# SEDIMENT CHEMISTRY OF TSO KHAR, A HIGH ALTITUDE LAKE IN LADAKH

**Aftab Ahmad[1*], Arshid Jehangir[1], A.R. Yousuf[1, 2], W.A. Shah[3*], F.A Bhat[4], Dilgeer Mehdi[5] and A. Tanveer[1]**

[1]Department of Environmental Science, University of Kashmir, Srinagar-190006
[2] Expert Member, National Green Tribunal, New Delhi- 110001
[3] Department of Chemistry, University of Kashmir, Srinagar, 190006
[4]Faculty of Fisheries, SKAUST-K, Shalimar, Srinagar 190006
[5]Govt. Degree College Nawa Kadal, University of Kashmir, Srinagar-190006
***Corresponding Authors email:** aftabbaziz@yahoo.com: shahwajaht@yahoo.com

**ABSTRACT**

Tso Khar is a shallow, saline land locked lake situated in eastern part of Ladakh, at an altitude of 4536 m (asl) and remains frozen for about three months during winter. There is no outlet to the lake and loss of water is through evapotranspiration and seepage. The lake sediments were found to be highly alkaline, especially in hypersaline zone (pH>10) with high conductivity (35000µS). Nitrate and exchangeable cations (Ca, Mg, Na and K) were significantly higher at hypersaline than fresh water zone, whereas organic carbon, organic matter, exchangeable phosphorus and total phosphorus were significantly higher at fresh water zone. Ammonia concentrations were high at saline sites but difference was insignificant. The progression of cation at saline site was Na> K> Mg>Ca whereas in fresh water expanse it was Ca> Mg> K>Na. The study revealed that the sediment chemistry of Tso Khar lake was mainly regulated by inflow components, selective removal of dissolved species and concentration processes in the lake basin.

***Keywords:*** Himalaya, hypersaline, endorheic, exchangeable cations, evapotranspiration, limnology

## INTRODUCTION

Lake sediments play an outstanding role in limnological studies as they can both reflect and affect what is occurring in the overlying water column (Håkanson, 1984). In fact, sediments are the product of lake life and, consequently, they reflect the lake type. In this sense, sediments can be regarded as a bank of information about environmental changes occurring in both the water body and in the catchment area (Kalff, 2002; Schmidt *et al*., 2002; de Vicente *et al.,* 2006). Besides considering lake sediments as a historical record, sediments may also affect the water quality as a consequence of their dynamic and active character resulting from a great variety of biogeochemical reactions and transformations (de Vicente *et al.,* 2006). Sediments can function as either a source or a sink for many of the essential nutrients involved in the eutrophication process (Ali *et al*., 1988). Exchange of nutrients between sediments and overlying water column is regulated by chemical characteristics of the water and of the sediments (Mortimer, 1971; Wetzel, 2001; Carling *et al*., 2013). Therefore sediment-water interactions are extremely important for understanding the whole nutrient dynamics in lakes (Boström *et al*., 1988).

The biogeochemical environment of sediments is generally anoxic and thus sites of reductive biogeochemical processes. The anaerobic sediments provide favourable conditions for generation and accumulation of soluble sulfide $H_2S$ which are highly toxic to plants and are considered to be main cause of disappearance and recession of macrophytes (Holmer *et al.,* 2005). The excessive organic matter in sediments often contains high concentration of toxic organic acids, and metabolic product which inhibit their growth (Mishra, 1938; Barko and Simth, 1986; Brenda *et al.,* 1993), thus playing key role in macrophytic distribution in lakes and wetlands.

Limited work has been carried out on Ladakh lakes especially sediment chemistry (Hutchison *et al*., 1943; Sekar, 2000). The main constraints in this direction have been the extreme climatic conditions, formidable topography and high altitude of the area. In the present study, therefore, an attempt has been made to investigate the sediment chemistry of the high-altitude lake Tso Khar.

## Study area and sites

Tso Khar is a saline, land locked lake located in the Ladakh region of Jammu and Kashmir state between 32˚ 40' and 33˚15' N latitude and 78˚15'and 78˚25' E longitude at an altitude of 4536 meters a.m.s.l. The lake is bounded by the Zanskar range in the south and Ladakh range in the north. The basin is bounded by two longitudinal faults (Wünnemann *et al*., 2010) and forms a graben structure where the central block has subsided to constitute a basin. The surface area of lake is 16.7 $km^2$ with catchment area of about 1042 $km^2$. With strong seasonal fluctuations, the Tso Khar basin receives water from nearby glaciers mainly in spring and early summer via the periodically active Pulong Kha Phu river from the east and the perennial Nuruchan Lungpa river from the south (Philip and Mazari, 2000). Both rivers enter the freshwater lake Startsapuk Tso while the hyper-saline Tso Khar is only fed by water exchange through a small conduit between the two water expanses. There are a number of freshwater and hot springs within and around the periphery of the lake basin which act as water sources to the lake.

Geologically the catchment of the Tso Khar comprises of Puga formation (Pre Cambrian), Sondu formation (cretaceous to Paleocene) and Liyan formation (Miocene). The Puga formation contains mainly micrictic limestone and gypsum. The region is characterized by extreme climatic conditions with local mean annual air temperature of about 4˚C, and annual precipitation less than 90 mm. Temperature during winter ranges from -20 to -40˚C (Bhattacharyya, 1989) while in summer it ranges from below 0˚C to 30˚C (Philip and Mazari, 2000). In the Tso Khar region vegetation cover comprises mainly desert steppe, scrub steppe and subnival cushion communities (Rawat and Adhikari, 2005). The basin popular is a popular seasonal grazing pasturing for domestic livestock, mainly yaks and horses and pashmina goats for the Champas. The marshes around the larger lake contain areas with extensive deposits of natron, borax, and other salts.

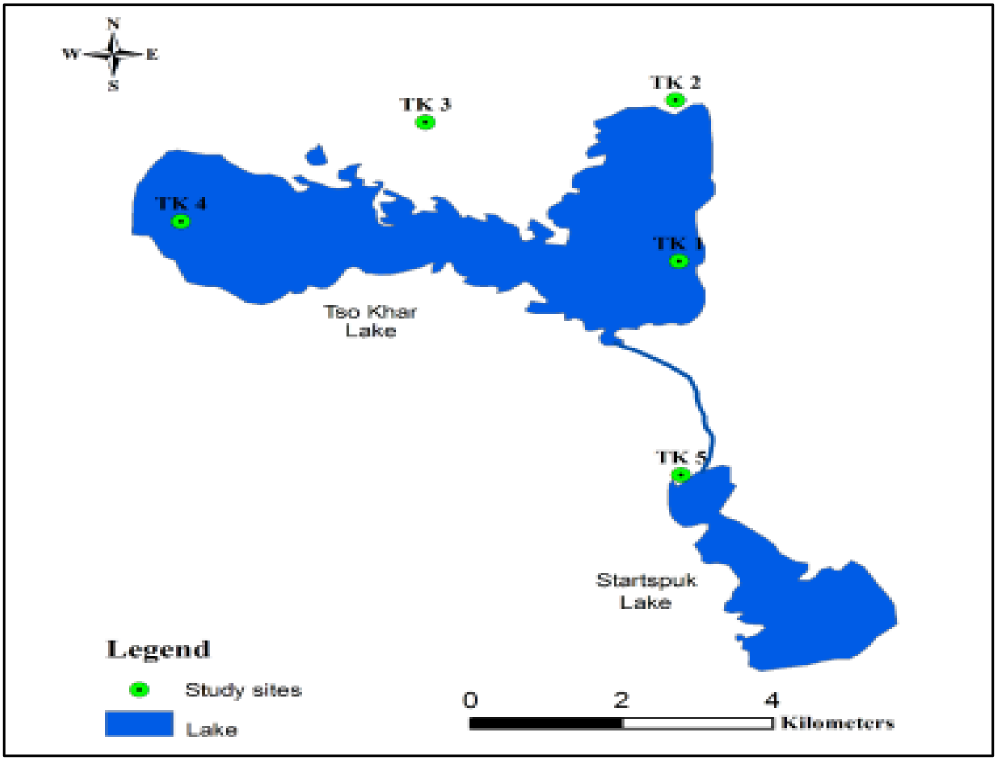


**Fig. 1. Map of Tso Khar lake showing location of study sites**

Four sites were selected for the present study (Fig.1):

**Site TK1:** The site was located in the northern part of the Tso Khar towards the eastern bank at 33º, 17.600' N and 78º, 03.156' E. The site was devoid of vegetation. The sediments were dark in colour with clayey texture.

**Site TK2:** The site was located in the northern part near Thugji Gompa in the Tso Khar village towards the north eastern shore at 33º, 21.467' N and 78º, 01.400' E. The catchment area was covered by the green meadows.

**Site TK4:** It was located in the northern part of the Tso Khar on western side at 33º, 19.450' N and 77º, 57.500' E. The site was devoid of vegetation. The sediments were brown in colour with clayey texture.

**Site TK5:** It was located in the fresh water (southern) part of the Tso Khar in front of watching tower at 33º, 16.300' N and 78º, and 01.972' E. The site has a luxuriant growth of macrophytes. The sediments in this area were brown in colour with loamy texture.

## MATERIAL AND METHODS

Sediment samples were collected with the help of Ekman dredge from the lake during 2004 to 2006 seasonal basis. The samples were transported to laboratory in deconta-minated polyethylene bags. The analysis was carried out on wet as well dry samples. pH, conductivity, nitrate and ammonia were immedia-tely analyzed on wet samples whereas the rest of parameters were analyzed on air dry samples. pH and conductivity was recorded by digital pH meter (Systronics-MKVI) and digital conductivity meter (Systronics-DB-104). Orga-nic carbon was estimated by Walkley and Black method,$NH_4^+$ was measured using the indophenol blue method (Page *et al.*, 1982) $NO_3$ was detrmined by Phenol-disulfonic acid method (Jackson, 1973). Available phosphorous was measured by Olsen's method and total phosphorus was estimated spectrophotometrically (Model-Systronics 106) by molybd-enum blue after triacid digestion method (Nitric acid: Sulphuric acid: Perchloric acid in the ratio of 9:4:1) (Page *et al.*, 1982). Exchangeable cations were extracted in 1N ammonium acetate solution by centrifugation and decantation method in a 1:10 soil extract ratio. Ca and Mg were estimated by versenate EDTA method, whereas Na and K were estimated by digital flame photometer (Systronics 130).

