Apatani Plateau. '-' indicates absence of the taxa

Class	Taxa	Bamin-michi	Hari	Buila	Hiza	Hong
Bacillariophyceae	*Achnanthes* sp1	-	+	+	-	-
	Achnanthes sp2	-	-	+	-	-
	Amphiplena pellucida	+	-	-	-	-
	Amphora	+	-	-	+	+
	Amphora ovalis	+	+	+	+	+
	Asterionella	-	-	-	+	-
	Cymbella sp1	+	+	+	+	+
	Cymbella sp2	-	+	-	-	-
	Diatoma sp1	+	+	+	+	-
	Diatoma sp2	-	-	+	+	-
	Diatoma vulgare	-	+	+	+	-
	Encyonema	+	+	+	+	+
	Epithemia	-	+	+	+	+
	Eunotia	+	+	+	+	+
	Fragellaria	-	+	+	+	-
	Frustulia	+	+	+	+	+
	Gomphonema	-	+	+	+	+
	Gomphonema angustrum	+	-	-	+	-
	Gyrosigma	-	+	-	-	-
	Gyrosigma valticum	-	-	-	+	-
	Himantidium	-	-	-	+	-
	Mastogloia	-	-	-	+	-
	Melosira	+	+	+	+	+
	Microcoleus vaginatus	+	+	-	+	-
	Pinnularia sp1.	+	+	+	+	+
	Pinnularia major	+	-	+	+	+
	Pinnularia Sp2.	-	+	+	-	-
	Pleurosigma	-	-	-	+	-
	Navicula gracillis	-	+	+	+	+
	Navicula placenta	+	+	+	+	+
	Navicula rhynchocephala	+	+	+	+	+
	Navicula sp.	+	+	+	+	+
	Navicula viridis	+	+	+	+	+
	Nitzschia	+	-	+	+	-
	Nitzschia sigmoida	-	+	+	+	-
	Stauastrum	+	+	+	+	+
	Stauastrum magnum	-	-	-	-	+
	Stauroneis	+	-	+	+	+
	Stauastrum brachiatum	+	-	-	-	-
	Stauastrum magnum	-	-	-	-	-
	Surirella sp1.	+	+	+	+	+
	Surirella sp2.	+	+	+	+	+
	Synedra	+	+	+	+	+
	Synedra fumosa	-	-	+	+	+
	Synedra ulna	+	+	+	+	+
	Tabellaria	+	-	+	-	-
	Tabellaria flocculosa	-	-	-	-	+
	Rholophalodia gibba	+	+	+	+	+
Chlorophyceae	*Ankistrodesmus*	-	+	+	-	-
	Closterium	+	+	+	+	+
	Closterium striolatum	-	-	-	+	-

	Cosmarium	-	-	-	-	+
	Desmidium	-	-	-	-	+
	Docidium	-	-	+	-	+
	Euastrum	-	-	-	-	-
	Euastrum crassum	-	-	-	-	-
	Gonatozygon	-	+	-	-	-
	Scenedesmus	-	+	-	-	-
	Spirogyra sp1	-	+	+	+	+
	Spirogyra sp2	-	+	-	-	-
	Ulothrix	-	-	-	-	+
	Zygnema	-	+	-	-	-
Cyanophyceae	*Anabaena*	-	+	+	+	+
	Aphanizomenon	-	+	+	+	+
	Nostoc	-	-	+	-	-
	Oscillatoria sp	-	+	+	-	-
	Phormidium	-	+	-	+	-

Table 3: Distribution of Zooplankton in the rice -fish system of Apatani Plateau

Group	Taxa	Bamin-michi	Hari	Bulla	Hiza	Hong
Cladocera	*Alona*	-	-	+	-	-
	Bosmina	-	-	+	+	+
	Chydorus	-	-	-	-	-
	Daphnia	-	+	-	+	+
	Leydigiopsis	-	-	+	-	-
	Moina	-	-	-	-	-
	Pleuroxus	-	-	+	-	-
Copepoda	*Cyclops*	-	+	-	-	-
	Canthocamptus	+	-	-	-	-
Calanoida	*Diaptomus*	- +	-	-	-	-
Decapoda	*Alonella*	-	+	+	+	+
	Palemonetes	-	-	+	-	-
Diplostraca	*Sida crystallina*	-	+	-	-	-
Rotifera	*Asplanchna*	-	+	-	-	-
	Brachionus	-	+	-	-	-
Total taxa	15	5	7	6	3	3

(Figure 4A). However, phytoplankton taxa was relatively rich in Hiza and poor in Hong (Table 2). Therefore, different reasons can be ascribed for the greater density of phytoplankton in two different stations of the rice field systems. In Hiza the greater phytoplankton density with more phytoplankton taxa might be due favorable environmental condition (particularly due to more alkalinity) for diverse taxa at that station. In Hong the greater phytoplankton density with less phytoplankton taxa might be due favorable environmental condition for selected taxa at that station.

Table 3 represents the distribution of zooplankton in the rice -fish system of the study area. It shows the presence of a total of 15 taxa of zooplankton in the study area belonging to groups Cladocera, Rotifera, Decapoda, Copepoda, Calanoida and Diplostraca. A total of 8 taxa belonged to Cladocera, 2 each to Rotifera and Copepoda besides 1 each to Decapoda, Copepoda, Calanoida and Diplostraca. It was observed that in all the sampling stations Cladocera was dominant zooplankton group (Figure 3) thereby indicating the rice-fish system to be free from intense pollution which favored their growth and reproduction (Ferdous and Muktadir, 2009). Besides, the abundance of Cladocera also indicates the presence of rich nutrients with weeds and shallow waters (Sharma *et al.*, 2012)

