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ASSESSMENT OF ECOLOGY OF AQUA-BIODIVERSITY AND ECONOMICAL DEVELOPMENT THROUGH AQUATIC TOURISM IN UTTARKASHI, UTTARAKHAND, INDIA

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Abstract: The Bhagirathi River is an extensively large water resource and traditionally considered as a source of Ganga River. It is balanced by natural ecosystem with indigenous biodiversity of cold water fish species. The need of the hour is to emphasize and recognize aquatic resources as a part of an integrated approach driven by concerns for poverty, people's livelihoods and rural development. There is a great potential for aquaculture and fisheries development for poverty alleviation in Uttarkashi. The Government provides household business to people in order to generate income from natural aquaculture lakes and ponds built by them. Aquaculture is a primary source of income and provides food security to the poor villagers of Uttarkashi. Therefore, it is required to focus research on identification of palatable fish species of Bhagirathi River and its tributaries. In view of this, the current research work was focused on the aquatic biodiversity of Barethi stream, Assiganga River and Bhagirathi River. The major fish species found in Bhagirathi and its tributaries are Snow trout (*Schizothorax* sp.), Mirror carp, Common carp, Brown trout (*Salmo trutta fario* L.), *Garra lamta,* Mahseer (*Tor tor, T. putitora*), *Glyptothorax*, *Nemacheilus* etc. Indigenous fish species along with exotic fish species are directly related with the enrichment of aquatic biodiversity of the region. However, increasing competition on the use of water resources and high population growth has lead to the depletion of resources and reduction in fisheries production. Therefore, proper management techniques such as electro-fishing, angling etc. are required to resist a marked decline in fish production of the region. This study provides information on the eco-social, aqua- bio-diversical and economic-cultural values of fisheries in Uttarkashi. Besides this, it also gives in-depth knowledge in breeding technology and tourism development with proper management of riverine fisheries. Moreover, sustainability of agriculture and its rural development approaches can be justified by taking into consideration the overall aspects of biodiversity and its aquatic resources.

Keywords: Aquaculture; Biodiversity; Exotic; Indigenous; Phytoplankton.

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INTRODUCTION

Freshwater constitutes about 2.5% of the total volume of water on Earth (Sandra *et al.,* 1996). Himalayan fresh water eco-system harbors rich aquatic biodiversity including micro and macro-benthos, various fish species and other aquatic life forms. Garhwal Himalayan region of Uttarakhand is a part of this intricate fresh water system. Uttarkashi is one of the border districts of Uttarakhand state that has rich floral and rare faunal diversity. This leads to phenomenal expanses of eco-tourism prospects that include jungle safaris, trekking on forest trails, nature walks, catch and release of *Mahaseer* and other fish species present in aquatic resources of the region. However, the outmost priority is to maintain biodiversity along with reducing ecological fragility of the region. In this context, indigenous fish species are providing

immense support to the environment of aquatic biota. Because of this vast aqua-biodiversity, foreigners and tourists from different parts of the country visit Uttarkashi. Unfortunately, the aquatic resources of this region are generally unrecognized and undervalued, and have so far been given limited consideration in rural development. A fishery system is composed of people (specifically the fisherman and their households) and fish species (Miller and Francis, 1989), while the tourism system is composed of brokers, locals and tourists (Miller and Auyong, 1991). Commercial fisheries have been characterized by change such as markets, utilization, economics and fish abundance change. Reports available within highland areas in Uttarakhand state suggests that there is a potential for aquaculture and fisheries development that will contribute to the rural development and poverty alleviation. Diverse fish species are having the potential of pharmaceuticals products such as source of vitamin A and D, Fe^{2+}, Ca^{2+}, minerals, proteins and fats. Nutrients obtained from aquatic bio-resources are easily digested and consumed by large classes of farmers, villagers and peoples. Efforts have been made to documented, the ecological and physico-chemical parameters of aquatic resources in the present study.