## RESULTS AND DISCUSSION

The mean sediment pH values were significantly higher ($F_{3,32}$= 135.1; p = 0.000) at TK1 (10.11±0.20) and TK4 (9.92±0.20) than at sites TK2 (8.27±0.31) and TK5 (8.30±0.40) (Fig.2a). The high pH (>8) in the sediments of Tso Khar could be attributed to high precipitation rates of calcium and magnesium carbonates due to alkalinity production via sulfate reduction reactions from saline water (Kilham and Cloke, 1990; Wang *et al*, 2007; Rodriguez *et al.,* 2008). Ryves *et al.* (2006) also reported that preferential precipitation of calcium carbonate with increase in salinity leads to increase in pH. Conductivity is influenced by a variety of factors like catchment geology, weathering rate, and mineralization processes. The conduc-tivity values of above 35000µS/cm were observed at saline sites. The mean sediment conductivity values were significantly ($F_{3,32}$= 407.6; p = 0.000) higher at TK1 and TK4 (Fig. 2b) than TK2 and TK5. This variability in conductivity among sites is likely due to high concentration of Ca, Mg, Na and K, which are precipitated as halite, crossnite and carbonates from hypersaline lakes (Xhenhao and Wenxuan, 2001; Rodriguez *et al.,* 2008). Patterns in conductivity closely follow those for major ions (Na, K, Ca an Mg) and displayed highly significant (p<0.01) correlations with conductivity (Table.1). The organic carbon content at saline sites (TK1 and TK4) was less than fresh water sites. TK2 ($F_{3,32}$=120.4; p = 0.000) had significantly higher concentration of organic carbon (3.5±0.9%) followed by TK5 (2.8%) and significantly low values were recorded at TK4 (Fig. 2c). Organic matter also followed the same trend as organic carbon during the study period (Fig.2d) being significantly ($F_{3,32}$=120.7; p = 0.000) high at TK2 (6.1±1.5%) followed by TK5 (4.8±1%) and least values were observed at TK4 (0.41±0.2%) and TK1 (0.39± 0.1%).The organic matter content of sediments is dependent on supply of organic matter via primary productivity, its subsequent retention in sediments and the rate of microbial decomposition (Godshalk and Barko,1985; Bianchini *et al.*, 2006; Rejmankova and Houdkova, 2006). The hypersaline zone of Tso Khar restrict the growth of macrophytes (Haller *et al.*, 1974) which are the major source of organic matter in the lakes (Wetzel, 2001), thus accountable for low levels of organic carbon and matter. The decreases in biodiversity with increase in salinity (Alceocer and Hammer, 1998; Last and Ginn, 2009) may also have decreased the organic matter at saline area of the Tso Khar. The mean values of $NO_3$-N found at TK1 (307.9±28.3 µg/g) and TK4 (306.4±39.5 µg/g) were significantly higher ($F_{3,32}$ = 157.3; p = 0.000) than mean values of TK2 (81.0±40.0 µg/g) and TK5 (84.2 ±24.7 µg/g) (Fig.2e).The highest mean value of $HN_3$-N was recorded at TK4 (118.8±40.3 µg/g) followed by TK2 (117.7±49.4 µg/g), and lowest at TK5 (112.3±27 µg/g), however, the mean values did not show any significant variation ($F_{3,32}$ = .055; p =0.983) between the study sites (Fig.2f). The high concentration $NO_3$-N at saline area might be due to diffusion of nitrate into the sediments from the overlying water column (Revsbech *et al.*, 2005) and from groundwater (Reddy and D'Angelo, 1997; Wetzel, 2001). The mean values of exchangeable phosphorus were significantly lower ($F_{3, 32}$ = 131.7; p = 0.000) at saline sites TK1 (41.9±13.2 µg/g) and TK4 (67.5±24.8 µg/g) than fresh water sites TK5 (364.2±62.9 µg/g) and TK2 (314.3±70.5 µg/g) (Fig.2g). The mean values of total phosphorus at saline site TK1 (365.0±80.3µg/g) and TK4 (365.7± 64.7 µg/g) were significantly lower ($F_{3,32}$ = 74.1; p = 0.000) than fresh water sites TK2 (850.4±110.3 µg/g) and TK5 (835.7±165.0 µg/g) (Fig.2h). Phosphorus is a key element which limits the growth of macrophytes (Wetzel, 2001). Sediments are considered as sinks for phosphorous in lakes (Ali *et al*., 1988). Phosphorous retention ability of sediments is regulated by various interacting factors like adsorption to clay minerals, co-precipitation with calcium, adsorbed to metal oxide (Al, Mn, and Fe), oxygen and organic carbon (Olila and Reddy., 1995; Wetzel, 2001; Wang *et al*., 2007). The low concentration of total phosphorous at saline sites could be attributed to low primary productivity which in turn leads to low inputs of organic matter to sediments. This fact is revealed by significant positive correlation of total phosphorous with organic matter (Table.1). Furthermore the enhanced internal phosphorus loading in saline lakes accelerated by sulfate reduction (Smolders *et al*., 2003) might be responsible for low concentration of phosphorus in sediments. This is the main reason why saline lakes are limited by nitrogen rather than by phosphorus (Khan, 2003).

The exchangeable Ca values at saline sites were almost twice than TK2 and TK5 during the study period. The mean value of exchangeable Ca were significantly higher ($F_{3,32}$ = 38.8; p = 0.000) at sites TK1 (30.9±4.5 cmoles (+)/kg) and TK4 (30.1±5.7 cmoles (+)/kg) than sites TK2 (15.4±5.4 cmoles (+)/kg) and TK5 (14.0±3.1 cmoles (+)/kg)( Fig.3a). Likewise mean values of exchangeable Mg were significantly lower ($F_{3,32}$= 9.504; p = 0.000) (11.4±3.3 cmoles (+)/kg) at TK2 as compared to TK1 (21.7±4.0 cmoles (+)/kg), TK4 (20.1±4.9 cmoles (+)/kg) and TK5 (17.7±4.4 cmoles (+)/kg).( Fig.3b).The mean values of exchangeable Na varied from 2.71±0.6 cmoles (+)/kg (TK2) to 810.4±164.7 cmoles (+)/kg (TK1) (fig. Fig.3c). Saline sites (TK1 and

TK4) had significantly higher ($F_{3,32}$ = 194.69; p = 0.000) mean values of exchangeable Na than that of fresh water sites(TK2 and TK5). The mean values of exchangeable K were significantly higher ($F_{3,32}$ = 217.5; p = 0.000) at TK1 (218.3±42.2 cmoles (+)/kg) and TK4 (188.5±28.8 cmoles (+)/kg) than TK2 (1.0±0.2 cmoles (+)/kg) and TK5 (1.1±0.2 cmoles (+)/kg) (Fig.3d). The geochemical evolution in evaporative lakes without river outlets is primarily controlled by inflow composition, selective removal processes of dissolved species, and concentration processes in the lake basin (Zang *et al.,* 2008). The major mechanism controlling the water chemistry of lakes is the evapo- precipitation (TDS: weight ratio of Na/(Na+Ca) (Gibbs, 1970). The TDS: weight ratio of Na/(Na+Ca) of saline sites is 0.99 as under such conditions different mineral get precipitated from water column and increase the concentration of major cations in sediments (Sekar, 2000). Kilham and Cloke (1990) reported significant precipitation of $CaCO_3$ and $MgCaCO_3$ in the saline lakes of Tanzania at high pH. Almost similar conditions were present at saline sites of Tso Khar lake which may have increased the major cation concentration. The high concentration of sodium and potassium may be attributed to chemical precipitation of halite and crossnite (Xhenhao and Wenxuan, 2001) during the evolution process of the brine, while high content of Ca at saline sites could be attributed to selective precipitation of Ca under high pH (Jones and Weir, 1983; Kilham, 1990) which is reflected by different ionic progression of saline (Na > K >Ca >Mg,) and fresh water (Ca > Mg >Na >K) areas of Tso Khar lake.

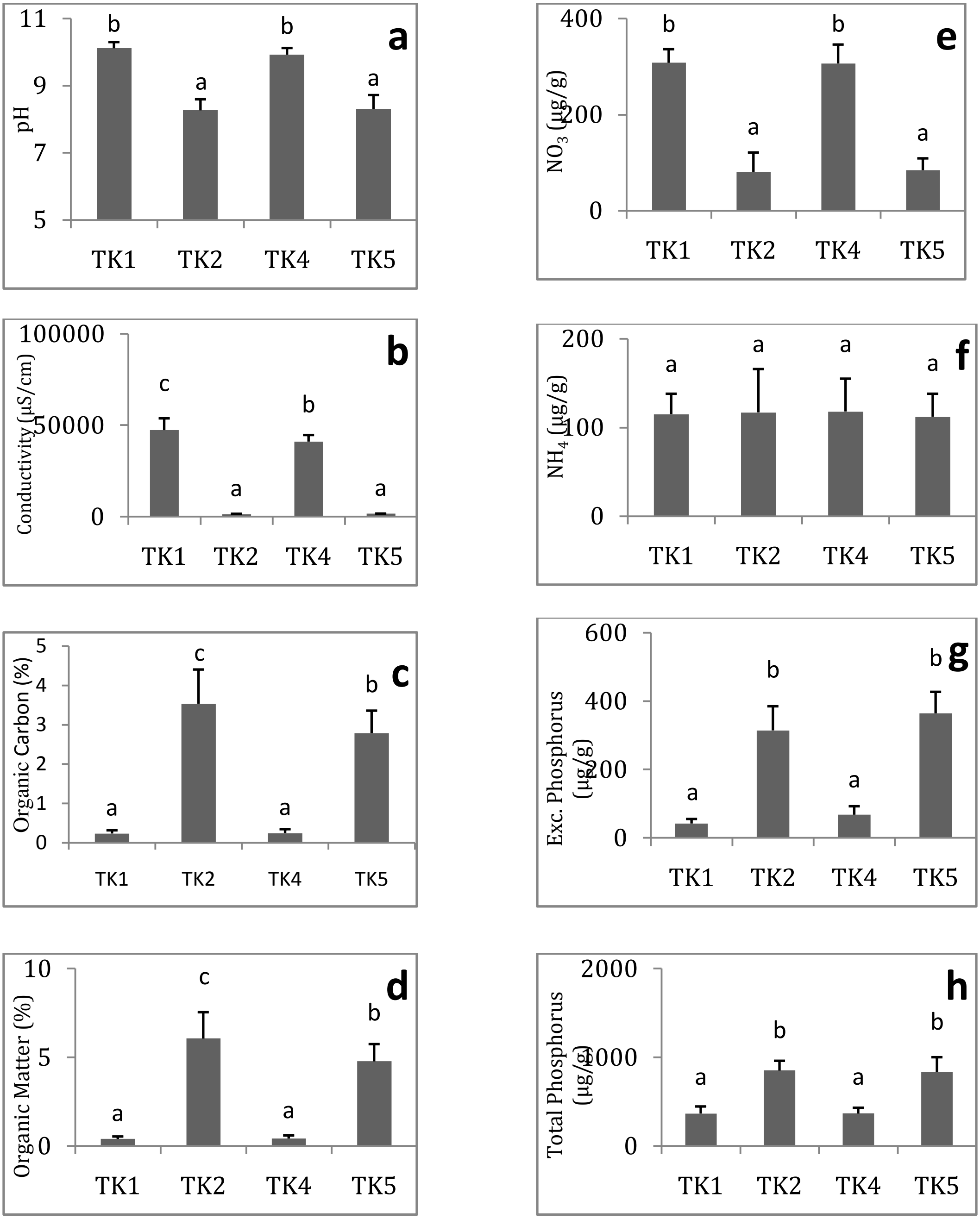


Fig. 2. Changes in pH (a), conductivity (b), OC (c), OM (d), $NO_3$-N (e), ammonia (f), Exe P (g) and total phosphorous (h) (at different study sites mean ± SD) in Tso Khar lake. Different letters on the bars indicate that the means are significantly ($p < 0.001$) different between the sites (Tukey HSD)