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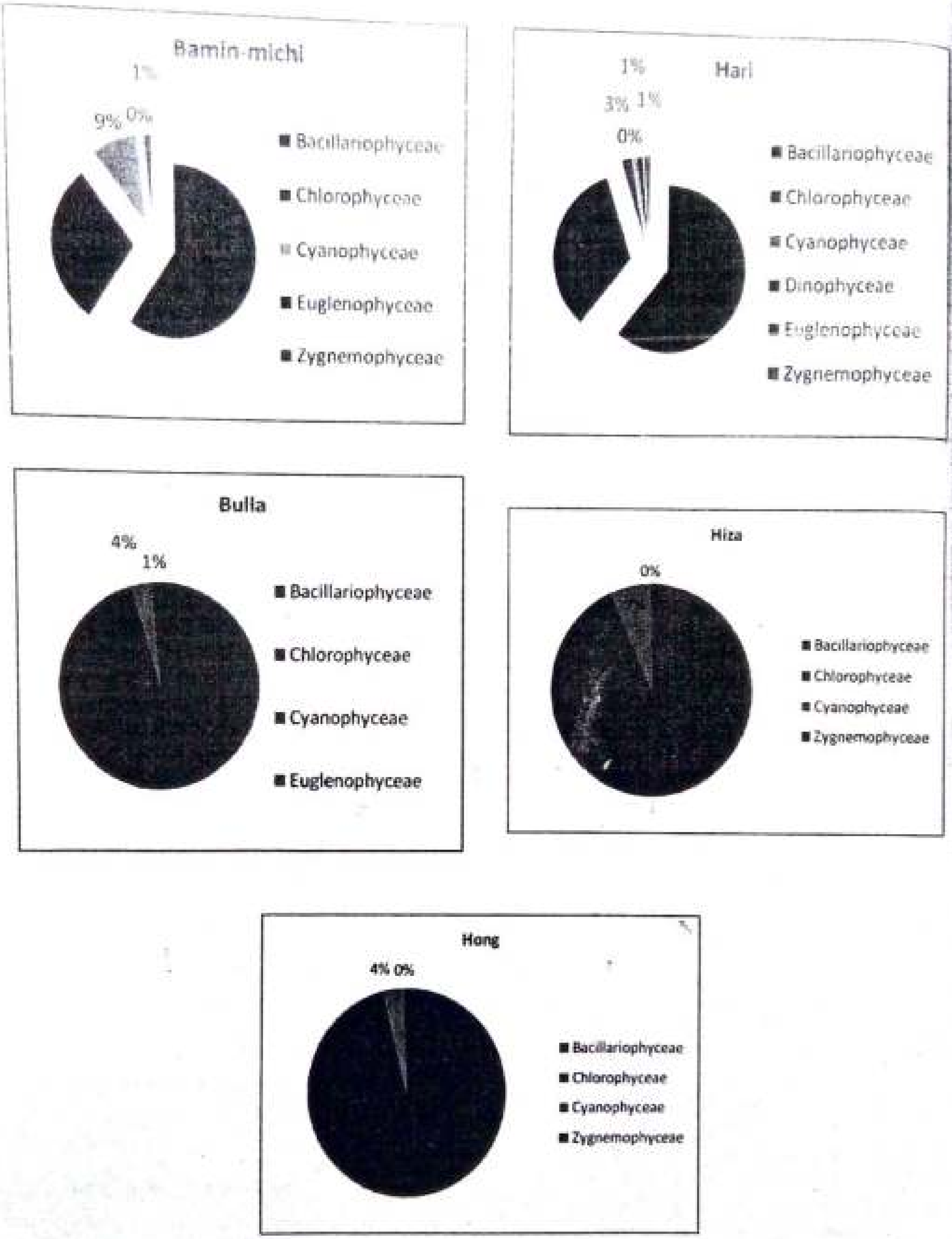

Figure 2. Class representation of phytoplankton in the rice-fish system of Apatani Plateau

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Figure 3. Order representation of zooplankton in the rice-fish system of Apatani Plateau

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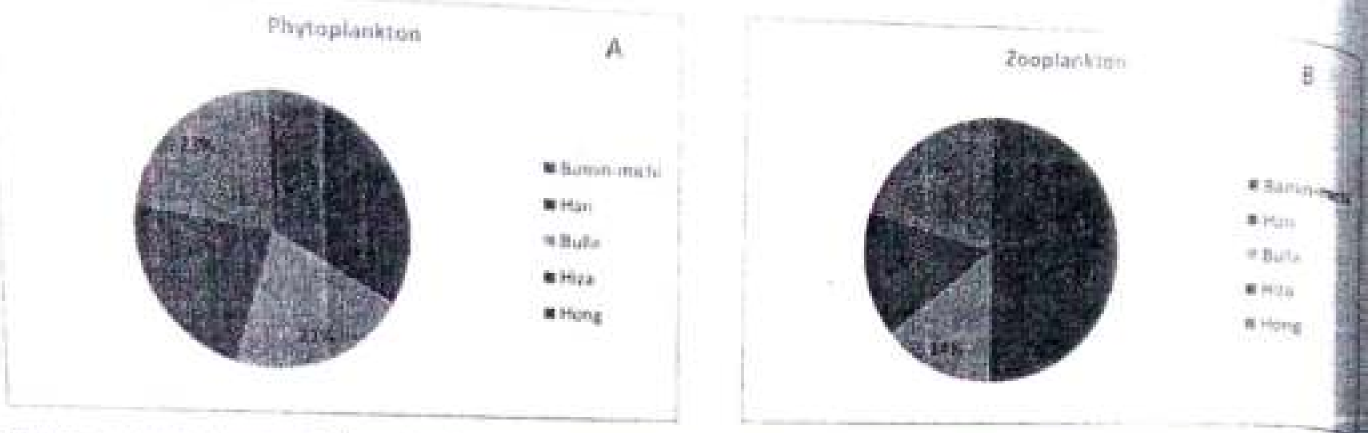

Figure 4. Total density of phytoplankton (A) and zooplankton (B) in the rice-fish system of Apatani Plateau

in the rice-fish system. Zooplankton density as well as its taxonomic richness in the rice-fish system of Apatani Plateau was highest in Hari and lowest in Hiza (Figure 4B and Table 3). This was perhaps due to greater variations in the water properties in both these station that favored the growth of zooplankton community in one station (Hari) while in the other station (Hiza) the water properties were not that congenial for the growth of diverse zooplankton.