EXPERIMENTAL

Study area: Uttarkashi (located between $30^0$22'-$31^0$25' N latitude to $77^0$51'-$79^0$27'E longitudes) is a border district of the state of Uttarakhand, India. It occupies one of the most important positions in the area of fresh water ecology as two great and reverent rivers *viz.* The Ganges (also called as Bhagirathi) and the Yamuna originate in this district. The mainstream, Bhagirathi, rises at Gomukh [elevation 3,892 m (12,769 feet)] at the foot of the Gangotri glacier which drains into it and is the centre river of present study. It is then joined by its tributaries; namely (in sequence), Kedar Ganga at Gangotri [elevation 3,049 m (10,003 ft)], Jadh Ganga at Bhaironghati [elevation 2,650 m (8,694 ft)], Kakora Gad and Jalandhari Gad near Harshil [elevation 2,745 m (9,006 ft)], Siyan Gad near Jhala [elevation 2,575 m (8,448 ft)], Assiganga near Uttarkashi [elevation 1,158 m (3,799 ft)], Bhilangana near Old Tehri [elevation 755 m (2,477 ft)]. The sampling and study area of this research activity are the fresh water streams and rivers of Uttarkashi. The aim of the present study is to evaluate the physico-chemical parameters and abundance of different fish species along with phytoplankton diversity present in Bhagirathi River and its tributaries. The study also focused on the contribution of aqua-biodiversity in social and economic development of peoples of Uttarkashi.

Sampling: The experimental material was exotic as well as indigenous fish species found in the streams and Bhagirathi river of Uttarkashi. Data were collected by random sampling in water resources and recorded through survey in Gaionla and Bhatwari village areas. Data were recorded on number and types of consumable fish species of area. Moreover, macro invertebrate communities along the stream were sampled for three months. The samples were taken from an area of about 100 m^2 in order to include all possible microhabitats at each location. The selected physicochemical parameters like dissolved oxygen, free carbon dioxide, alkalinity were analyzed for Barethi stream, Assiganga river and Bhagirathi river from September 2011 to February 2012 following standard method outlined by Welch (1952), Trivedy and Goel (1986) and APHA (1995). The water temperature was measured by thermometer, pH by portable Hanna pocket pH meter (H196-107), turbidity by Systronics Digital Nephelo-Turbidity Meter (132) and conductivity by MAC soil and water analysis kit. Phytoplankton samples were collected by filtering 100 litres of water through phytoplankton net of 20µm size and were preserved in 4% formalin. Phytoplankton was identified up to the lowest recognizable taxonomic unit, mostly genus following keys by Needham and Needham (1962) and Ward and Whipple (1959). Phytoplankton was enumerated using Sedgwick-Rafter Cell Counter and number of phytoplanktons per ml of water was calculated according to Welch (1952).The identification of different fishes was done as cited in Day (1878), Srivastava (1968), Badola (1979) and Talwar and Jhingran (1991). The correlation coefficient between diversity and breeding prospects of fish species was computed as suggested by Hoshmand (1988).