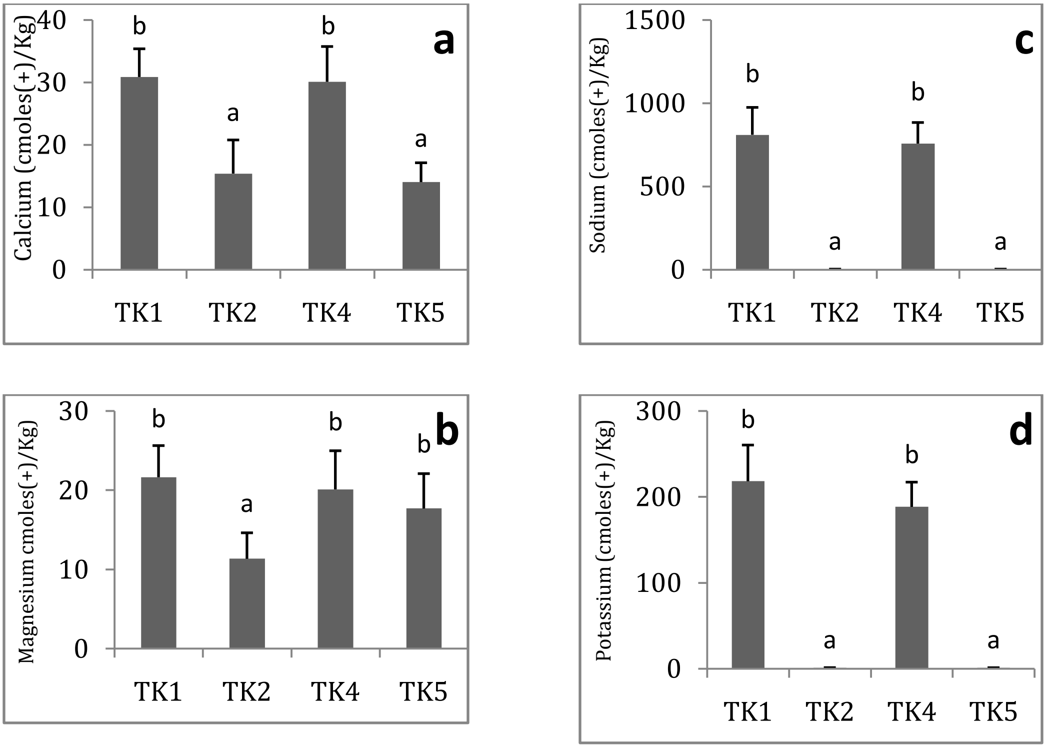


Fig. 3. Changes in exchangeable Ca (a), Mg (b), Na (c) and K (d) at different study sites (mean ± SD) in Tso Khar lake. Different letters on the bars indicate that the means are significantly ($p < 0.001$) different between sites

**Table 1. Pearson's correlations coefficients calculated for chemical parameters of Sediments in Tso Khar lake (N=36)**

| | pH | Cond | OC | OM | NO3 | NH4 | ExP | TP | ExCa | ExMg | ExNa |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cond** | .936(**) | | | | | | | | | | |
| **OC** | -.949(**) | -.924(**) | | | | | | | | | |
| **OM** | -.950(**) | -.924(**) | 1.000(**) | | | | | | | | |
| **NO3** | .888(**) | .955(**) | -.887(**) | -.886(**) | | | | | | | |
| **NH4** | -0.139 | 0.047 | 0.166 | 0.167 | 0.204 | | | | | | |
| **ExP** | -.931(**) | -.933(**) | .915(**) | .915(**) | -.893(**) | 0.079 | | | | | |
| **TP** | -.957(**) | -.901(**) | .955(**) | .956(**) | -.861(**) | 0.22 | .941(**) | | | | |
| **ExCa** | .773(**) | .893(**) | -.769(**) | -.769(**) | .914(**) | 0.259 | -.834(**) | -.755(**) | | | |
| **ExMg** | .502(**) | .638(**) | -.604(**) | -.605(**) | .628(**) | 0.13 | -.550(**) | -.535(**) | .698(**) | | |
| **ExNa** | .934(**) | .965(**) | -.917(**) | -.917(**) | .937(**) | 0.059 | -.919(**) | -.902(**) | .892(**) | .610(**) | |
| **ExK** | .933(**) | .959(**) | -.915(**) | -.915(**) | .952(**) | 0.023 | -.926(**) | -.901(**) | .900(**) | .582(**) | .969(**) |

** Correlation is significant at the 0.01 level (2- tailed).
* Correlation is significant at the 0.05 level (2-tailed).

## CONCLUSIONS

The sediment chemistry of evaporative lakes without river outlets is primarily controlled by inflow composition, selective removal processes of dissolved species, and concentration processes in the lake basin. The high pH and conductivity values of sediments were due to selective removal process of carbonates minerals calcium and magnesium. The cation composition of saline and fresh water areas of the lakes showed significant difference which reflects evapo-crystallization and precipitation processes under saline conditions. The low organic matter in saline zone was due to restriction of macrophytic species and low biodiversity. The saline sediments retained low phosphorous concentration due to sulfate induced internal phosphorous loading to overlying water column.

## ACKNOWLEDGEMENTS

We gratefully acknowledge Space Application Centre (SAC), Indian Space Research Organization (ISRO) for financing of this study. We also thank Director/Head CORD/Environmental Science for providing laboratory facilities. Thanks to all the research scholars who helped us in field and laboratory.

## REFERENCES

Alcocer, J. and Hammer, U. T. 1998. Saline lake ecosystems of Mexico. *Aquatic Ecosystem Health and Management*, **1**(3-4): 291-315.

Ali, A., Reddy, K. R. and De Busk, W. F.1988. Seasonal changes in water and sediment chemistry of subtropical shallow eutrophic lake. *Hydrobiologia,* **159**: 159-167.

A.P.H.A. 1998. *Standard Methods for the Examination of Water and Wastewater*.20th Ed. American Public Health Association, Washington, D.C. New York.

Barko, J. W., and Smart, R. M. 1986. Sediment-related mechanisms of growth limitation in submersed macrophytes *Ecology*, **67**(5): 1328-1340.

Bianchini, Jr. I., Peret, A. M. and Cunha-Santino, M. B. 2006. A mesocosm study of aerobic mineralization of seven aquatic macrophytes. *Aquat. Bot.,* **85**: 163-167.

Bhattacharyya, A. 1989. Vegetation and climate during the last 30,000 years in Ladakh, India. *Palaeogeography, Palaeoclimatology*, *Palae-oecology* **73** (1-2): 25-38.

Boström, B., Andersen, J. M., Fleischer,S. and Jansson, M. 1988. Exchange of phosphorus across the sediment-water interface. *Hydrobiologia,* **170**: 229-244.

Brenda, L., Pompay, S., and Martin, D.F. 1993. Effects of metabolic products of cellulose ulitilizing organisms on *Hydilla*. *J. Aquat. Plant Manage*., **31**: 109-113.

Carling, G. T., Richards, D. C., Hoven, H., Miller,T. Fernandez, D. P., Rudd, A., Pazmino, E. and Johnson, W. P. 2013. Relationships of surface water, pore water and sediment chemistry in wetlands adjacent to Great Salt Lake, Utah, and potential impacts on plant community health. *Science of the Total Environment,* **443**: 798–811

de-Vicente, I., Amores, V. and Cruz-Pizarro, L. 2006. Instability of shallow lakes: A matter of the complexity of factors involved in sediment and water interaction. *Limnetica*, **25**(1-2): 253-270.

Gibbs, R. J. 1970. Mechanisms controlling world water chemistry. *Science*, **170**: 1088-1090.

Godshalk, G.L. and Barko, J.W. 1985. Vegetative succession and decomposition in reservoirs. In: Gunnison, D. (Ed.), *Microbial Processes in Reservoirs. Dev. Hydrobiol*., **27**: 59-77.

Haller, W. T., Sutton, D. L., and Barlowe, W. C. 1974. Effects of salinity on growth of several aquatic macrophytes *Ecology*, **55**: 891-894.

Håkanson, L. 1984. On the relationship between lake trophic level and lake sediments. *Wat. Res*., **18**: 303-314.

Holmer, M., Frederiksen, M.S., Mollegaard, H. 2005. Sulfur accumulation in eelgrass (*Zostera marina*) and effect of sulfur on eelgrass growth. *Aquat. Bot.,* **81**: 367-379.

Hutchinson, G. E., Anne, W. and Setlow, J. K.1943. The chemistry of lake sediments from Indian Tibet. *Ammerican Journal of Sciences,* **241**: 533-542.

Jackson, M. L. 1973. *Soil Chemical Analysis*. Printice Hall of India, Pvt. Ltd. New Delhi.

Jones, B. F. and Weir, A. H. 1983. Clay minerals of Lake Abert, an alkaline, saline lake. *Clays Clay Mineral*., **31**: 161-172

Kalff, J. 2002. *Limnology*. Prentice Hall. New. Jersey. 592 pp.

Khan, T. A. 2003. Limnology of four saline lakes in western Victoria, Australia; Physico chemical parameters. *Limnologica*, **33**: 316-32.

Kilham, P. 1990. Mechanisms controlling the chemical composition of lakes and rivers: Data from Africa. *Limnol. Oceanogr.*, **35**(1): 80-83.

Kilham, P. and Cloke, P. L. 1990. The evolution of saline lake waters: gradual and rapid biogeochemical pathways in the Basotu Lake District, Tanzania. *Hydrobiologia*, **197**: 35-50.

Last, W. M. and Ginn, F. M. 2009. The chemical composition of saline lakes of the Northern Great Plains, Western Canada. *Geochemical News,* 141.