CONCLUSION

Overall, the study shows that the physico-chemical properties of water of rice-fish system of Apatani Plateau varied considerably from one station to the other. Investigation of planktonic community revealed that the rice-fish systems of Apatani Plateau are moderately nutrient rich shallow lentic ecosystems. The phytoplankton were more diverse than the zooplankton. Amongst phytoplankton the most dominant class was Bacillariophyceae followed by Chlorophyceae with 45 and 13 taxa respectively. Amongst zooplankton the most dominant group was Cladocera with 8 taxa in the study area as a whole.

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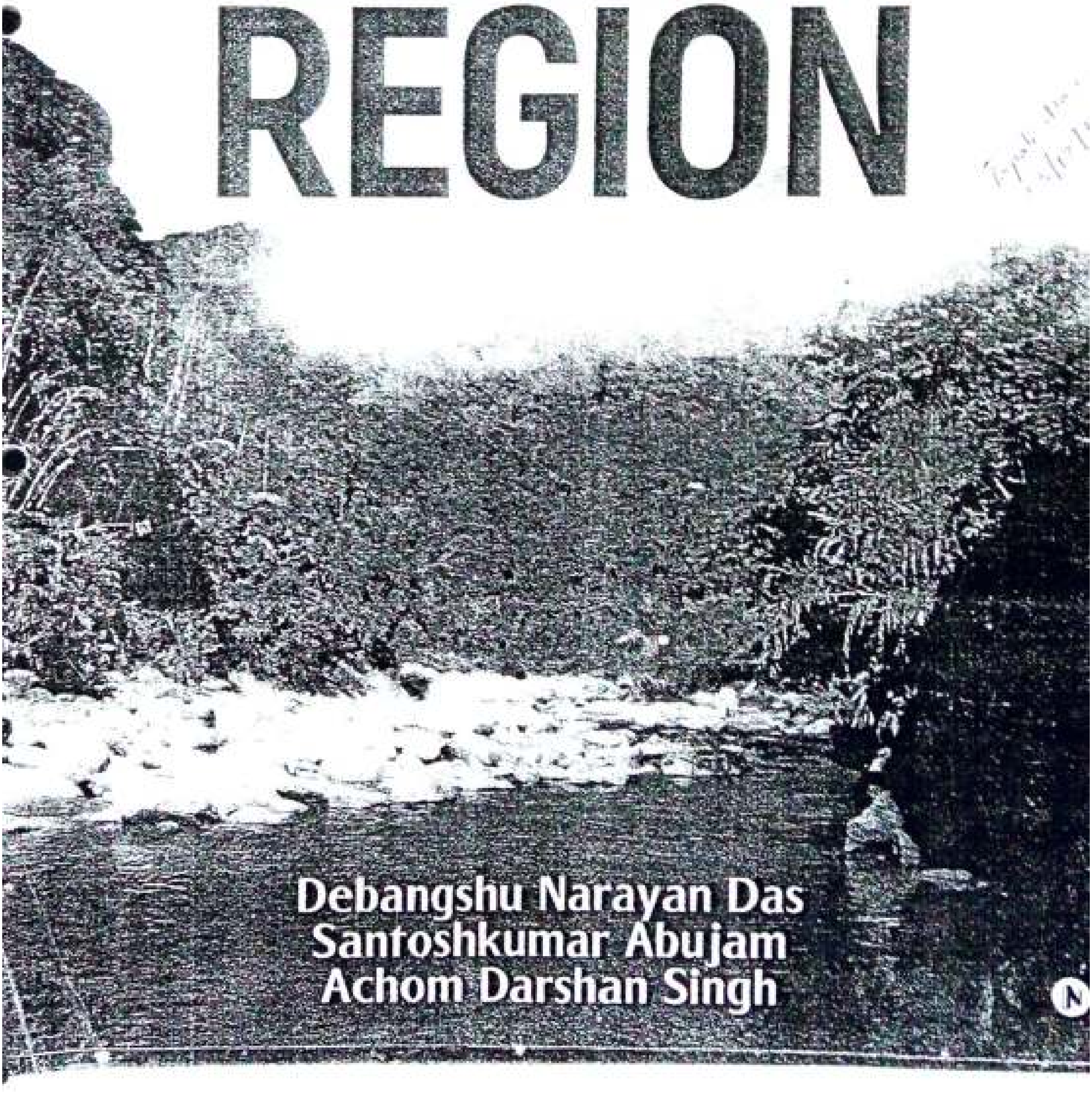

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Food Preference and Feeding of *Cyprinus carpio* stocked in High Altitude Rice-Fish System: A Case Study from Apatani Landscape of Arunachal Pradesh

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Abstract

The present study was conducted in high altitude rice-fish system of Apatani Plateau, Arunachal Pradesh to assess food preference and feeding of the stocked fish, *Cyprinus carpio*. Sampling was done during the fish stocking stage in the rice-fish system of the Apatani Plateau i.e., from May to August, for two consecutive years i.e., 2013 and 2014. Analyses of plankton in the rice field water, periphyton on rice-stems, and gut content analyses and computation of different feeding indices of *Cyprinus carpio* stocked in the rice-fish system were done. The study revealed the fish to be omnivorous in its feeding habit. Algae, both the suspended and the attached forms, dominated the food items of the stocked fish. Besides, the stocked fish also fed on zooplankton/zoo-periphyton communities, and miscellaneous food items like detrital matters and insects and insect larvae etc. Amongst phytoplankton/phyto-periphyton belonging to class Bacillariophyceae was the dominant food item of the fish and amongst zooplankton/zoo-periphyton the group Cladocera was the dominant food item. During the initial stage of stocking the fish preferred the food items available in the rice field water. However, with maturity, it shifted its food source to periphytic organisms present on the rice stems and on detrital matters available in the water logged rice field.