RESULTS AND DISCUSSION

Significance of Physico-chemical parameters for Aquatic Biodiversity

The physico-chemical characters are the important parameters in determining the health and ecology of freshwater river and streams. The aquatic biodiversity depends upon the abiotic factors such as temperature, pH etc influencing the stream ecology. Therefore, assessments of these parameters help in knowing the habitat and food habit of aquatic species dominating in the river/stream fauna i.e. fish species. The observations on the physico-chemical environment of Barethi stream, Assiganga River and Bhagirathi River during September 2011 to February 2012 are given in Table 1. The temperature varies from 14.5-22.5^{0}C in Barethi stream, 8.0-17.0^{0}C in Assiganga River and 9.0-24.0^{0}C in Bhagirathi River. The pH ranged from 7.3-7.8 in Barethi stream, 7.4-7.7 in Assiganga River and 7.2-7.8 in Bhagirathi River. The conductivity ranged between 74.0–81.0 S/cm in Barethi stream, 67.6–96.3 S/cm in Assiganga River and 70.0–125.0 S/cm in Bhagirathi River. The turbidity varies from 0.3-2.3 NTU in Barethi stream, 0.7-5.2 NTU in Assiganga River and 0.3-4.0 NTU in Bhagirathi River. The dissolved oxygen ranged from 7.0 to 12.5 mg/l in Barethi stream, 8.2 to 9.8 mg/l in Assiganga River and 6.0 to 12.0 mg/l in Bhagirathi River. Dissolved oxygen requirements vary with species, age, prior acclimation temperature, water velocity, activity level, and concentration of substances in the water (McKee and Wolf, 1963). In Kumaun region the dissolved oxygen varied from 9.5-11.5 mg/l in Sarju River (Bhandari and Pande, 1991). The free carbon dioxide was lowest recorded in river Bhagirathi i.e., 0.22 mg/l and highest 3.90 mg/l in Assiganga river. Free carbon dioxide is the normal component of all natural water. It is an end product of respiration, aerobic decomposition of organic matter and infiltration through the soil (Welch, 1952) and necessary for the photosynthetic activities of phytoplankton and hydrophytes. Agarwal et al. (2003) observed minimum carbon dioxide (1.50±0.00) in winter and maximum (3.10±0.26) during the summer. The alkalinity showed minimum value (9.0 mg/l) in Bhagirathi river and Assiganga river whereas, highest value (25.00 mg/l) present in Barethi stream. According to Moyle (1946), water bodies having total alkalinity above 50 mg/l can be considered productive. The alkalinity showed minimum value (9.0 mg/l) in Bhagirathi river and Assiganga river whereas, highest value (25.00 mg/l) present in Barethi stream. Here, the value of alkalinity never goes above 25.00 mg/l, thus shows the lower productivity of the rivers (Table 1). Since for protection of aquatic life the buffering capacity should be at least 20 mg/L. If alkalinity is naturally low, (less than 20 mg/L) there can be no greater than a 25% reduction in alkalinity (Brian Oram, Wilkes University Center for Environmental Quality Environmental Engineering and Earth Sciences). However, it should be noted that the quality and quantity of available habitat is a more important factor rather than alkalinity in determining the overall density of trout fishery. A stream with high alkalinity, but if it lacks quality habitat, the density of trout population may still be quite low. On the other hand, streams with low alkalinity and excellent habitat can have outstanding trout populations (Pennsylvania Fish and Boat Commission).

Environmental variables (e.g. temperature, dissolved oxygen, conductivity and pH) characterize aquatic environments. Also, fish community composition varies in response to these parameters. Ostrand and Wilde (2002) suggested that the assemblage structure is determined more by average or persistent differences in environmental conditions among sites than by seasonal variation in environmental conditions. Matthews *et al.* (1992) comparing large water quality and fish abundance data sets, found spatial distribution of stream fishes of Arkansas to be significantly related to an aggregate of water-quality conditions. Understanding environmental variables (spatial and temporal variations) is an important issue for environmental managers for shaping fish community structure. For temperate rivers, numerous studies have tested effect of environmental changes on fish assemblages (Matthews et al., 1988; Fausch and Bramblett, 1991; Brown, 2000). The study further showed direct impact of snow melting and high rainfall in the physico-chemical parameters of stream that affect the availability of fish population (*Schizothorax*, *Nemacheilus etc*). The research revealed that the prospects of physico-chemical parameters are quite effective in notifying the habitat of fish species. It indicates the abiotic requirement of fish for survival and adaptability. Secondly, the host interaction with neighboring fish species and other stream dwelling benthos always depends on the association between abiotic and biotic factors of the environment pertaining in

particular geographical area. Also, the brown trout and cold water fishes found in different river and streams of Uttarakhand varied in abundance along with their population because of the variability of physico-chemical parameters and availability of other feeds (fish food) in the cold water.