Misra, R., 1938. Edaphic factors in the distribution of aquatic plants in the English lakes. *J. Ecol*., **26:** 411-450.

Mortimer, C. H. 1971. Chemical exchanges between sediments and water in the Great lakes speculations on probable regulatory mechanisms. *Limnol. Oceanogr*., **16**: 387-404.

Olila, O. G. and Reddy, K. R. 1995. Influence of pH on phosphorus retention in oxidized lake sediments. *Soil Sci. Soc. Am. J*., **59**: 946-959.

Page, A. L., Miller, R. H. and Keeney, D. R. 1982. *Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties*. Agronomy Monograph no. 9 (2nd edition).

Philip, G. and Mazari, R.K. 2000. Shrinking lake basins in the proximity of the Indus Suture zone of northwestern Himalaya: A case study of Tso Kar and Startsapuk Tso, using IRS-1C data. *International Journal of Remote Sensing*, **21**(16): 2973-2984.

Rawat, G.S. and Adhikari, B.S. 2005. Floristics and distribution of plant communities across moisture and topographic gradients in Tso

Kar Basin, Changtang Plateau, Eastern Ladakh. *Arctic, Antarctic and Alpine Research,* **37** (4), 539-544.

Reddy, K. R. and D'Angelo, E. M. 1997. Biogeochemical indicators to evaluate pollutant removal efficiency in constructed wetlands. *Water Sci. Technol*., **35**(5): 1-10.

Rejmankova, E and Houdkova, K. 2006 Wetland plant decomposition under different nutrient conditions: what is more important, litter quality or site quality? *Biogeochemistry*, **80**: 245-262.

Revsbech N.P., Jacobsen, J.P. and Nielsen, L.P. 2005. Nitrogen transformations in micro-environments of river beds and riparian zones. *Ecological Engineering*, **24**: 447-455.

Rodriguez, R., Amrhein, C. and Anderson, M. A. 2008. Laboratory studies on the coprecipitation of phosphate with calcium carbonate in the Salton Sea, California. *Hydrobiologia*, **604**: 45-55.

Ryves, D. B., Battarbee, R.W., Juggins, S., Fritz, S. C. and Anderson, N. J. 2006. Physical and chemical predictors of diatom dissolution in freshwater and saline lake sediments in North America and West Greenland. *Limnol. Oceanogr*., **51**(3): 1355-1368.

Schmidt, R., Koinig, K. A., Thompson R. and Kamenik C. 2002. A multi proxy core study of the last 7000 years of climate and alpine land-use impacts on an Austrian mountain lake (Unterer Landschitzsee, Niedere Tauern). *Paleogeography, Paleo-climatology, Paleoecology*, **187**: 101-120.

Sekar, B., 2000. Interpretation of past climatic changes around Tso Kar Lake, Ladakh for the last 33 ka on the basis of chemical data. *Palaeobotanist,* **49**: 519-527.

Smolders, A. J.P., Lamers. L. P. M., den hartag, C. and Roeloef, J.G. M. 2003. Mechanism involved in the decline of *Stratiotes aloides*. L in the Netherlands; sulphate as a key variable. *Hydrobiologia*, **506-509**(1-3):603 - 610.

Wang, S., Jin, X., Zhao, H., Zhou, X. and Wu, F. 2007. Effects of *Hydrilla verticillata* on phosphorus retention and release in sediments. *Water Air Soil Pollut*., **181**(1-4): 329-339.

Wetzel, R. G. 2001. *Limnology. Lake and River Ecosystems*. 3rd edition. Elsevier Academic Press, San Diego.

Wünnemann, B., Demske, D., Tarasov, P., Kotlia, B. S., Reinhardt, C., Bloemendal, J., Diekmann, B., Hartmann, K., Krois,J., Riedel, F. and Arya, N. 2010. Hydrological evolution during the last 15 kyr in the Tso Kar lake basin (Ladakh, India), derived from geomorphological, sedimentological and palynological records. *Quarternary Science Reviews,* **30**:1-18.

Xhenhao, D and Wenxuan, H. 2001. The accumulation of potash in a continental basin; The example of Qarhan saline lake, Qaidam Basin, West China. *European Journal of Mineralogy*, **13**(6): 1223-1233

Zhang, Q., Kang, S., Wang, F., Li, C. and Xu, Y. 2008. Major ion geochemistry of Nam Co lake and its sources, Tibetan Plateau. *Aquat Geochem*., **21**: 321-336.

# A PRELIMINARY STUDY ON PERIPHYTIC ALGAE OF FEROZPUR AND NINGAL NALLAH IN GULMARG WILD LIFE SANCTUARY OF KASHMIR HIMALAYA

**Inam Sabha* and Sami Ullah Bhat**

P.G. Department of Environmental Science, University of Kashmir, Srinagar-190006, J&K

*Corresponding author:e-mail: inamsabha@yahoo.com

**ABSTRACT**

The present study was carried out on composition of periphytic algal community in different streams of Gulmarg catchment area from May to December 2012. A total of 37 taxa of periphyton were found from Ningal Nallah and Ferozpur Nallah belonging to Bacillariophyceae (23 taxa), Chlorophyceae (8 taxa) and Cyanophyceae (6 taxa) in decreasing order of dominance. The diversity pattern revealed the dominance of Bacillariophyceae followed by Chlorophyceae and Cyanophyceae. The most common periphytic species found among all the sites were: *Navicula* sp., *Cymbella* sp., *Amphora* sp., *Diatoma* sp., *Fragillaria* sp., *Gomphonema* sp., *Meridion* sp., *Pinnularia* sp. and *Oscillatoria* sp. Various species, especially diatoms were found in good abundance thus indicating their ability to thrive well in cold waters and to bear the extreme environmental conditions. Most of the taxa belonging to various classes were found common throughout the sampling period which is an indicative of more or less similar environmental factors governing the growth and multiplication of these periphytic algae such as water chemistry, physical habitat, watershed vegetation and geology.

***Key words***: Periphyton, Gulmarg, Ferozpur nallah, Ningal nallah

## INTRODUCTION

All microscopic organisms (both plants and animals) which grow attached on the materials submerged in water are known as Periphyton. The assemblage of attached organisms on submerged surfaces, including associated non-attached fauna are referred to as periphyton (van Dam *et al*., 2002). Periphyton is the primary producers in a stream ecosystem, turning nutrients into food for aquatic macroinvertebrates and fish. An important benefit of periphyton communities is their ability to absorb dissolved and suspended matter, inclusive of organic matter from the water column, reducing bottom accumulation while maximizing the percentage of organic matter remaining exposed to aerated conditions in the water column. Besides entrapping organic detritus, periphyton removes nutrients from the water column and helps to control the dissolved oxygen concentration and the pH of the surrounding water (Azim *et al*., 2002; Dodds *et al.,* 2003). Further, periphyton has the potential to be used as indicators of water quality due to their ability to grow at the rapid rate, to respond to the changes quickly. Due to the sedentary nature of periphyton, the community composition and biomass are sensitive to changes in water quality. While as nuisa-nce blooms are usually symptoms of a system stressed by factors such as excessive nutrients, elevated temperatures, or stagnant conditions. Excessive algal growth can reduce biodiversity by making habitat unsuitable for benthic fish and macroinvertebrates and by altering diurnal dissolved oxygen patterns. Excessive algae levels are generally associated with an increase in tolerant macroinvertebrates. Grazers (scrapers) such as snails generally dominate a benthic community influenced by excessive algae growth.

## STUDY AREA

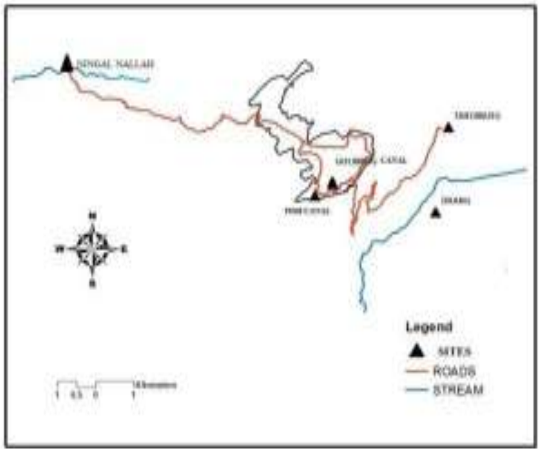


**Fig.1. Map showing various sampling stations at Gulmarg Wildlife Sanctuary**

**Gulmarg**

Gulmarg literally means meadow of flowers. It is a majestic hill station in the district Baramullah of Jammu and Kashmir, India. The hill station lies at an altitude of 2730 m a.s.l. Gulmarg is 57 km southwest from the capital city of Srinagar. It is located at 34° 03′ 00″ N and 74° 22′ 48″ E at an average altitude of >2,680m in the Baramullah district of J and K state (Fig.1). It is one among the most famous mountain resorts of the world. It may be noted that agricultural activity occurs mainly in the flat areas having a slope range of < $20^o$, while the slope range from $20^o$ – $50^o$ is covered by evergreen forests and above that the alpine pastures, scrub, bare rocky areas and perennial snow dominate the land cover. A total of five sites were selected to study the periphytic algal community of Ferozpur and Ningal nallah in Gulmarg wildlife sanctuary.

**Site 1 (Tangmarg Canal)**

Tangmarg is 32km away from Srinagar in district Baramullah with geographical coordinate N 34°03′ 30.5′′ E 74°25′ 29.9′′ having altitude of about 2153m. This is also the check point for passing on towards the Gulmarg. Ferozpur Nallah originates in Pirpanjal range having a glacial source and covers a distance of about 40km before it merges with River Jhelum, an important drainage system of Kashmir valley. This stream covers a larger area by passing through Drang, Ferozpur and Treran etc. This canal is cemented and it is the branch of actual stream of Ferozpur nallah constructed for irrigation purposes. The canal is surrounded with number of rural settlements, restaurants and hotels. The mean temperature of water body at site 1 was 8.3°C, whereas mean pH was about 7.6. The stream is shallow with small boulders, stones and gravel in the stream bed. It has highest flow of water in July and lowest in December.

**Site 2 (Drang)**

It is 3.5km away from Tangmarg with geographical coordinates N 34°02′ 14.9′′ E 74°24′ 26.0′′ having altitude of about 2126m. It catches the snow melt from Pirpanjal range. This place is isolated and is surrounded by dense forests and with large mountains, the Ferozpur nallah passing by is used for the trout culture by the fisheries department. The bottom substrate is represented by large boulders and stones. The mean water temperature recorded at this site was about 7.3°C and pH was about 7.3. The flow of water body is more in summer i.e. during July and less in winter i.e. December.

