hypophthalmus in carp as well as shrimp aquaculture farms. It is important to point out that demand for carps is still greater and it costs more, at Rs.50-70/kg. Farmers are producing *P. hypophthalmus* at a lower investment but the cost of production is escalating considering the cost of antibiotics and other chemicals. This situation is impacting marginal farmers, consumers, culture environment and socio-economic conditions.

Conclusion

The study was based on interaction with aquaculturists, state fishery officials, fish dealers in the markets, laboratory studies of diseased samples in the states of West Bengal and Andhra Pradesh and desktop analysis of the world literature related to the culture of *P. hypophthalmus*. Based on the study the following scenario emerges for *P. hypophthalmus* culture in India:

- The culture of *P. hypophthalmus* was found to be prevalent in the states of West Bengal and Andhra Pradesh.
- Further spread of *P. hypophthalmus* farms in fishery sensitive and biodiversity rich areas such as Western and Eastern Ghats can harm indigenous fish diversity.
- *P. hypophthalmus* is a riverine fish and it has a great potential to mature and breed in rivers.
- The escapee *P. hypophthalmus* may enter the natural waters and compete with wild fish affecting the ecosystem balance.
- Use of fishmeal, trash fishes in *P. hypophthalmus* feed will deplete resources on which other local fish depend as food.
- *Pangasianodon hypophthalmus* is prone to diseases such as haemorrhagic septicemia, bacillary diseases, *Flavobacterium columnarae*, *Trichodina* and can impact farmed and wild stocks.
- Inappropriate use of antibiotics and chemicals practiced in *P. hypophthalmus* culture can have adverse impacts on the environment and human health.

Consequently, the culture of *P. hypophthalmus* in India warrants a very cautious and regulated approach. It is suggested to discourage and prevent the practice of free and widespread culture of *P. hypophthalmus* in the country as it could be a threat to our aquatic biodiversity.

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Life of a river in the Himalaya: An ecological study of Trisuli River system in Nepal

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There are three major river systems in Nepal – the Koshi in the east, Gandaki in the centre, and Karnali in the west. All of them drain into the Ganges River basin, flowing through northern India and emptying in the Bay of Bengal.

The Trisuli River, one of the seven major tributaries of Gandak River Basin, originates in the Gosainkunda Lake (approximately 4,500 altitude) of Rasuwa District in Central Nepal. According to Hindu legend, the Trisuli River originated by Lord Shiva driving his trident 'Trisul' in the hill just above the Gosainkunda to create three springs when he needed a cool place to rest in the Lake Gosainkunda. The Gandaki River system is the main tributary and mixes with other rivers such as Buri Gandaki, Marsyangdi and Seti Rivers as it flows ahead. Trisuli River starts from Betrawati (625 altitude) and flows to Narayanghat (170 altitude) over a distance of 141 km. Trisuli joins the Bhote Kosi that flows from Tibet, and which is a most popular rafting river with impressive gorges and exciting rapids. After Betrawati it joins other major rivers to its flow such as Buri Gandaki, Marshyangdi and Seti. The Kaligandaki River originates in Mustang and converges with Trishuli at Deoghat in Chitwan and changes its name to the Narayani, which goes on to meet the Ganges in India. The river runs about 240 km traversing through high mountains, midhills and terai of Rasuwa, Nuwakot, Dhading, Gorkha, Tanahu and Chitwan Districts, and merges with six other rivers - Burhi Gandaki, Kali Gandaki, Madi, Darondi, Marsyangdi and Seti to become Narayani in Devghat.

The main source of the Trisuli River discharge is the snow and glacier melt from the higher Himalayas. The Bhotekoshi River is the major tributary that feeds the river in the upper stretch, although there are many other tributaries. Fish biodiversity in the Trisuli is rich and the average catch is 18kg/ha, amounting to about 7,031 tonnes annually, providing essential income and nutrition for the local people living around the river system.

We conducted a study of the Trisuli river system with the objectives to:

- Study the seasonal and spatial variations in physico-chemical parameters.
- Study the flora and fauna of the river.
- Evaluate the influence of ecological settings and human behaviour on the river system.
- Forty seven sampling stations were taken based on mainly perennial tributary confluence of Trisuli River along the longitudinal stretch from Gosainkunda, Rasuwa to Trivenighat, Nawalparasi except in some stations based on riparian urbanisation and industrial activities in the Narayani River (Figure 1). A field survey was conducted in two seasons during post monsoon in September 2008 and pre-monsoon in March/April 2009 respectively.