Phytoplankton diversity

Phytoplankton density was also recorded in Barethi stream, Assiganga River and Bhagirathi River (Table 2). A total of 31, 32 and 30 genera were identified in Barethi stream, Assiganga River and Bhagirathi River, respectively. The major phytoplantonic groups recorded were Bacillariophyaceae. Prominent member of this class included *Gomphonema*, *Selenastrum*, *Pinularia*, *Nitzschia*, *Saturories*, *Navicula*, *Cymbella*, *Synendra*, *Tabellaria*, *Diatoma*, *Frustullia*, *Epithemia*, *Achanthes*, *Amphora*, *Melosira*, *Zygenema* and *Gyrosigma*. The main Chlorophyceae members were *Tetraspora*, *Gongosira*, *Richetera* and *Hydrodictyon*. Phytoplanktons are microscopic single celled aquatic plants forming the prime component in the food chain of an aquatic ecosystem. Some phytoplankton species are also often used as good indicators of water quality including pollution (Rajashree, 1993). Phytoplankton maintains true potamoplanktonic communities only in the widest lowland rivers (Allan, 1995). Phytoplankton density in Himalayan rivers and streams has been depicted in Table 2. In river Bhilangana, Gusain (1994) reported a phytoplankton density of 60-3990 unit/l, while, Badola (2009) observed the density in the range from 535±35.36 to 5545±14.85 unit/l in Ganga river. A total of 93 genera of different phytoplantonic groups were identified in Barethi stream, Assiganga River and Bhagirathi River, respectively. Majority of them were members of Bacillariophyaceae and Chlorophyceae.

Diversity in Fish species and breeding prospects

The variability and abundance of different species of fish present in aquatic resources of Uttarkashi has been presented in Table 3. Majority of them are Mirror carp, Common carp, Brown trout (*Salmo trutta fario* L.), *Garra gotyala,* Snow trout (*Schizothorax* sp.), Mahseer (*Tor tor, Tor putitora*), *Glyptothorax* and *Nemacheilus*. Most of them are present in Ganga, Assiganga, Maneri Dam and Yamuna river. Only mirror carp and common carp were found in Nachiketatal, whereas, Rainbow trout and Brown trout were mostly found in Dodital. The species of fish present in aquatic resources of Uttarkashi were Mirror carp, Common carp, Brown trout (*Salmo trutta fario* L.), *Garra lamta,* Snow trout (*Schizothorax* sp.), Mahseer (*Tor tor, Tor putitora*), Glyptothorax and Nemacheilus. The study on fish fauna of Garhwal Himalaya have been initiated by Badola and Pant (1973), who reported 18 species from Uttarkashi district, while Sharma (1988) reported 23 species of fishes by surveying the entire ecosystem of the Bhagirathi. Most of the fish species were found in river and only few were found in streams of Himalayas. The details about number of individuals of exotic fish species used for breeding purpose by the fishery department of Uttarkashi during year 2009, 2010 and 2011 are represented in Figure 1. The source of this was taken from Fishery Department, Vikas Bhavan, Uttarkashi. Higher and highly significant correlation ($r = 0.996^{**}$) was observed between male and female brown trout and significant correlation ($r = 0.929^{*}$) was observed between male and female of common carp, respectively. It indicates the presence of appreciable numbers of male and female individuals for breeding programme and development of hatchery in streams. In the breeding scenario, Uttarkashi Fishery Department showed tremendous potential in case of exotic fish as well as indigenous species. The male and female number of common carp and brown trout showed significant correlation ($p > 0.05$) with each other. It indicates that male and female individuals for breeding programme are present in healthy number and hatchery practices and could be enhanced by villagers for commercial exploitation. Most of the times, the productivity of fish depends on the number of adults present in populations. Secondly, growth and maturity should encompass with the demographic structure of species particularly in hatcheries. In general, there is a relationship between growth and reproduction (Campbell et al., 2006). The time of sexually maturity which leads to significant changes in body composition, also plays a key role in the growth regulation between both sexes (Bhatta et al., 2012). Interaction between growth and reproduction occurs in many vertebrates and is particularly obvious at certain stages of the life cycle (Campbell et al., 2003; Campbell et al., 2006).

Seed production and Distribution of important fish species

The management objective includes distribution of seed to the farmers and villagers for livelihood and sustainability of reservoirs and aquatic-biota. The observations on the data on seed production and distribution to the farmers has been given in Table 4 and provided by Fishery Department, Uttarkashi. The production and distribution of seed of mirror carp has been found to increase from year 2008 to 2012, which show significant contribution in the economy of poor peoples. Further, number of farmers using the seed also showed increasing trends with the progression of years. In 2011-12, the carp and brown trout seed were used by 42 and 7 farmers, respectively. The distribution of seed occurs at block level in Bhatwari, Chinyalisaur, Dunda, Naogaon, Purola regions of Uttarkashi. The figures given in the table do not show appropriate outlook of the status of villagers and farmers of Uttarkashi, despite the best climatic and environmental conditions available for the world famous game fish i.e., brown trout and edible fishes like carp etc. But the farmer lacks knowledge, scientific principles and proper guidelines of seed production. Moreover, unavailable harvesting technique and improper management of water resources leads to depletion of aqua-biodiversity (ponds, streams, lakes, rivers etc.) and fish farming become challenging prospects for employment and income generation.