**Site 3 (Ningal Nallah)**

Botapathri is 3 km away from Gulmarg. The stream passing from there is known as Ningal nallah with the geographical coordinate N 34°04 ′28.7″ E 74°24′ 26.0″ having altitude of 2781m. The mean temperature of water was about 6.5°C whereas pH was 6.9. The stream is surrounded by the forest with very less human interference. The bottom of the stream is represented by large boulders, stones and sand etc.

**Site 4 (Gulmarg Canal)**

Gulmarg is 53 km away from the Srinagar with geographical coordinate N 34°03′31.2″E 74°23′01.0″ having altitude of about 2630m. Sampling was carried out along the road side of canal surrounded by meadow and forest. The bottom of the stream is filled with mud, small stones with small boulders and gravel. The mean water temperature was about 10.7°C whereas mean pH was7.1. The canal is having medium flow of water all the time but the pollution level was high during July.

**Site 5 (Fish Canal)**

Fish canal is located on the other side of Gulmarg canal with geographical coordinate N 34°03′ 29.2″ E 74°22′ 58.6″ with altitude of 2634m.The culture of trout fish for the recreational purpose occurs there. The canal is cemented with barriers to maintain the flow of water and as barriers grills attached with cement and bricks are used. The bottom of the canal is little muddy and cemented. The mean water temperature was about 10.4˚C and mean pH was about 7.5. The highest flow of the canal was in July and the lowest flow was in December, as in this month the whole canal was frozen.

## MATERIAL AND METHODS

The sampling of periphyton was done on monthly basis during day time from May 2012 to December 2012. The samples were collected over a period of five months i.e., May, June, July, October and December. The samples were collected by scraping the 4 $cm^2$ surface area of stones, boulders, cemented edges, using blade, scale and brushes. The material collected was then stored in small vials having capacity of 25 ml and preserved in 4% formalin raised to the volume of 25 ml by adding distilled water. The process of identification of algae up to generic level was carried under microscope with standard works (Prescott, 1939; 1951; Edmondson, 1992; Cox, 1996; APHA, 1998; Biggs and Kilroy, 2000). Sedgwick-Rafter (S.R cells) of 1ml capacity was used for counting of the individuals/ cells/ filaments/ colonies. 1ml of the preserved sample after vigorous shaking was transferred using a dropper to the S. R- cell carefully so that no air bubbles get entrapped. The sample was allowed to settle for 15 minutes before counting. Samples were discarded and replaced by diluted ones if it was too dense to count. 1 cm of filamentous organisms was taken as one individual, while as colony if any was taken as unit. Shannon-Wiener index (1949) was used to calculate species diversity between various sites. The similarity between various sites was calculated by Sorenson similarity coefficient (Sorenson, 1948).

## RESULTS AND DISCUSSION

The periphytic algal community of various streams at Gulmarg Wildlife sanctuary was represented by 37 taxa which belonged to 3 major classes namely Bacillariophyceae (23), Chlorophyceae (8) and Cyanophyceae (6) (Fig.2). The most common periphytic genera found among all the sites were: *Navicula* sp., *Cymbella* sp., *Amphora* sp., *Diatoma* sp., *Fragillaria* sp., *Gomphonema* sp., *Meridion* sp., *Pinnularia* sp. and *Oscillatoria* sp. Among 37 taxa, the maximum numbers of genera were noted at Fish canal and Gulmarg canal, followed by Tangmarg canal and Drang, whereas minimum taxa i.e. about 12 were found at Ningal nallah (Table 1). Among the various periphytic classes, Bacillariophyceae dominated qualitatively and quantitatively at each site.

During the present study the maximum periphytic algal genera were recorded at Fish canal, though there was a not significant variation in the species composition.

The highest Shannon- Weiner index was recorded for Gulmarg canal (2.91), followed by Drang (2.80), Tangmarg canal (2.73), Fish canal (2.44) and the minimum was of Ningal nallah (2.27) (Fig.4).There was lot of similarity at each site as was reflected by high Sorenson similarity coefficient (50%)(Fig 5). Taxa like *Merismopedia* sp. was restricted to Tangmarg canal, while as *Denticula* sp. was reported in fish canal and Tangmarg canal. Taxa such as *Tylopothrix* sp. was found only at Gulmarg canal while as *Microcystis* sp. and *Maugeotia* sp were found only at Fish canal.

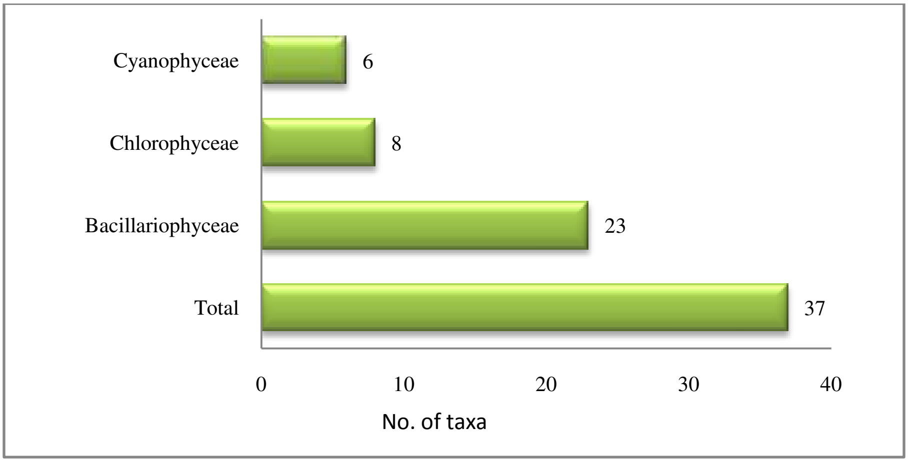


**Fig.2. Species composition (No of taxa) of periphytic algae at various sampling stations in Gulmarg Wildlife Sanctuary**

**Table 1. Mean variations in density (ind. /cm$^2$) of periphytic algae at five different sites during May - December 2012**