The temperature, dissolved oxygen, turbidity, conductivity, pH, alkalinity, and total hardness were measured on site whereas for nutrients analysis NH_4-N and NO_2-N+NO_3-N inorganic phosphate (PO_4-P), total phosphorus, and chlorophylla and pheopigment[1] were carried out in the laboratory.

Phytoplankton and zooplankton were measured qualitatively up to species and quantitatively with the help of microscope using standard methods. Fish samples were collected through the fishermen and the local markets along the river sides including information fish species available in the river system through local people and fishermen. The fish species were identified and classified according to classification of Jayaram[2], Shrestha[3] and Talwar and Jhingran[4].

Findings

Physico-chemical parameters

Water temperature in the Trisuli River system widely differed along with the altitude between the origin of water at Gosaikunda (4,400 msl) and Narayani River-the Trivenighat (84 msl) from 12.5-27.4°C during post-monsoon and from 6.1-29.6°C during pre-monsoon season (Table 1). The maximum water temperature (29.6°C) was after direct mixing of untreated effluents from a beer factory in the Narayani River that might have increased the water temperature. Glacial waters dominated the Trisuli River system until the Tadi River joined Trisuli at Devighat. Water temperature has shown a strong positive correlation ($r=0.75$, $P\leq0.01$), which was reported similarly by Sharma and Shrestha[5]. Weather, altitude, stream bank vegetation, impoundments, discharge of sewage and polluted water, urban storm water, rain and flood, landslides, settlement of dense population, groundwater inflows to the river etc. are the causes of changing in water temperature.

Water temperature affects the ability of water to hold oxygen, rate of photosynthesis by aquatic plants and the metabolic rates of aquatic organisms. The pH value was almost within the permissible level (6.5-8.5) having mostly alkaline ranging from 6.5-8.6 during post monsoon and from 5.5-8.2 during pre monsoon (Table 1). The pH in Trisuli River system is favourable for all types of aquatic organisms since the optimum standard is 6.5-8.5[6,7,8,9] except in few places (5.5), where direct discharge of sewerage and household waste mixed into the river.

Turbidity ranged from 0.5->440 NTU showing highest during post-monsoon and from 0.9-185.6 NTU during pre-monsoon. The turbidity is high in Nepalese river systems due to mostly to feed by glaciers ranging from 300-1,500 NTU for 6 months from April to September[10,11]. Turbidity was high after joining at Narayani due to the direct discharge of untreated effluents from paper and beer factories. High turbidity during post-monsoon might be due to flow of high suspended particles which can absorb more heat and raise water temperature.

Table 1. Physico-chemical parameters of water quality of Trisuli River system.

	AT	WT	pH	Turbidity	CON	DO	TA	TH	TP	PO_4-P	NH_4-N	NO_2-N + NO_3-N	Chlorophyll[a]	Pheo-pigment
Post-monsoon														
Min	11	12.5	6.5	0.5	8.2	5.6	30.0	0.0	0.002	0.000	0.002	0.000	0.002	-0.163
Max	38	27.4	8.6	440	251.0	9.6	140.1	94.0	0.200	0.003	0.013	0.138	0.096	-0.002
Mean	29.5	21.9	7.7	259	110.4	8.4	65.8	42.6	0.060	0.001	0.005	0.032	0.037	-0.062
SD	4.8	3.2	0.6	178	51.8	0.8	21.1	17.5	0.056	0.001	0.001	0.042	0.031	0.053
Pre-monsoon														
Min	7.8	6.1	5.5	0.9	12.2	7.8	10.0	0.0	0.000	0.000	0.000	0.000	0.001	-0.125
Max	36.3	29.6	8.2	186	534.0	12.5	190.2	320.0	0.177	0.177	0.003	0.056	0.073	-0.002
Mean	27.8	20.4	7.4	53.1	190.8	9.3	66.2	188.7	0.015	0.010	0.0004	0.031	0.008	-0.015
SD	5.3	4.2	0.6	43.1	81.5	1.1	28.5	64.8	0.026	0.026	0.0008	0.016	0.014	0.023

High turbidity can leads to decrease photosynthetic activities and dissolved oxygen affecting the aquatic organism, especially fish fauna mostly during post monsoon due to rain washed into the river from different places including soil erosion making more turbid water.