Tourism development in Uttarkashi

The tourism development in Uttarkashi during year 2009, 2010 and 2011 are represented in Pie-chart (Figure 2). The source of the present data of study was taken from Fishery Department, Vikas Bhavan, Uttarkashi. Total number of Indian visitors in the year 2009, 2010 and 2011 were 1261626. Total number of foreign visitors in the year 2009, 2010 and 2011 were 3230. The category of researchers, scholars and tourism department personal for Indian and foreign visitors were 5% and 3.5%, respectively. The aquatic biodiversity management system must carefully balance sound conservation objectives with the interests of people~~s~~ and communities. Also, ecosystem management seemingly implies dramatic improvement in our performance as conservators of ecological integrity and biodiversity (Salwasser, 1992 and Montgomery et al., 1995). Integrating additional ecosystem data into existing aqua-diversity management plans is an ongoing process that requires careful and comprehensive analysis. Conclusions should not be reached hastily and should be supported by scientific facts. The variation in number of fish species, seasonal distribution and relative abundance of fish fauna is directly related to change in physico-chemical nature, variation in altitude and longitude, channel course and water discharge, co-morphological adaptive organs of the fishes, vast aerial expansion and higher number of streams, pattern and geometry of tributaries. At present, development work is taking place in the management, recreation and enjoyment which has lead to tourism development in Uttarkashi. The research provides in-depth knowledge of importance of aquatic life for social well being and generation of revenue for state authority (Tourism Department, Uttarkashi). Open water fishery and capture fishery is often the only source of livelihood for the fisher's communities near water bodies. Food, employment, pharmaceuticals, recreational and ornamental values are obtained from captured fisheries of natural water resources. Haylor (2000) and DFID (2000) recognized potential of aquaculture and fisheries development which ~~to~~ contribute to poverty alleviation in the highland areas of Asia.

Potential of streams and reservoir fisheries at the local level, including cage and pen culture, the yield potential from streams and reservoirs is higher than that for rivers and is an important factor in local nutrition, income generation and employment. Management is easy in such water bodies because of their local nature. If there is good access to roads, part of the yield can be sold in distant markets, increasing the well-being of local communities. The increasing number of hydroelectric power stations and irrigation projects is likely to add more water bodies in the years to come. This may increase~~s~~ the production potential for reservoirs dramatically although there may be a decline in the yield from rivers. The negative impact of dams on riverine fisheries must be counteracting to avoid fish migration routes and their spawning behaviour. Similarly, the failure of spawning or ineffective spawning and feeding grounds of Mahseer inhabiting Bhagirathi and Bhilagana at the impacted zone of the river was observed by Sharma (2004) in the area of Tehri Dam Project. Duvel et al. (1976) reported that modification of streams had a

direct deleterious effect on trout populations, as large trout were denied suitable natural hiding places (holes, undercut, bank vegetation, etc.). The development of aquatic biodiversity tourism along with the opportunity of employment diversification is aiming to regenerate and help rural communities along with fishermen in particular of Uttarkashi that are experiencing economic hardship as a result of the decline of their income from traditional fishing activities. The major emphasis is on the integrated approach driven by people livelihoods and concerns for rural development (Phillips et al. 2002). The tourism may propagate eco-awareness and the principles of sustainable development on both the parties involved, operators and customers, fishermen and tourists. Aqua-biotic-resources tourism provides environmentally sound, sustainable development to meet the needs of the present generation without damaging the resource base for future generations in Uttarkashi.

Table 1. Physico-chemical parameters of Barethi stream, Assiganga river and Bhagirathi river during September 2011 to February 2012.