| S.No | Taxa | Sites | May | June | July | Oct | Dec | Total | Mean |
|---|---|---|---|---|---|---|---|---|---|
| | **Bacillariophyceae** | | | | | | | | |
| 1. | *Amphipluera* sp. | Tangmarg | 62 | 25 | - | 69 | 50 | 206 | 41.2 |
| | | Drang | - | - | 175 | 25 | 224 | 444 | 88.8 |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | - | - | 125 | 62 | - | 187 | 37.4 |
| | | Fish canal | - | - | - | - | - | - | - |
| 2. | *Amphora* sp. | Tangmarg | 275 | 75 | 150 | 125 | 69 | 694 | 138.8 |
| | | Drang | - | - | 175 | 125 | 156 | 456 | 91.2 |
| | | Ningal | 150 | 62 | * | * | * | 212 | 106 |
| | | Gulmarg | 37 | 300 | 337 | 141 | 87 | 905 | 181 |
| | | Fish canal | 31 | 125 | 337 | 162 | 618 | 1273 | 254.6 |
| 3. | *Cymbella* sp. | Tangmarg | 537 | 125 | 525 | 219 | 631 | 2037 | 407.4 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Drang | 731 | 62 | 131 | 244 | 325 | 1493 | 298.6 |
| | | Ningal | 25 | 75 | * | * | * | 100 | 50 |
| | | Gulmarg | 75 | 250 | 544 | 62 | 131 | 1062 | 212.4 |
| | | Fish canal | 119 | 212 | 575 | 200 | 675 | 1781 | 356.2 |
| 4. | *Cyclotella* sp. | Tangmarg | - | - | - | - | - | - | - |
| | | Drang | 19 | - | - | - | 125 | 144 | 28.8 |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | 75 | - | - | - | - | 75 | 15 |
| | | Fish canal | - | - | - | - | - | - | - |
| 5. | *Denticula* sp. | Tangmarg | - | - | - | 62 | - | 62 | 12.4 |
| | | Drang | - | - | - | - | - | - | - |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | - | - | - | - | - | - | - |
| | | Fish canal | - | - | 112 | - | 281 | 393 | 78.6 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6. | *Diatoma* sp. | Tangmarg | 200 | 75 | 106 | 75 | 112 | 568 | 113.6 |
| | | Drang | 37 | - | 200 | 62 | 219 | 518 | 103.6 |
| | | Ningal | 25 | 19 | * | * | * | 44 | 22 |
| | | Gulmarg | 169 | - | - | 75 | 69 | 313 | 62.6 |
| | | Fish canal | 150 | 237 | 206 | 87 | 275 | 955 | 191 |
| 7. | *Diatomella* sp. | Tangmarg | 125 | 69 | 162 | 237 | 481 | 1074 | 214.8 |
| | | Drang | 50 | - | - | 37 | 131 | 218 | 43.6 |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | - | - | - | - | - | - | - |
| | | Fish canal | 31 | - | - | - | 300 | 331 | 66.2 |
| 8. | *Didmosphenia* sp. | Tangmarg | - | - | - | 62 | 337 | 399 | 79.8 |
| | | Drang | - | - | - | 687 | 656 | 1343 | 268.6 |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | - | - | - | - | 175 | 175 | 35 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Fish canal | - | - | - | - | 219 | 219 | 43.8 |
| 9. | *Diplonies* sp. | Tangmarg | 81 | - | - | - | 56 | 137 | 27.4 |
| | | Drang | - | - | - | - | - | - | - |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | 50 | - | 125 | - | 106 | 281 | 56.2 |
| | | Fish canal | - | - | - | - | - | - | - |
| 10. | *Fragillaria* sp. | Tangmarg | 62 | 69 | 112 | 125 | 250 | 618 | 123.6 |
| | | Drang | - | 87 | - | 69 | 319 | 475 | 95 |
| | | Ningal | 31 | 200 | * | * | * | 231 | 115.5 |
| | | Gulmarg | 37 | 1125 | 625 | 56 | 169 | 2012 | 402.4 |
| | | Fish canal | 75 | 62 | 5400 | 144 | 412 | 6093 | 1218.6 |
| 11. | *Frustulia* sp. | Tangmarg | - | - | - | - | - | - | - |
| | | Drang | - | - | - | 31 | 100 | 131 | 26.2 |
| | | Ningal | - | - | * | * | * | - | - |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Gulmarg | 31 | 94 | 237 | 31 | 62 | 455 | 91 |
| | | Fish canal | - | 75 | - | 37 | 50 | 162 | 32.4 |
| 12. | *Gomphonema* sp. | Tangmarg | 225 | 50 | 125 | 94 | 225 | 719 | 143.8 |
| | | Drang | 31 | 50 | 62 | 25 | 162 | 330 | 66 |
| | | Ningal | 156 | 50 | * | * | * | 206 | 103 |
| | | Gulmarg | 81 | 200 | 237 | 62 | 125 | 705 | 141 |
| | | Fish canal | 31 | 125 | - | 44 | 156 | 356 | 71.2 |
| 13. | *Gomphonies* sp. | Tangmarg | 187 | 112 | 125 | 69 | 181 | 674 | 134.8 |
| | | Drang | 25 | - | 131 | 25 | 100 | 281 | 56.2 |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | 37 | 150 | 175 | 69 | - | 431 | 86.2 |
| | | Fish canal | 37 | 62 | - | 44 | 37 | 180 | 36 |
| 14. | *Hannea arcus* | Tangmarg | - | - | 87 | - | 87 | 174 | 34.8 |
| | | Drang | - | - | 112 | - | 168 | 280 | 56 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Ningal | 31 | - | * | * | * | 31 | 15.5 |
| | | Gulmarg | - | - | - | - | - | - | - |
| | | Fish canal | - | - | - | - | - | - | - |
| 15. | *Meridion* sp. | Tangmarg | 62 | 50 | 137 | 137 | 125 | 511 | 102.2 |
| | | Drang | 62 | 62 | 137 | 137 | 131 | 529 | 105.8 |
| | | Ningal | 56 | 31 | * | * | * | 87 | 43.5 |
| | | Gulmarg | 37 | 200 | 244 | 69 | - | 550 | 110 |
| | | Fish canal | 50 | - | - | - | 175 | 225 | 45 |
| 16. | *Navicula* sp. | Tangmarg | 644 | 144 | 275 | 106 | 350 | 1319 | 303.8 |
| | | Drang | 100 | 187 | 256 | 237 | 131 | 911 | 105.8 |
| | | Ningal | 75 | 131 | * | * | * | 206 | 103 |
| | | Gulmarg | 131 | 1262 | 900 | 44 | 119 | 2456 | 491.2 |
| | | Fish canal | 62 | 206 | 412 | 103 | 769 | 2486 | 497.2 |
| 17. | *Nitzschia* sp. | Tangmarg | 50 | 44 | 37 | 112 | 175 | 418 | 83.6 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Drang | - | - | - | 44 | 331 | 375 | 75 |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | 25 | 300 | 187 | 56 | - | 568 | 113.6 |
| | | Fish canal | - | - | - | - | - | - | - |
| 18. | *Ophephora* sp. | Tangmarg | - | - | - | - | - | - | - |
| | | Drang | - | - | - | - | - | - | - |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | - | - | - | - | - | - | - |
| | | Fish canal | - | - | - | 32 | - | 32 | 6.4 |
| 19. | *Pinnularia* sp. | Tangmarg | - | 75 | 112 | 69 | 75 | 331 | 66.2 |
| | | Drang | 31 | - | 94 | 19 | 112 | 256 | 51.2 |
| | | Ningal | 81 | 25 | * | * | * | 106 | 53 |
| | | Gulmarg | 31 | 175 | 237 | - | - | 443 | 88.6 |
| | | Fish canal | 262 | - | - | - | - | 262 | 52.4 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 20. | *Surirella* sp. | Tangmarg | - | - | - | 31 | 62 | 93 | 18.6 |
| | | Drang | - | - | - | - | - | - | - |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | 869 | - | - | - | - | 869 | 173.8 |
| | | Fish canal | - | - | - | - | - | - | - |
| 21. | *Stauronies* sp. | Tangmarg | - | - | - | - | - | - | - |
| | | Drang | - | - | - | - | - | - | - |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | 56 | 156 | 525 | 37 | 125 | 899 | 179.8 |
| | | Fish canal | - | - | - | 31 | 62 | 93 | 18.6 |
| 22. | *Synedra* sp. | Tangmarg | - | - | - | - | - | - | - |
| | | Drang | 25 | - | - | 25 | 144 | 194 | 38.8 |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | 19 | 250 | 500 | 69 | 112 | 950 | 190 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Fish canal | 69 | 56 | 3360 | 137 | 119 | 3741 | 748.2 |
| 23. | *Tabellaria* sp. | Tangmarg | - | - | - | - | - | - | - |
| | | Drang | - | - | - | - | - | - | - |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | - | - | - | - | - | - | - |
| | | Fish canal | - | - | 2400 | - | - | 2400 | 480 |
| | **Chlorophyceae** | | | | | | | | |
| 24. | *Cosmarium* sp. | Tangmarg | - | - | - | - | - | - | - |
| | | Drang | - | - | - | - | - | - | - |
| | | Ningal | - | 31 | * | * | * | 31 | 15.5 |
| | | Gulmarg | - | - | - | - | - | - | - |
| | | Fish canal | - | - | - | - | 119 | 119 | 23.8 |
| 25. | *Chlorococcum* sp. | Tangmarg | - | - | - | 369 | 319 | 688 | 137.6 |
| | | Drang | - | - | - | - | 100 | 100 | 20 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | 37 | - | - | 31 | - | 68 | 13.6 |
| | | Fish canal | - | 75 | 62 | 94 | 112 | 343 | 68.6 |
| 26. | *Chlorella* sp. | Tangmarg | - | - | - | - | - | - | - |
| | | Drang | 31 | - | - | - | 62 | 93 | 18.6 |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | 44 | - | - | 106 | 244 | 394 | 78.8 |
| | | Fish canal | - | - | - | 137 | - | 137 | 27.4 |
| 27. | *Chlostrium* sp. | Tangmarg | - | - | - | - | - | - | - |
| | | Drang | - | - | - | - | 94 | 94 | 18.8 |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | - | - | 150 | 37 | 137 | 324 | 64.8 |
| | | Fish canal | - | - | - | 194 | 69 | 263 | 52.6 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 28. | *Maugeotia* sp. | Tangmarg | - | - | - | - | - | - | - |
| | | Drang | - | - | - | - | - | - | - |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | - | - | - | - | - | - | - |
| | | Fish canal | - | - | - | - | 37 | 37 | 7.4 |
| 29. | *Oedogonium* sp. | Tangmarg | - | - | - | - | - | - | - |
| | | Drang | - | - | - | - | - | - | - |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | - | - | - | - | - | - | - |
| | | Fish canal | - | - | - | - | 25 | 25 | 5 |
| 30. | *Spirogyra* sp. | Tangmarg | - | - | - | - | - | - | - |
| | | Drang | - | - | - | - | - | - | - |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | - | 137 | - | - | - | 137 | 27.4 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Fish canal | - | - | 69 | 100 | - | 169 | 33.8 |
| 31. | *Ulothrix* sp. | Tangmarg | 556 | 900 | 1087 | - | - | 2543 | 508.6 |
| | | Drang | - | 81 | 287 | 112 | 25 | 505 | 101 |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | - | 200 | - | - | - | 200 | 40 |
| | | Fish canal | 12 | - | - | 31 | 19 | 62 | 12.4 |
| | **Cyanophyceae** | | | | | | | | |
| 32. | *Anabaena* sp. | Tangmarg | 62 | - | - | - | 56 | 118 | 23.6 |
| | | Drang | - | - | - | - | - | - | - |
| | | Ningal | - | 37 | * | * | * | 37 | 18.5 |
| | | Gulmarg | - | 106 | - | - | 62 | 168 | 33.6 |
| | | Fish canal | - | - | - | 112 | - | 112 | 22.4 |
| 33. | *Merismopedia* sp. | Tangmarg | - | - | - | 87 | - | 87 | 17.4 |
| | | Drang | - | - | - | - | - | - | - |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | - | - | - | - | - | - | - |
| | | Fish canal | - | - | - | - | - | - | - |
| 34. | *Microcystis* sp. | Tangmarg | - | - | - | - | - | - | - |
| | | Drang | - | - | - | - | - | - | - |
| | | Ningal | - | - | - | - | - | - | - |
| | | Gulmarg | - | - | - | - | - | - | - |
| | | Fish canal | - | 250 | - | - | - | 250 | 50 |
| 35. | *Oscillatoria* sp. | Tangmarg | 187 | 69 | 294 | - | - | 550 | 110 |
| | | Drang | 44 | 125 | 187 | 56 | - | 412 | 206 |
| | | Ningal | - | 206 | * | * | * | 206 | 103 |
| | | Gulmarg | - | - | 87 | 81 | - | 168 | 33.6 |
| | | Fish canal | - | 69 | - | 281 | 125 | 475 | 95 |
| 36. | *Spirulina* sp. | Tangmarg | - | - | - | - | - | - | - |

 ISSN 0973-7502

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Drang | - | - | - | - | - | - | - |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | - | - | - | - | 31 | 31 | 6.2 |
| | | Fish canal | - | - | - | - | - | - | - |
| 37. | *Tylopothrix* sp. | Tangmarg | - | - | - | - | - | - | - |
| | | Drang | - | - | - | - | - | - | - |
| | | Ningal | - | - | * | * | * | - | - |
| | | Gulmarg | - | 244 | 331 | - | - | 575 | 115 |
| | | Fish canal | - | - | - | - | - | - | - |

*sampling not done –Taxa not found

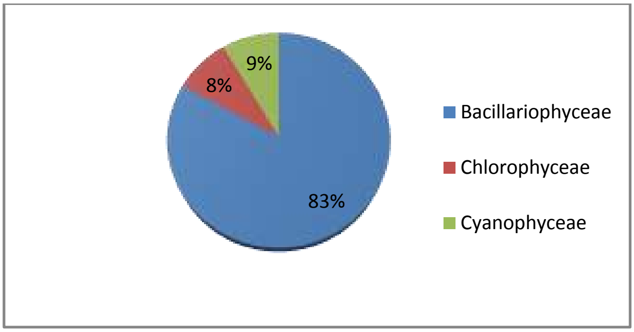


**Fig.3. Relative Density (%) of periphytic algae at five study sites**

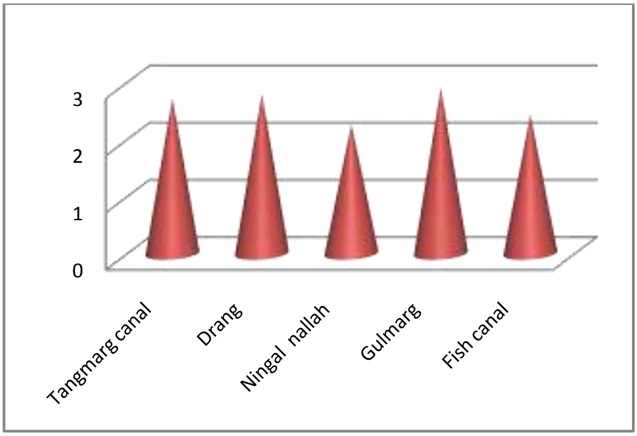


**Fig.4. Shannon – Wiener diversity index of periphytic algae at different sites**

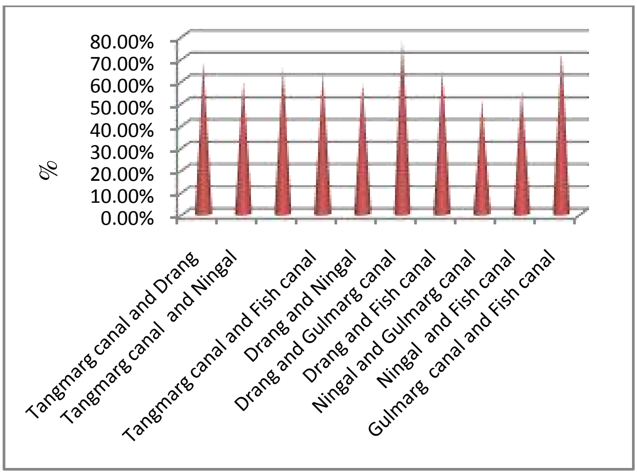


**Fig.5. Sorenson's similarity coefficient of periphytic algae at different sites**

The algal diversity of these four streams is relatively low and it seems difficult to find comparable studies for its evaluation, as the species diversity is related and dependent on number of sites, number of samples and level of taxonomic effort. Diatoms from stream ecosystems have been observed in large numbers as increase of Southern Alps where 254 diatom species from 30 streams have been reported (Cantonati, 1998) a part from other studies (Moore, 1979; Allan, 1997). In case of Bacillariophyceae, numbers of taxa reported at each site were almost similar as in Gulmarg canal i.e., 18 followed by Fish canal, Tangmarg canal and Drang with (17) and lowest at Ningal (9).