Key words: Rice-fish system, *Cyprinus carpio*, gut content, Apatani Plateau

Introduction

Apatani tribe dwelling in Apatani Plateau, located in lower Subansiri district of Arunachal Pradesh, North East India, are involved in integrated agriculture aquaculture in their wet rice fields since 50 years. The *Apatani* tribe is the only tribal community in India who traditionally practice rice-fish culture which is free from the use of agrochemicals and supplementary feed for the stocked fish (Saikia and Das 2004). The *Apatanis* do mono-cropping of rice in their fields. They principally use three traditional varieties of rice namely, *Emeo*, *Pyape* and *Mypia*. Regarding fish species, three strains of common carp viz., *Cyprinus carpio specularis*, *Cyprinus carpio communis*, *Cyprinus carpio nudus* are used to stock just after 10–15 days of rice transplantation into the fields. Being a simple production method, both fish and rice grow synergistically in rice-fish system and harness the existing environmental resources within the water logged rice fields. About 1.5 to 2.5 t/ha of rice and 150 to 250 kg/ha of fish per season are harvested from such system (Saikia and Das, 2004) which is far below the carrying capacity of the field in comparison to similar systems elsewhere like China.

In order to increase the fish productionfurther studies are needed to get complete information on available food and feeding behaviour of the stocked fish with respect to its growth in such systems. Earlier studies showed a close relationship of food intake by the stocked fish with the available plankton and rice-stem periphyton communities in the rice-fish system (Gupta *et al.*, 2015). In the present study attempt has been made to get detailed information on the overall feeding habit and food preference of *C. carpio* stocked in the rice-fish system during successive months of fish stocking in relation to its growth.

Materials and Methods

Study area: For the present study a total of 3 villages of the Apatani landscape were selected. These were Bamin-michi, Bulla and Hong (Fig. 1).

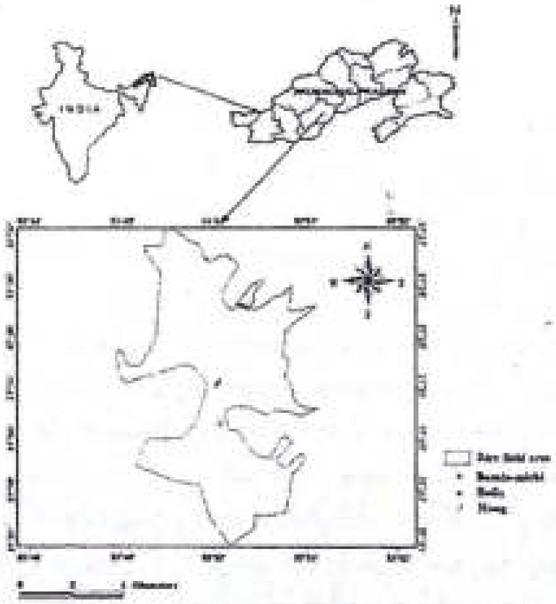

Fig 1: Map showing the sampling stations

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Field Sampling

In order to assess the available food of the stocked fish in the rice-fish system sampling of plankton in rice field water, periphyton on the rice stem were done during the fish stocking stage for 4 months from *May* to August for two consecutive years i.e., 2013 and 2014. The planktonic organisms present in rice field water were collected by passing 25 litres of rice-field water through plankton net of 40 μm screen size, and was immediately preserved in glass vials using 2 ml formalin (4%) which was later on brought to the laboratory for identification. The periphyton communities on the rice stem were collected by scrapping gently few representative rice stems (from 1cm² surface area) within the rice-fish system using a fine scalpel and preserved in glass vial using 2 ml formalin (4%) which were later on brought to the laboratory.

In order to know the food preferences of the stocked fish in the rice-fish system, fish samples from the rice-fish system were collected during the sampling period i.e., from *May* to *August* of years 2013 and 2014 which were immediately preserved in 10% formalin solution. Later on the samples were brought to the laboratory.

Laboratory Analysis

In the laboratory after one week of keeping the preserved plankton and periphyton samples for their settlements in the bottom of the container the final volumes of all the samples of plankton and rice stem periphyton collected from the rice fields were made to 10 ml either by decanting the excess supernatants very carefully or by adding distilled water. For the fish samples their respective lengths and weights were noted down after drying them with tissue paper. Intact guts were separated out from the fish samples and were weighed using an electronic balance (make: Shimadzu, model: Ax200, No D440420098). This was followed by noting down the length of the gut using a measuring scale. Afterwards, the individual guts were dissected out separately and their contents were taken out and preserved with 4 ml 4% formalin with little distilled water in separate test tubes. For gut content analysis of the stocked fish, stomach of each fish sample was dissected out and its contents were removed very carefully on Petri dish. Contents of the gut were diluted to 10 ml by adding distilled water. Identifications of plankton, rice stem periphyton and gut content of the stocked fish in the rice-fish system were done drop wise on glass slides and looking through binocular microscope (make: Magnus; model: MLXi). Microscopic identifications of plankton, rice stem periphyton and gut content of the stocked fish at lowest possible taxonomic level was done at 10X and 40X magnifications following standard keys Ward and Whipple (1959); Needham and Needham (1972); Biswas (1980); Ghosh and Sengupta (1982); Michael (1984); Vazirani (1984); Gohan (1988); Anand (1989, 1998); Santhanam *et al.* (1989); Battish (1992); Santra (1993) etc. For quantitative estimation of the plankton in the rice field water and periphyton on the rice stem and fish gut content, Lacky's drop method (Lackey, 1938) was followed. Quantification of food preference by the stocked fish was done using index of preponderance following Natarajan and Jhingran (1961). Intensity of feeding by the stocked fish in the rice-fish system was determined using Gastro-somatic index (GSI) following

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Desai (1970). Variations in food selectivity of the stocked fish were determined using relative gut length (RGL) following Al-Hussainy (1949).