Conductivity ranged from 8.2-251.0 µS/cm during post-monsoon and from 12.2-534.0 µS/cm the higher during pre-monsoon (Table 1) but mostly within range acceptable for fisheries (150-500 µS/cm) except little higher in some places. The conductivity was low in the upper stream as glacial fed water is low in content of ions and minerals but increased downstream after mixing with many large and small rivers or tributaries and the discharge of untreated effluents from a beer factory including heavy ionic load in Narayani River, similar to the reports of Bhat[12,13]. The variation is due to the ionic composition of the precipitation and diluting effects of the large volume of the rain[8,14]. The conductivity is influenced by temperature and high temperature will improve conductivity[9]. Water temperature and conductivity have shown strong direct correlation in our study ($r=0.75$, $P \leq 0.01$).

Dissolved oxygen ranged from 5.6-9.6 mg/l during post-monsoon and from 7.8-12.5 mg/l during pre-monsoon showing above the limit (>5 mg/l) that considered good for all kinds of aquatic organisms[6,15] (Table 1). It was found higher during pre-monsoon due to more turbid water with heavy rain flows into the river. Dissolved oxygen showed inverse correlation with temperature ($r=-0.60$, $P \leq 0.01$) similar report made by Mishra and Yadav[13,16]. The low temperature and high speed of water flow increase dissolved oxygen in upstream and high temperature with low speed of water flow decrease dissolved oxygen in downstream. So the fast moving water and colder water contain higher dissolved oxygen than slow or stagnant water and warmer water.

Total alkalinity ranged from 30.0-140.1 mg/l during post-monsoon and from 10.0-190.2 mg/l during pre-monsoon (Table 1). Alkalinity is the measure of weak acids and weak acid-salts14 and is important factor for aquatic life to protect against pH changes keeping pH fairly constant. Alkalinity >20 mg/l is considered to be very good in buffering capacity[9] and it was >20 mg/l in all stations except in Gosainkunda (10 mg/l) and was highest (190 mg/l) near beer factory. A positive correlation has shown between alkalinity and pH ($r=0.50$, $P \leq 0.01$) and alkalinity and phosphate ($r=0.75$, $P \leq 0.01$). Total hardness varied from 0.0-94.0 mg/l during post-monsoon and higher from 0.0-320.0 mg/l during pre-monsoon (Table 1), which might be due to the low concentration of calcium and magnesium ions during post-monsoon[17] and has shown strong positive correlation ($r=0.75$, $P \leq 0.01$) with total alkalinity. High content of total hardness is a characteristic of Nepalese river systems due to heavy rocks available containing high amounts of calcium and magnesium. Total hardness was high downstream after joining the Narayani River near Narayanghat bajar due to intense bathing and washing activities. Total phosphorus and phosphate-phosphorus were very low in Trisuli River system ranging from 0.002-0.200 mg/l during post-monsoon and from 0.0-0.177 mg/l during pre-monsoon (Table 1). The highest value recorded (0.177 mg/l) after joined river at Narayani River near the beer factory followed by the paper mill.

Total phosphorus was slightly higher in post-monsoon than pre-monsoon similar to reports by Panigrahi24. PO_4-P ranged from 0.000-0.003 mg/l during post-monsoon and from 0.000-0.177 mg/l during pre-monsoon. Total phosphorus and phosphate-phosphorus come from human and animal wastes, phosphate-rich rocks, wastes from laundries, cleaning and industrial processes, and farm fertilisers[14], which are present in high amounts near the beer factory and paper mill. Phosphate stimulates the growth of plankton and provides food for fish and might support aquatic life, particularly fish populations, to enhance and improve productivity in the Trisuli River system. NH_4-N was absent in almost all stations during pre-monsoon except some places near farmland, settlements and industrial areas and varied from 0.002-0.013 mg/l during post-monsoon and from 0.0-0.003 mg/l during pre-monsoon. NH_4-N above 0.02 mg/l concentration is lethal to fish species[18] but it was below in both seasons and unionised ammonia is toxic to aquatic organisms, especially to the fish species and it was very low during post monsoon which might be due to dilution and flushing by rainwater. NO_2-N+NO_3-N ranged from 0.0-0.138 mg/l during post-monsoon and from 0.0-0.056 mg/l during pre-monsoon (Table 1). NH_4-N, nitrate, nitrite and phosphate showed very limited concentration indicating the water in the Trisuli River system is not polluted and good for aquatic life particularly for fish except in heavy flood during monsoon and when landslides occur and unwanted things are washed into the river system.