Parameters	Barethi Stream		Assiganga river		Bhagirathi River	
	Min.	Max.	Min.	Max.	Min.	Max.
Water Temperature (^{0}C)	14.50	22.50	8.00	17.00	9.00	24.00
pH	7.30	7.80	7.40	7.70	7.20	7.80
Conductivity (S/cm^2)	74.00	81.00	67.60	96.30	70.00	125.00
Turbidity (NTU)	0.30	2.30	0.70	5.20	0.30	4.00
Dissolved oxygen (mg/l)	7.00	12.50	8.20	9.80	6.00	12.00
Free carbon dioxide (mg/l)	0.88	2.67	2.50	3.90	0.22	2.86
Alkalinity (mg/l)	11.00	25.00	9.00	16.80	9.00	23.00

Table 2. Class-wise density variation of phytoplankton in Barethi stream, Assiganga river and Bhagirathi river during September 2011 to February 2012 (in unit/l).

Sites	Bacillariophyceae		Desimidiaceae		Chlorophyceae		Myxophyceae		Miscellaneous	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Barethi stream	780.0	1780.0	180.0	730.0	800.0	980.0	-	-	-	-
Assiganga river	100.0	1000.0	-	-	10.0	300.0	2.0	30.0	2.0	10.0
Bhagirathi river	60.0	1527.0	-	-	10.0	820.0	4.0	40.0	4.0	20.0

Table 3. Different species of fish present in aquatic resources of Uttarkashi

Fish species	Bhagirathi	Assiganga	Nachiketa Tal	Dodi Tal	Maneri Dam	Yamuna
Mirror carp	Present	-------	Present	-------	-------	-------
Common carp	Present	-------	Present	-------	-------	-------
Brown trout (*Salmo trutta fario* L.)	Present in upper region (Harsil & Dharali)	Present	-------	Present	Present but rarely	Present in upper region
Rainbow trout (*Oncohynchus mykiss*)	-------	-------	-------	Present	-------	-------
Garra lamta	Present	-------	-------	-------	--------	Present

Snow trout (*Schizothorax* sp.)	Present	Present	-------	-------	Present	Present
Mahseer (*Tor tor, Tor putitora*)	Present	-------	-------	-------	-------	Present
Glyptothorax	Present	Present but rarely	-------	-------	Present	Present
Nemacheilus	Present	Present	-------	-------	Present	Present

Table 4. Year wise production of fish seed and its distribution to the farmers

Seed available	Year	2008-09	2009-10	2010-11	2011-12
Mirror carp/ Common Carp	Production (in lakhs)	60200	61000	128000	130000
	Seed distribution	32000	15000	22000	60000
	Number of farmers	14	10	30	42
Brown trout		4	5	4	7
Distribution of seed	Blocks	Bhatwari, Chinyalisaur and Dunda	Bhatwari, Chinyalisaur and Dunda,	Naogaon, Dunda and Bhatwari	Purola, Dunda, Bhatwari and Chinayalisaur

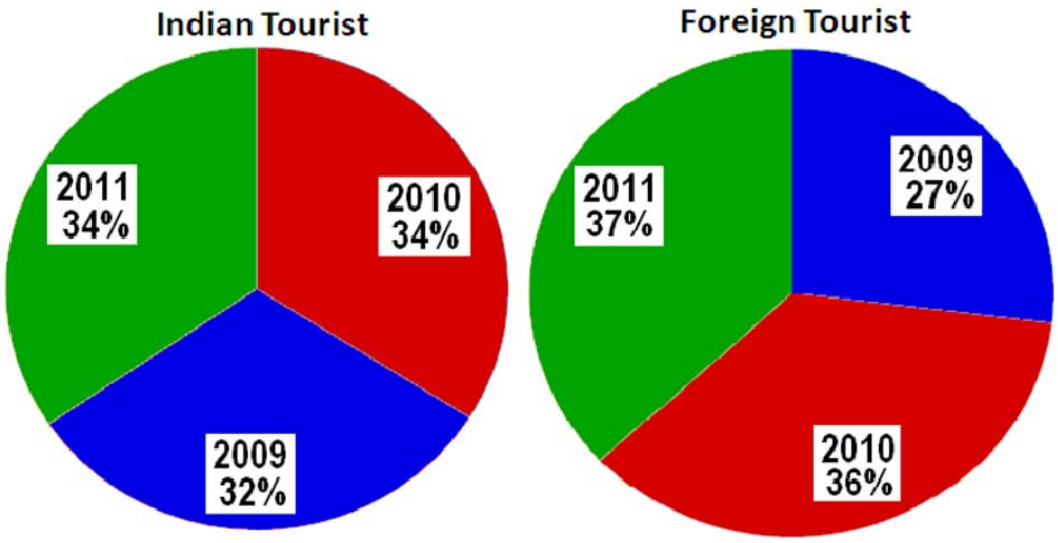

Figure 2. Pie-chart showing percentage of Indian and foreign visitors in Uttarkashi