Results and Discussion

The phytoplankton/phyto-periphyton communities present in the fish gut consisted of 68 taxa belonging to classes Bacillariophyceae, Chlorophyceae, Cyanophyceae, Rhodophyceae, Euglenophyceae, and Zygnemophyceae. On the other hand, zooplankton/zoo-periphyton communities present in the fish gut consisted of 12 taxa belonging to groups Protozoa, Bryozoa, Cladocera, Copepoda and Rotifera. Amongst phytoplankton/phyto-periphyton communities present in the fish gut, most dominant classes were Bacillariophyceae followed by Chlorophyceae and Cyanophyceae. Amongst zooplankton/zoo-periphyton communities present in the fish gut, the most dominant groups were Cladocera followed by Copepoda (Table 1). Index of preponderance showed that there were variations in food selection. However, certain taxa such as *Melosira* sp., *Navicula* sp., *Pinularia* sp., *Docidium* sp., *Staurastrum* sp., *Closterium* sp., *Cosmarium* sp., *Phormidium* sp. and *Anabaena* sp. amongst phytoplankton/phyto-periphyton communities; and *Bosmina* sp., *Alona* sp., *Macrotrrix* sp., *Chydorous* sp. and *Cyclops* sp. amongst zooplankton/zoo-periphyton communities were common in the gut of the stocked fish. Phytoplankton/phyto-periphyton belonging to classes, Zygnemophyceae, Rhodophyceae and Euglenophyceae and zooplankton/zoo-periphyton belonging to groups Protozoa, Bryozoa and Rotifera acted as occasional food items for the stocked fish (Table 1).

When comparison for fish gut content with plankton in rice field water and periphyton on rice stem was done it was observed that out of a total of 97 taxa of phytoplankton/phyto-periphyton from the the rice-fish system as a whole, 87 taxa were found in the rice field water, 79 taxa on rice-stem and 66 taxa in the fish gut (Table 2). On the other hand, out of a total of 20 taxa of zooplankton/zoo-periphyton from the selected stations of the rice-fish system as a whole, 20 taxa were found in the rice field water, 8 taxa on rice-stem and 12 taxa in the fish gut (Table 2). The result, therefore, indicates that the stocked fish do not feed all the available planktonic and rice-stem periphytic taxa in the rice field.

In the rice field water, phytoplankton comprised of 90% and zooplankton 10% (Fig. 2A) of the total plankton communities. On the rice-stem, phyto-periphyton comprised of 99% and that of zoo-periphyton 1% (2B) of the total rice-stem periphyton communities. In the fish gut, phytoplankton/phyto-periphyton comprised of 95% and zooplankton/zoo-periphyton comprised of 5% (Fig. 2C). All these, therefore, highlights the fact that in the rice-fish system there is thedominance of algae, both suspended (in the rice field water) and attached (on the rice-stem) forms with less occurrence of zooplankton/zoo-periphyton communities. The stocked fish feed on these food items with maximum feeding on the algal communities (phytoplankton/phyto-periphyton). Such feeding activity by the stocked fish in the rice-fish system also help the rice plants in better utilization of theavailable nutrients present in the rice field by reducing its competition for nutrients with the algae in such system.

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The month-wise cluster analyses amongst plankton from rice field water, periphyton from rice-stem and gut content of stocked *C. carpio* in the rice-fish system (Fig. 3) reveals that during May the gut content of the stocked fish had more similarity with plankton taxa present in the rice field water. It, therefore, indicates that during the initial stage of fish stocking (in the month of May) the juvenile fishes took most of the food items from the rice field water. During June, the gut content of the stocked fish had more similarity with the periphyton taxa on the rice-stem. This indicates that during June most of the food items of the stocked fish were from the rice-stem. During July, the gut content of the stocked fish formed a separate cluster, which indicates that during July the stocked fish depended equally on rice field water and rice-stem for its feeding purpose. During August, the gut content of the stocked fish had more similarity with the rice-stem periphyton. This indicates that with maturity the stocked fish depended more on the rice-stem for its feeding. The cluster analyses, therefore, revealed that there is a change in the selectivity of live food by the stocked fish in the rice field in the successive months of its stocking with respect to its growth. The results revealed that in the initial stage of fish stocking the juvenile fish preferred planktonic organisms. However, with maturity, its food preference shifted to periphytic organisms on the rice-stem. The present finding is also corroborated by similar observations of Saikia and Das (2009).

Monthly variations in relative values of index of preponderance (%) of *Cyprinus carpio* with respect to phytoplankton/phyto-periphyton and zooplankton/zoo-periphyton feeding in the rice-fish systemrevealed that maximum feeding on zooplankton/zoo-periphyton took place in the initial stage of stocking i.e., during May (Fig. 4) which dropped down in the succeeding months and the feeding shifted to algal biomass particularly those attached to the rice stems.

Variations in index of preponderance (%) of *Cyprinus carpio* with respect to phytoplankton/rice-stem phyto-periphyton classes and zooplankton/rice-stemzoo-periphyton groups in the rice-fish system showed that more than 70% of live food organisms of the stocked fish comprised of diatoms. This was followed by filamentous algae particularly those belonging to class Chlorophyceae (Fig. 5). On the other hand, amongst zooplankton/zoo-periphyton, group Cladocera was the most preferred food item of the stocked fish (Fig. 5).