Since the periphytic algal community in these headwater streams was dominated by diatoms which in turn were dominated by *Fragillaria* sp., *Navicula* sp., *Diatoma* sp., *Cymbella* sp., *Tabellaria* sp., and *Synedra* sp. It may also be attributed due to the presence of good concentrations of $SiO_2$ in water bodies which probably helps in the frustules formation (Wetzel and Likens, 1991) and its ability to thrive well in cold waters (Rao, 1955; Sarwar and Zutshi, 1988). The headwater streams of various orders emanating from Gulmarg catchment has the potential to be under stress due to ever increasing demand of opening more pristine areas for tourists as it is the case of Botapathri opened after 24 years.

The low flow of water during cold months seems responsible for growth and multiplication of Chlorophyceae among study sites. The presence of Cyanophyceae may be attributed to the reason that due to the inflow of sewage into the water bodies which may have provided good organic nutrients for the growth and multiplication of Cyanophyceae at different sites.

Most of the taxa belonging to various classes were found common throughout the sampling period which is an indicative of more or less similar environmental factors gove-rning the growth and multiplication of these periphytic algae such as water chemistry physical habitat, watershed vegetation and watershed geology. Further, the Sorensen simil-arity index value of these streams also points out towards the habitat homogeneity of these headwater streams as they seem to be in pristine conditions of the streams reflected by water chemistry except by Gulmarg which bears the brunt of nutrient enrichment from the Gulmarg bowl from heavy tourist infrastructure.

## CONCLUSIONS

The present investigation of periphytic community revealed that the most of the algal taxa were common thereby indicating their potential to strive in diverse habitats. The Gulmarg area exhibits a good density and diversity of periphytic algal community. The dominance of diatoms at Fish canal, Gulmarg canal and Tangmarg canal depict the organic enrichment in the streams and density pattern of periphyton at Fish canal seems directly related anthropogenic factor due to the fish feed in the canal.

## ACKNOWLEDGEMENTS

The authors are highly thankful to, H.O.D Environmental Science, University of Kashmir for providing the necessary laboratory facilities to carry out this work.

## REFERENCES

Allan, J.D.1997. *Stream Ecology: Structure and Functioning of Running Waters*. Chapman and Hall, London,1995.

A.P.H.A. 1998. Standard Methods for Examination of water and Waste Water. 20th Ed. *American Public Health Association*, Washington, DC.

Azim, M.E., Wahab, M.A., van Dam, A.A., van Rooij, J.M., Beveridge, M.C.M. and Verdegem, M.C.J. 2002. The effects of artificial substrates on freshwater pond productivity and water quality and the implications for periphyton-based aquaculture. *Aquatic. Living Resource,* **15**:231-241.

Biggs, B. J. F. and Kilroy, C. 2000. *Stream Periphyton Monitoring Manual*. The New Zealand Ministry for the Environment, NIWA, Christchruch.

Cox, E. J. 1996. *Identification of Freshwater Diatoms From Live Materials.* Ist Edition Chapman and Hall, London, UK. 158p.

Cantonati,M. 1998. Diatoms communities of springs in Southern Alps. J. *Diatom Research,* **13**: 201- 220.

Dam, A.A.V, Beveridge, M.C.M, Azim, M.E. and Verdegem, M.C.J. 2002. The potential of fish production based on periphytic algae. *Reviews in Fish Biology and Fisheries,* **2**:1-31.

Edmondson, W.T.1992. *Ward and Whipple Fresh Water Biology.* 2nd ed. International Books and Periodicals Supply Service New Delhi.

Moore, J. W. 1979. Seasonal changes in the standing crop of epilithic population on the north western shore of Great Slave lake. *Can. J. Bot.,* **57**(1): 17-22.

Prescott, G. W. 1939. Some relationship of phytoplankton to limnology and aquatic biology. *Publ. Amer. Asso. Adv. Sci.*,**10**:65-78.

Rao, K. 1955. Plankton ecology of the River Hooghly at Palta, West Bengal. *Ecology,* **36**:169-175.

Ruthner, F. 1953. *Fundamentals of Limnology.* University Toronto Press 242pp.

Sarwar, S. G. and Zutshi, D. P. 1988. Species distribution and community structure of periphytic algae on artificial substrate. *Trop. Ecol.,* **29**(2):116-120.

Shannon, C. E. and Wienner, W. 1949. *The Mathematical Theory of Communication.* Univ. Illinois Press, Urbana. 117pp.

Sorensen, T. 1984. A method of establishing groups of equal amplitude in plant sociology based on similarity of species and its application to analyses of the vegetation on Danish commons. *Biol. Skr.*, **5**: 1-34.

Dodds, Walter K, and Biggs and Barry, J. F. 2003. Water velocity attenuation by stream periphyton and macrophytes in relation to growth form and architecture. *Journal of the North American Benthological Society*, **21**: 2-15.

 **ISSN 0973-7502**

Wetzel, R. G. 1979. Periphyton measure-ments and appli-cations p. 3-33. In: Wetzel R.G.(ed.), *Methods and Mea-surements of Periphyton Communities: A Review*, Am-erican Society for Testing and Materials, Phila-delphia.

Wetzel, R.G. and Likens, G.E. 2000. *Limnological Analysis*. 3rd ed. Verlag, new York, Inc. New York, pp.429.

# RECENT VARIATION IN TEMPERATURE TRENDS IN KASHMIR VALLEY (INDIA)

**Sumira Nazir Zaz and Shakil Ahmad Romshoo**

Deptt. of Earth sciences, University of Kashmir, Hazratbal, Srinagar, 190006

Corresponding authors: Email: zaz.sumira@gmail.com; Shakilrom@yahoo.com

**ABSTRACT**

Climate change and global warming are widely recognized as the most significant environmental dilemma today. Studies have shown that Himalayan region as a whole has warmed by about 1.8°F since 1970's, which has alerted scientists to lead several studies on climate trend detection at different scales. This paper examines the recent variation in air temperature in Kashmir valley (India). Time series of near surface air temperature data for the period ranging from 1980 to 2010 of five weather observatories were collected from the Indian Meteorological Department (Pune) on which Mann-Kendall Rank Statistic and Regression tests were performed for examination of temperature trends and its significance. Both the tests showed significant increase in the mean Annual, mean Minimum as well as in mean Maximum temperature at a confidence level of 90% -99% at all the five stations. Seasonally very significant increase was recorded in Spring and Winter temperature (90-99%) at all stations. The analysis reveals that such increase in the temperature particularly in spring can occur due to decrease in winter snowfall and its early melting as less snow cover/depth melts within short period of time there by leaving more period of time for warming the surface of earth. Thus, such variation in temperature can lead to water scarcity throughout the valley.

***Key words:*** Nonparametric, parametric; mankendall test, linear regression test, western disturbances

## INTRODUCTION

Prevalence of varied climatic conditions that are similar to those of widely separated latitudinal belt, within a limited area, make the high mountain areas such as the Himalaya, the Alps, the Andes, the Rockies etc. the ideal sites for the study of temperature change (Singh *et al.*, 2010). The high mountains of South Asia covering the Hindu-Kush, Karakoram Himalaya (HKKH) belt have reported warming trend in the past few decades (Viviroli *et al.*, 2007; Immerzeel *et al.*, 2010).The Himalayas exhibit a stronger warming trend for every season (Immerzeel *et al.*, 2010). Snow cover is one of the important climatic elements which interact with the global atmosphere by changing the energy regime as a result of the large albedo and net radiation loss (Namias, 1985; Sarthi *et al.,* 2011). Several studies have also shown that decrease in snowfall days in western Himalayas is related to the occurrences of western disturbance (Archer, 2004; Fowler and Archer, 2006; Dimiri *et al.,* 2013; Hatwar *et al.,* 2005; Wiltshire, 2013). Various workers have suggested that decrease in snowfall has resulted in the increase of temperature in Himalayas (Kulkarni *et al.,* 2002; Negi 2005a; Fowler and Archer, 2006; Negi 2009b; Jeelani 2012; Sarthi, *et al.,* 2011, Kaab *et al.,* 2012). Concern on climate change has brought several studies on temperature trend detection (Brohan, 2006; Jones, 2003; Landscheidt, 2000; Vinnikov and Grody, 2003, Joeri *et al.,* 2011).Water resources are considered vulnerable in the region due to increasing temperature (Barnett *et al.,* 2005). Due to increase in temperature seasonal storage of water in snow and ice results early runoff (Immerzeel *et al.,* 2010; Kaser *et al.,* 2010; Schaner *et al.,* 2012; Siderius *et al.,* 2013). Considering this importance, this paper attempts to understand the temperature changes in the valley of Kashmir that lies between the Himalayan range in the north and the Pir Panjal range in the south for a period of three decades from 1980 to 2010. This region has abundant water resources in the form of glaciers, snow and lakes that feed water to number of river tributaries which finally drains in the river Jhelum. The Himalaya exercises a dominant control over the meteorological and hydrological conditions in the valley of Kashmir. Even a minor change in their climate has a potential to cause disastrous consequences on the socio-economic survival of millions of people (Archer, 2004;Fowler and Archer, 2006;Jeelani *et al.,* 2012). Runoff from the melting of winter snow and perennial ice makes a significant contribution to river flow during the summer season that is vital for irrigation and hydropower production in the region.