CONCLUSION

It is of paramount importance that maintenance of aquatic biodiversity is required for the sustainable development for the peoples inhabiting the geographical areas of Himalayas. The source of economy mainly depends on the tourism aspects of mountains in the form of scenic beauty, river rafting, fishing in cold water stream, river dams etc. Also, aquatic tourism provides potential benefits to the villagers and farmers living in the harsh environmental conditions of the Himalayas. This study illustrates that ecosystems associated with fresh water have vast biodiversity in the form of fresh water fish species and assist local authorities in making rational river bank management decisions. It was also revealed a lack of management instruments for local authorities for to developing natural resource-based tourism in Uttarkashi, and thus the need for the municipality and village Gram Sabha to cooperate and coordinate with other management units and levels of Government.

REFERENCES

Agarwal N.K., Rawat U.S., Thapliyal B.L., Raghuvanshi S.K. (2003). Seasonal variation in physico-chemical characteristics of the river Bhagirathi and its impact on phytoplankton and benthic entomofauna. *In:* Proceedings of 12th National Symposium on Enviroment. pp: 430-437.

Allan J.D. (1995). Stream ecology: structure and function of running waters. Chapman and Hall, New York.

APHA (1998). Standard methods for the examination of water and wastewater, 18th Ed. American Public health Association, Washington, DC, pp. 45-60.

Badola S.P. (2009). Ichthyology of the central Himalaya. Transmedia publication, Srinagar Garhwal, Uttarakhand, pp. 206.

Badola S.P., Pant M.C. (1973). Fish fauna of the Garhwal Hills, Part I. *Ind. J. Zoot*., 14 (1): 37-44.

Bhandari N.S., Pande R.K. (1991). Solute Dynamics of River Sarju in the Central Himalayas, India. In Ecology of the Mountain Waters, Bhatt S.D. and Pande R.K. Ashish Pub. New Delhi, pp 104-124.

Bhatta S., Iwai T., Miura T., Higuchi M., Maugars C., Miura G. (2012). Differences between male and female growth and sexual maturation in tilapia (*Oreochromis mossambicus*). Kathmandu University Journal of Science, Engineering and Technology, Vol. 8, no. II, 57-65.

Brown L.R. (2000). Fish communities and their associations with environmental variables, lower San Joaquin River drainage, California. *Environmental Biology of Fishes*, 57: 251–269.

Campbell B., Dickey J., Beckman B., Young G., Pierce A. and Swanson P. (2003). Endocrine changes associated with the growth of pre-vitellogenic oocytes in coho salmon (*Oncorhynchus kisutch*). *Fish Physiology and Biochemistry*, 28, 287-289.

Campbell B., Dickey J., Beckman B., Young G. (2006). Previtellogenic oocyte growth in Salmon: relationship among body growth Plasma insulin-like growth factor-I, estradiol - 17β, follicle – stimulating hormone and expression of ovarian genes for insulin-like growth factors, steroidogenic-acute regulatory protein and receptors for gonadotropins, growth hormone and somatolactin. Biology of Reproduction, 75, 34-44.

Day F. (1878). The fishes of India. William Dawson and Sons Ltd. pp. 590-591.

DFID (2000). Aquatic Resources Management for Sustainable Livelihoods of Poor People: Proceedings of the DFID-SE Asia Aquatic Resources Management Programme E-mail conference, DFID, Bangkok, Thailand. pp: 148.

Fausch K.D., Bramblett R.G. (1991). Disturbance and fish communities in intermittent tributaries of Western Great Plains River. Copeia, pp 659–674.