Euclidean distance amongst plankton from rice field water, periphyton from rice stem and gut content of *C. carpio* stocked in the rice-fish system reveal that gut content of the stocked fish had more similarity with the periphyton taxa present on the rice-stem (Fig. 6). This therefore, reveals the fact that the stocked fish in the rice-fish system depend mostly on attached algae and animalcules on rice stems as the major source of its live food items.

Month-wise variations in gastro-somatic index of the stocked fish decreased consistently from May to August (Fig. 7A). This indicates a decrease in feeding activity of the stocked fish with increase in maturity. RGL was lowest in June and highest in August (Fig. 7B). This indicates the shift in feeding habit of the stocked fish. Lower value of RGL during June indicates predominance of omnivorous feeding during this month. This is due to the presence of diverse live food organism for the stocked fish during June.

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Greater value of RGL of the stocked fish in August indicates the tendency towards detritus feeding. This is due to greater availability of detrital matters in the rice field during that month. Because with maturity of the rice plant there is death of the leaves located at the lower portion of rice plant which act as source of detrital food for the stocked fish. Moreover, after weeding activities (as part of management practice in the rice field by the *Apatanis*) in the preceding months the lumps of weed which were heaped in the rice field get converted to detrital source of feed for the stocked fish in the rice-fish system. As RGL of the stocked fish was greater than one and less than 3, therefore it indicates predominance of omnivorous diet (Ward-Campbell and Beamish, 2005) by the stocked fish in the rice-fish system.

Conclusion

The various results related to food and feeding of the stocked *C. carpio* in the rice-fish system reveals that the fish is omnivorous in its feeding habit. Algae, both the suspended and the attached forms, dominated the food items of the stocked fish. Besides, the stocked fish also fed on zooplankton/zoo-periphyton communities, and miscellaneous food items like detrital matters and insects and insect larvae etc. During the initial stage of stocking the fish preferred the food items available in the rice field water. However, with maturity, it shifted its food source to periphytic organisms present on the rice stems and on detrital matters available in the water logged rice fields.

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Table 1: Gut content and index of preponderance of *Cyprinus carpio* stocked in the rice-fish system of Apatani Plateau

Gut contents	Class/group	Taxa present in the fish gut	Index of preponderance
Phytoplankton/ Phyto-periphyton (Total taxa = 68)	Bacillariophyceae	*Achnanthes* sp., *Achnanthes biasolettiana, Amphora* sp., *Amphora ovalis, Cyclotella* sp., *Cymbella* sp., *Diatoma* sp. *Diatoma vulgare, Encyonema* sp., *Eunotia* sp., *Epithemia* sp., *Flagellaria* sp., *Frustula* sp., *Frustula saxonica, Gomphonema* sp., *Pinnularia* sp., *Pinnularia major, Pinnularia acrosphaeria, Rhopaladia gibba, Himantidium* sp.,*Melosira* sp., *Navicula* sp., *Navicula mutica,, Navicula placenta, Navicula rhynchocephala,, Navicula viridis, Nitzschia* sp., *Nitzschia sigmoida, Stauroneis* sp., *Surirella* sp., *Sydera* sp., *Sydera ulna, Synedra fumosa, Tabellaria* sp.	*Melosira* > *Pinnularia* > *Navicula* >*Cyclotella* > *Navicula placenta* >*Cymbella* > *Achnanthes* >*Encyonema* >*Eunotia* >*Surirella* >*Synedra fumosa* > *Tabellaria*> *Frustula*> *Gomphonema*> *Navicula rhyncocephala*> *Stauroneis*> *Sydera*> *Ulna*> *Flagellaria*> *Amphora*> *Diatoma*> *Amphora ovalis*> *Nitzschia*> *Striatella*> *Rophalodia gibba*> *Diatoma vulgare*> *Pinnularia major*
	Chlorophyceae	*Ankistrodesmus* sp., *Closterium* sp., *Closterium kuetzingii, Cosmarium* sp., *Desmidium* sp., *Desmidium bailry, Docidium* sp.,*Euastrum oblongum, Gonatozygon* sp.,*Hydrodictyon* sp.,*Oocystis* sp.,*Pediastrum*	*Docidium* >*Staurastrum* >*Closterium* >*Cosmarium* >*Spirogyra* >*Hydrodictyon* >*Scenedesmus* >*Akistodesmus* >*Aphanizomenon* >*Desmidium* >*Oocystis* >*Staurastrum bengalense* >*Microcystis* >*Gonatozygon*

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		sp., *Scenedesmus* sp., *Selenastrum acuminatum*, *Spirogyra* sp., *Staurastrum* sp., *Staurastrum bengalense*, *Staurastrum oblongum*, *Tetraedron* sp., *Ulothrix* sp., *Zygnema* sp.	
	Cyanophyceae	*Anabaena* sp., *Aphanizomenon* sp., *Nostoc* sp., *Oscillatoria* sp., *Microcoleus vaginatus*, *Phormidium* sp.	*Phormidium* > *Anabaena* > *Nostoc* > *Oscillatoria*
	Rare phytoplankton /phyto-periphyton classes (Zygnemophyceae, Rhodophyceae, Euglenophyceae)	*Micrasterias* sp., *Micrasterias radiosa*, *Triploceras gracile*, *Batrachospermum*, *Phacus*, *Euglena*, *Trachelomonas*	*Batrachospermum* > *Trachelomonas* > *Micrasterias* > *Euglena* > *Phacus*
Grand total zooplankton/ zoo – periphyton taxa: 12	Cladocera	*Alona* sp., *Bosmina* sp., *Macrothrix* sp., *Pleuroxus* sp., *Chydorus* sp., *Daphnia* sp.	*Bosmina* > *Alona* > *Macrothrix* > *Chydorus* > *Pleuroxus* > *Daphnia*
	Copepoda	*Cyclops* sp., *Bryocamptus* sp., *Diaptomus* sp.	*Cyclops* > *Diaptomus*
	Rare zooplankton/ zoo-periphyton groups (Protozoa, Bryozoa, Rotifera)	*Centropyxis* sp., *Plumatella* sp., *Brachionus*	*Centropyxis* > *Brachionus*
Miscellaneous items		Detritus, disintegrated body parts of insects and insect larvae etc	-