Plankton

Plankton is a very important source of food in some rivers[19,20] and they form basic food source in any aquatic organism, especially for fish species. Phytoplankton was observed from 32 species belonging to 6 groups dominating by Bacillariophyceae (84%) with 19 species followed by Chlorophyceae (9%) with seven species, Cynophycea (4%) with four species, Eugleniae (2%) with two species and Dinophyceae (0.5%) and Chrysophyceae (0.5%) with one species each, respectively (Figure 2). Similar results were reported by Kostkeviciene[21] and Nwadiaro and Ezefili[22]. Among bacillariophyceae, *Synedra ulna* (30.3%) was the highest density followed by *Navicula hasta* (12.2%) and *Cocconeis placentula* var. lineata (7.1%) and others, respectively. *Closterium gracile* (3.5%) and *C. acerosum* (2.4%) were dominated in Chlorophyceae, whereas *Surirella sp, Gyrosigma distortum*, *Elakatothrix gelatinosa*, *Spirogyra* sp., *Ceratium hirundinella*, *Amphora ovalis*, *Frustulia* sp., *Nitzschia* sp., *Dinobryon bavaricum* and *Oscillatoria* sp. were the least abundant (<1%). Phytoplankton density (48 cell/ml) and species richness were high after joining in the Narayani River at Trivenighat near the beer factory. Zooplankton were predominantly protozoa (41%) and rotifera (39%) (Figure 3) in the Trisuli River similar finding by Ali[23] and Djurkovic[24]. 17 species of Rotifera were observed: *Brachionus angularis*, *B. forficula*, *B. rubens*, *B. quadridentatus*, *Keratella cochlearis*, *Platyias quadricornis*, *Euchlanis dilatata*, *Kellicottia longispina*, *Lepadella patella*, *Lecane luna*, *Monostyla bulla*, *M. hamata*, *Trichocera cylindrical*, *Polyarthra trigla*, *Conochilus unicornis* and *Philodina roseola*, and nine species of protozoa: *Enchelydium* sp., *Bursaria* sp., *Actinophrys* sp., *Arcella vulgaris*, *Difflugia corona*, *Cileatea* sp., *Nebella* sp. and *Centropyxis aculeate*. Seven species of cladocera were observed: *Diaphanosoma brachyurum*, *Daphnia* sp., *Bosmina longirostris*, *Bosminopsis deitersi*, *Chydorus sphaericus*, *Alona* sp. and *Camptocercus rectirostris* and four species of copepoda: *Cyclops vicinus*, *Mesocyclops leuckarti*, *Nauplius* sp. and *Bryocamptus* sp., respectively. *Difflugia corona* (16%) was the highest in number followed by *Keratella cochlearis* (12.9%), *Brachionus rubens* (10.2%), *Difflugia* sp. (9.8%) and other species, respectively. Zooplankton diversity, species richness and density (67,500 individuals/l) were recorded to be highest after the join of the Narayani River, before entering urban territory near the beer factory.

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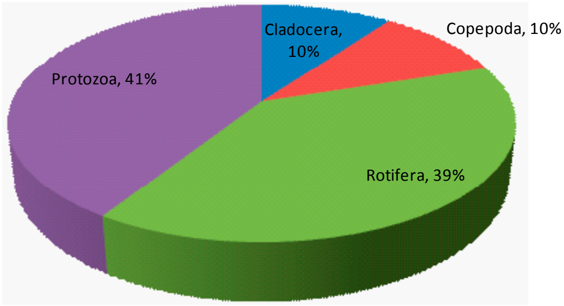
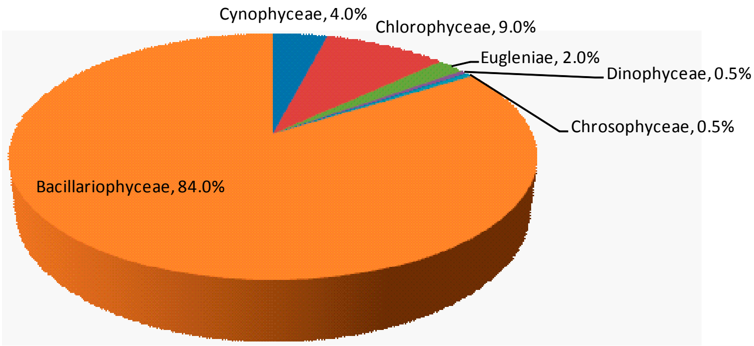
Phytoplankton composition.



Zooplankton composition.



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