Gusain O.P. (1994). Himalayan mahseer- Ecological Perspectives migration routes, river Bhilangana. *In:* P. Nautiyal (Ed.) Mahseer- The Game Fish. Pp. 147-168

Haylor G. (2000). Eight successful systems for promoting sustainable livelihoods through developing aquatic resource management systems that benefit the poor in SE Asia. Aquatic Resource Management Programme Briefing Paper 2. DFID SEA.

Hoshmand A.R. (1988). Simple Linear Regression and Correlation Statistical Methods for Agricultural Sciences, pp 251-281.

Matthews W.J., Cashner R.C., Gelwich F.P. (1988). Stability and persistence of fish fauna and assemblage in three midwestern stream. *Copeia*, 945–955.

Matthews W.J., Hough J.D., Robinson, H.W. (1992). Similarities in fish distribution and water quality patterns in stream of Arkansas: congruence of multivariate analyses. *Copeia*, 296–305.

McKee J.E., Wolf H.W. (1963). Water quality criteria*.* State water quality control board, Publ. 3A. Sacramento, CA. 548.

Miller M.L., Auyong, J. (1991). Coastal zone tourism and marine affairs: A potent force affecting environment and society. Marine Policy (March) 75-99.

Miller M.L., Francis R.C. (1989) Marine fishery management. Fisheries: Harvesting life from water. IO: Kendall/Hunt. 212-224.

Montgomery D.R., Grant G.E., Sullivan K. (1995). Watershed Analysis as a Framework for Implementing Ecosystem Management. Water Resources Bulletin, 31: 369-386.

Moyle J.B. (1946); Some chemical factors influencing the distribution of aquatic plants in Minesota. Amer. *Midl. Natl*., 34: 402-426.

Needam, J.G., Needam P.R. (1962). A Guide to the study of Fresh Biology. Holdan Day Inc. San. Francisco.

Ostrand, K.G., Wilde, G.R. (2002). Seasonal and spatial variation in a prairie stream-fish assemblage. Ecology of Freshwater Fish 11: 137–149. River Oregon. Transactions of the American Fisheries Society, 116: 196–209.

Phillips M.J., Reantaso M.B., Bueno P.N. (2002). Environment, livelihoods and indigenous cold water fishes. FAO Corporate Document Repository. Fisheries and Aquaculture Department.

Rajashree G., Panigrahy R.C. (1993). Monthly variations of some hydrographic parameters in the Rushikulya estuary east coast of India. Mahasgar Bulletin National Institute Oceanogr, 26 (2): 73-85.

Salwasser H. (1992). From New Perspectives to Ecosystem Management: Response to Frisscll *et al.,* and Lawrence and Murphy. *Conservation Biology.* 6: 469-472.

Sandra L.P., Gretchen C.D., Ehrlich, P.R. (1996). Human Appropriation of Renewable Fresh water. Science. 271: 785-88.

Sharma R.C. (1988). Fish and Fisheries of the snowfed river Bhagirathi of Garhwal Himalayas. Proc. Nat. Acad. Sci. India, 58 (B), II: 181-192.

Sharma R.C. (2004). Protection of an endangered fish *Tor tor* and *Tor putitora* population impacted by transportation network in the area of Tehri Dam Project, Garhwal Himalaya, India. *In*: Proceedings of the 2003 International Conference on Ecology and Transportation, Eds. Irwin CL, Garrett P, McDermott KP. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC. pp: 83-90.

Srivastava G.J. (1968). Fishes of Eastern Uttar Pradesh, Vishwavidayalaya Prakashan, Varanasi. 1-163 p.

Talwar P.K., Jhingran A.G. (1991). Inland fisheries of India and adjacent countries, Vol. I & II: 1-1158. Oxford and IBH Publishing Co. Pvt. Ltd.

Trivedi R.K., Goel P.K. (1984). Chemical and Biological methods for water pollution studies. Environ. Publ. Karad (India). 251 p.

Ward H.B., Wipple G.G. (1959). Freshwater Biology (Eds.) W.T. Edmondson. John Willy & Sons, Inc. New York.

Welch P.S. (1952). Limnological Methods, XVIII McGraw Hill Book Co. Inc. New York.

CONFLICT OF INTEREST : Nothing