Table 2: Comparative analyses of plankton in rice field water, periphyton on rice stem and plankton/periphyton in the gut of stocked *C. carpio* in the rice-fish system

Plankton/Periphyton	Taxa	Rice field water	Rice stem	Fish gut
Phytoplankton/phyto-periphyton class				
Bacillariophyceae	*Achnanthes* sp.	+	+	+
	Achnanthes biasolettiana	+	-	+
	Amphidinium sp.	+	+	-
	Amphipleura pellucida	+	-	-
	Amphora sp.	+	+	+
	Amphora ovalis	+	+	+

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	Asterionella sp.		+	
	Cyclotella sp.	+	+	+
	Cymbella sp.	+	+	+
	Encyonema sp.	+	+	+
	Eunotia sp.	+	+	+
	Epithemia sp.	+	+	+
	Diatoma sp.	+	+	+
	Diatoma vulgare	+	+	+
	Flagellaria sp.	+	+	+
	Frustula sp.	+	+	+
	Frustula saxonica	+	+	+
	Gomphonema sp.	+	+	+
	Himantidium sp.	-	+	+
	Melosira sp.	+	+	+
	Navicula sp.	+	+	+
	Naicula placenta	+	+	+
	Navicula gracilis	+	+	-
	Navicula mutica	+	+	+
	Navicula radiosa	+	-	-
	Navicula rhynchocephala	+	+	+
	Navicula sp.2	+	+	-
	Navicula viridis	+	+	+
	Nitzschia sp.	+	+	+
	Nitzschia sigmoidea	+	+	+
	Pinnularia sp.	+	+	+
	Pinnularia major	+	+	+
	Pinnularia acrosphaeria	+	-	+
	Pinnularia braunii	+	-	-
	Pleurosigma sp.	+	-	-
	Rhopalodia gibba	+	+	+
	Stauroneis sp.	+	+	+
	Surirella sp.	+	+	+
	Surirella elegans	+	+	-
	Sydera sp.	+	+	+

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	Sydera ulna	+	+	+
	Synedra fumosa	+	+	+
	Synura sp.	-	+	-
	Tabellaria sp.	+	+	+
	Tabellaria flocculosa	+	-	-
Total taxa	45	42	38	34
Chlorophyceae	*Ankistrodesmus* sp.	+	-	+
	Closterium sp.	+	+	+
	Closterium kuetzingii	+	-	+
	Cosmarium sp.	+	+	+
	Cosmarium aequale	+	-	-
	Cosmarium sexangulare	+	-	-
	Desmidium sp.	+	+	+
	Desmidium bailey	+	+	+
	Docidium sp.	+	+	+
	Euastrum sp.	+	-	-
	Euastrum oblongum	-	+	+
	Gonatozygon sp.	+	+	+
	Gonatozygon ralfsii	+	-	-
	Hydrodictyon sp.	+	+	+
	Netrium sp.	-	+	-
	Oocystis sp.	+	-	+
	Pediastrum sp.	+	+	+
	Scenedesmus sp.	+	+	+
	Selenastrum acuminatum	+	+	+
	Spirogyra sp.	+	+	+
	Staurastrum sp.	+	+	+
	Staurastrum bengalense	+	-	+
	Staurastrum magnum	+	-	-
	Staurastrum magaritacum	+	±	-
	Staurastrum nonanum	+	-	-
	Staurastrum oblongum	+	-	+
	Tetrahedron sp.	+	-	+

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	Ulothrix sp.	+	-	-
	Zygnema sp.	+	-	-
Total taxa:	29	27	16	21
Cyanophyceae	*Anabaena* sp.	+	+	+
	Aphanizemenon sp.	+	+	+
	Cylindospermum sp.	+	+	-
	Lyngbia sp.	+	-	-
	Merismopedia sp.	+	-	-
	Microlecus vaginatus	+	+	+
	Nostoc sp.	+	+	+
	Oedogonium sp.	+	-	-
	Oscilatoria sp.	-	+	+
	Phormidium sp.	+	+	+
	Spirulina sp.	+	+	-
Total taxa:	**11**	**10**	**8**	**6**
Rhodophyceae	*Batrachospermum* sp.	-	+	+
Total taxa:	**1**	**0**	**1**	**1**
Dinophyceae	*Ceratum* sp.	-	+	-
Total taxa:	**1**	**0**	**1**	**0**
Euglenophyceae	*Euglena* sp.	+	+	+
	Phacus sp.	-	+	+
	Trachelomonas sp.	+	+	+
Total taxa:	**3**	**2**	**3**	**3**
Zygnemophyceae	*Micrasterias* sp.	+	-	+
	Micrasterias alata	+	-	-
	Micrasteriasis radiosa	+	-	+
	Triploceras gracile	+	-	+
	Xanthidium antilopaeum	+	+	-
Total taxa:	**5**	**5**	**1**	**3**
Xanthophyceae	*Vaucheria* sp.	+	+	-
Total taxa:	**1**	**1**	**1**	**0**
Grand total taxa:	**96**	**87**	**79**	**68**
Zooplankton/zoo-periphyton group				
Protozoa	*Centropyxis* sp.	+	+	+
Total taxa:	**1**	**1**	**1**	**1**

Bryozoa	*Plumatella* sp.	+	+	+
Total taxa:	1	1	1	1
Cladocera	*Alona* sp.	+	-	+
	Alonella sp.	+	-	-
	Bosmina sp.	+	+	+
	Bosmina longirostris	+	-	-
	Chydorous sp.	+	+	+
	Daphnia sp.	+	-	+
	Macrothrix sp.	+	-	+
	Moina sp.	+	-	-
	Leydigiopsis sp.	+	-	-
	Pleuroxus sp.	+	+	+
Total taxa:	**10**	10	3	6
Copepoda	*Bryocamptus* sp.	+	-	+
	Canthocamptus sp.	+	-	-
	Cyclops sp.	+	+	+
	Diaptomus sp.	+	-	+
	Palemonetes sp.	+	-	-
Total taxa:	5	5	1	3
Rotifera	*Asplanchana* sp.	+	-	-
	Brachionus sp.	+	+	+
	Lecane inopinata	+	+	-
Total taxa:	3	3	2	1
Grand total:	**20**	20	8	12

Legend: '+' indicates presence and '-' indicates absence of the taxa concerned

Fig 2: Relative abundance of phytoplankton and zooplankton communities in rice field water (A), phyto-periphyton and zoo-periphyton communities on rice stem (B) and plankton/periphyton in gut of *Cyprinus carpio*(C) stocked in the rice-fish system

Fig 3: Monthly variations in Euclidean distance amongst plankton from rice field water (RFW), periphyton from rice-stem (RS) and gut content (FG) of *Cyprinus carpio* stocked in the rice-fish system

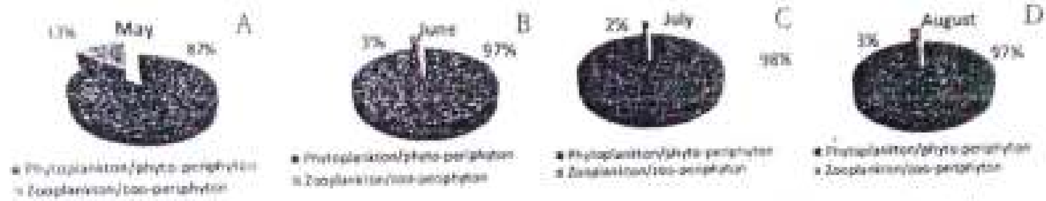

Fig 4: Monthly variations in relative values of index of preponderance (%) of *Cyprinus carpio* with respect to phytoplankton/phyto-periphyton and zooplankton/zoo-periphyton feeding in the rice-fish system.

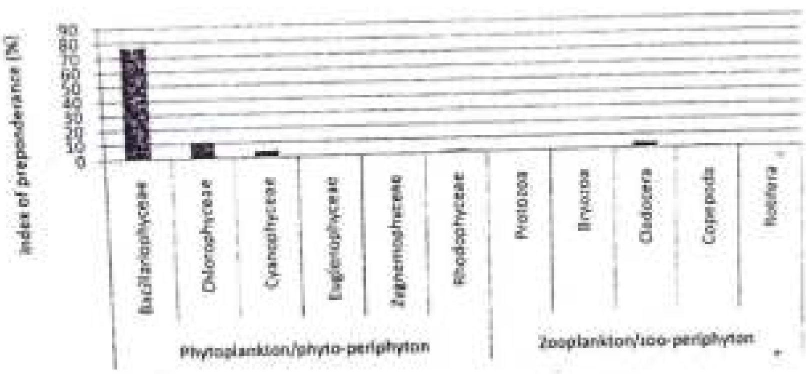

Fig 5: Variations in index of preponderance (%) of Cyprinus carpio with respect to phytoplankton/rice-stem phyto-periphyton classes and zooplankton/rice-stem zoo-periphyton groups in the rice-fish system

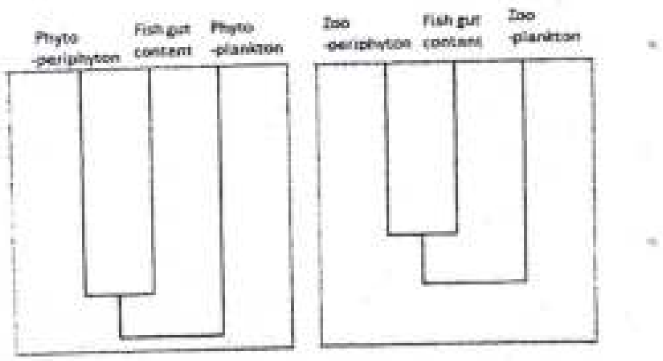

Fig 6: Euclidean distance amongst planktonfrom rice field water, periphyton from rice stem and gut content of *C. carpio* stocked in the rice-fish system

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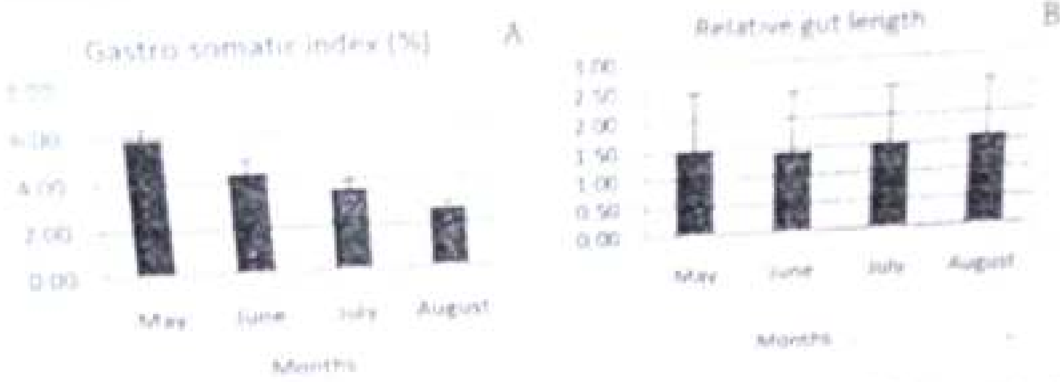

Fig 7: Month-wise variations in gastro-somatic index (A) and relative gut length (B) of *Cyprinus carpio* stocked in the rice-fish system

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