## STUDY AREA

The valley of Kashmir lies between the Himalayan range in the north and the Pir Panjal range in the south, situated between latitude 33°55' to 34°50' and longitude, 74° 30' to 75° 35' in India. The Kashmir valley is located at the elevation of approximately 1500mts above the sea level. This region has very rugged topography and the highest elevation is around 5600mts above the sea level. The location of the study area is shown in Fig. 1. On the Greater Himalayan tracts, bordering the north-western part of Kashmir valley are Ladakh, Baltistan and Gilgit (Raza *et al.*, 1978). The total area is approximately more than 15,836 $km^2$. The river Jhelum originates from the Verinag in the Pir Panjal ranges passes through the middle of the valley and has a length of 160kms in the Indian territory of Kashmir (Wadia, 1979). The river receives water from more than twenty four tributaries and some of them are fed by the glaciers important among them is the 'Kolahoi glacier' in lidder watershed that joins river Jhelum near Sangam station. River Jhelum drains alluvial lands in the Kashmir Valley that is known as the rice bowl of Kashmir. The weather in the Kashmir Himalaya has a marked seasonality in temperature and precipitation, which is dominated by midlatitude frontal disturbances. The region experiences four distinct seasons: winter (December to February), spring (March to May), summer (June to August), and autumn (September to November). The average rainfall, as observed from the nearest meteorological station at Srinagar, is 650 mm, and average temperature ranges from 2.5°C in winter to 23.8°C in summer (Jeelani, 2012).

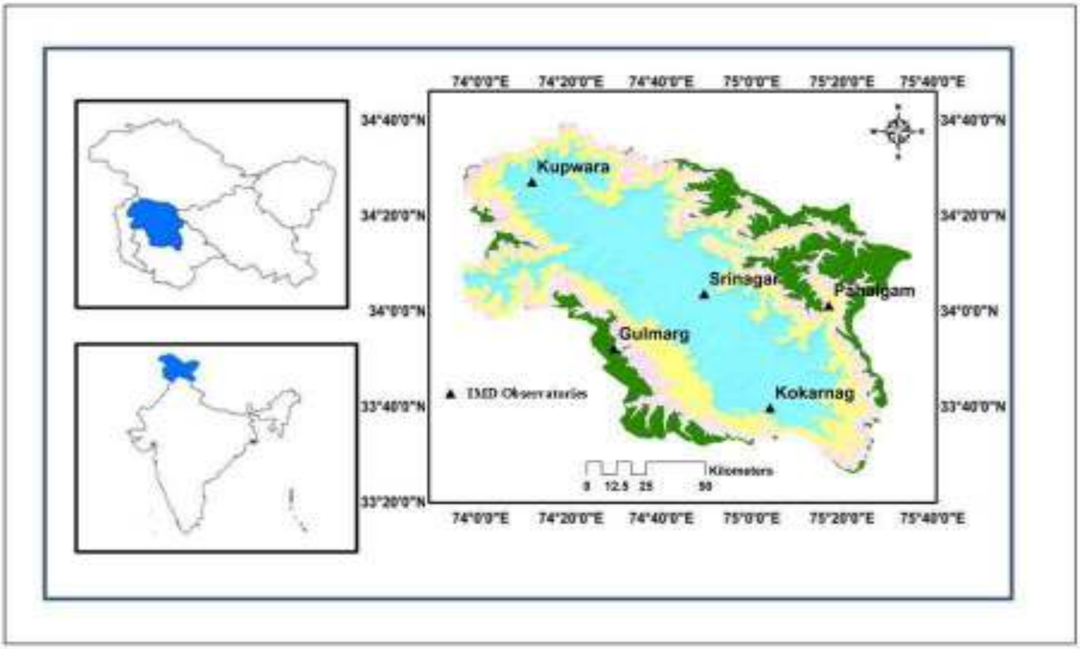


**Fig. 1. Map of study area**

## MATERIAL AND METHODS

Temperature data was procured from Indian Metrological center (IMD) Pune for five - stations of different elevations, located at Pahalgam, Gulmarg, Srinagar, Kokarnag and Kupwara. The average minimum, Maximum, Annual and Seasonal (Winter, spring, summer, autumn) temperature data was analyzed at all stations. The magnitude of trend and statistical significance was carried out using Mann-kendall (non-parametric) and linear regression (parametric) tests. These tests were performed using the trend statistical software.

## RESULTS

The results of mean Annual, mean Maximum, mean Minimum and Seasonal temperature data using parametric and nonparametric test for the Gulmarg, Pahalgam, Qazigund, Kokernag, Kup-wara and Srinagar stations for last 30 years from 1980-2010 are shown as under.

**Gulmarg station**

This station lies to the north of the valley at an elevation of 2949 mts at latitude of 33°50' and 74° 21' longitude. The average temperature at this station is 7.8 °C. From 1980-2010 the mean Annual and mean Minimum temperature showed a significant increasing trend at a confidence level of 99% using Mann-Kendall and linear regression tests. (Table1 and Fig 2). Analysis of mean Maximum temperature at this station showed an increasing trend at confidence level of 90% using both the test. The temperature in Winter, Spring and Autumn season showed an increasing trend at confidence level of 95%. However, the Summer temperature showed insignificant increasing trend during these 30 years (Table 1 and Fig. 2).

**Table 1. Annual and Seasonal temperature trends at Gulmarg station**

| | Temperature of Gulmarg station in°C | | | | | |
|---|---|---|---|---|---|---|
| **Statistical tests** | **Names** | **Test statistic** | **a=0.1** | **a=0.05** | **a=0.01** | **Result** |
| **Mankendall test** | Annual average | 2.923 | 1.645 | 1.96 | 2.576 | S (0.01) |
| | Average maximum | 1.564 | 1.645 | 1.96 | 2.576 | S (0.1) |
| | Average minimum | 3.059 | 1.645 | 1.96 | 2.576 | S (0.01) |
| | Winter Season | 2.43 | 1.645 | 1.96 | 2.576 | S (0.05) |
| | Spring Season | 2.006 | 1.645 | 1.96 | 2.576 | S (0.05) |
| | Summer Season | 0.986 | 1.645 | 1.96 | 2.576 | NS |
| | Autumn Season | 2.159 | 1.645 | 1.96 | 2.576 | S (0.05) |
| **Linear regression test** | Annual average | 3.12 | 1.699 | 2.045 | 2.756 | S (0.01) |
| | Average maximum | 1.942 | 1.699 | 2.045 | 2.756 | S (0.1) |
| | Average minimum | 3.79 | 1.699 | 2.045 | 2.756 | S (0.01) |
| | Winter Season | 2.259 | 1.699 | 2.045 | 2.756 | S (0.05) |
| | Spring Season | 2.224 | 1.699 | 2.045 | 2.756 | S (0.05) |
| | Summer Season | 0.829 | 1.699 | 2.045 | 2.756 | NS |
| | Autumn Season | 2.32 | 1.699 | 2.045 | 2.756 | S (0.05) |

NS= Non significant; S=Significant. S= Significance 0.01=99% , 0.05=95%, 0.1=90%

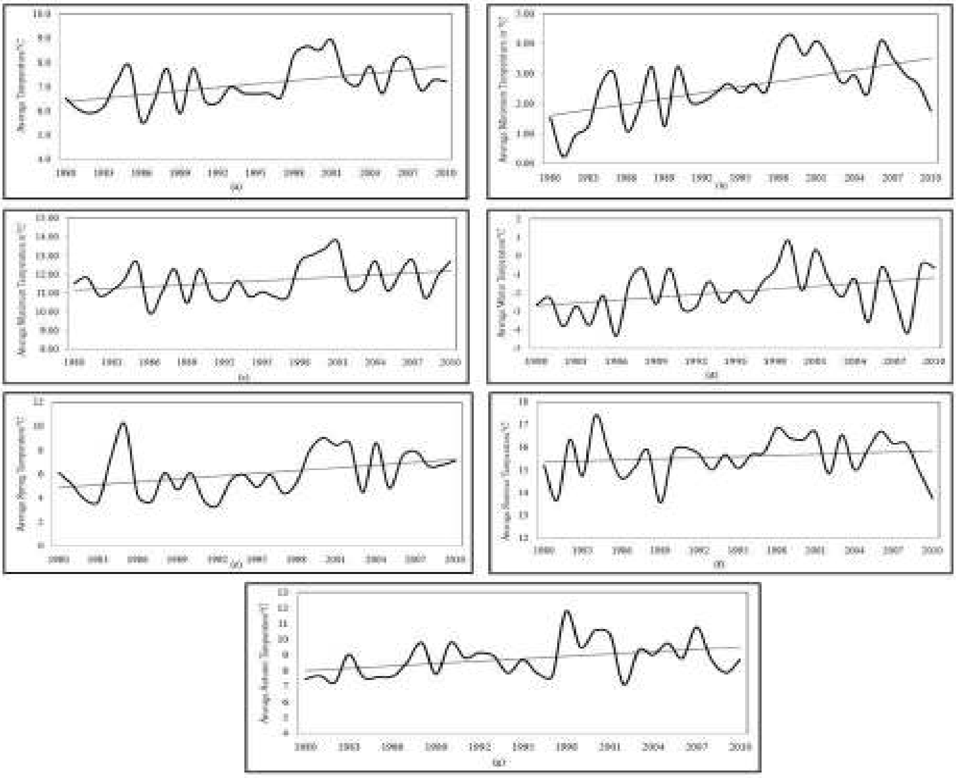

**Fig. 2. Annual and seasonal temperature trends at Gulmarg station**

### Srinagar station

This station located at the latitude 34º 00´ and 75º 00´ longitudes at the elevation of 1500mts. The average temperature is 12°C. The average temperature at this station showed significant increasing trend from 1980-2010 at confidence level of 95% using both the tests (Table 2 and Fig. 3). The analysis of Minimum and winter temperature during these years showed increasing trend at significant level of 90% using both parametric and nonpara-metric tests (Fig. 3). The Maximum temperature showed significant increa-sing trend at confidence level of 99% (Table 2). Seasonally, Summer and Autumn showed insignificant increasing trend, while the Spring season showed a significant increase at confidence level of 95% using Mann-Kendall test and 99% and linear regression test.

**Table 2. Annual and seasonal temperature trends at Srinagar station**

| Statistical test | Temperature at Srinagar station in°C | | | | | |
|---|---|---|---|---|---|---|
| | **Name of the Season** | **Test statistic** | **a=0.1** | **a=0.05** | **a=0.01** | **Result** |
| **Mankendall test** | Annual average | 2.108 | 1.645 | 1.96 | 2.576 | S (0.05) |
| | Annual maximum | 2.804 | 1.645 | 1.96 | 2.576 | S (0.01) |
| | Annual minimum | 1.391 | 1.645 | 1.96 | 2.576 | S(0.1) |
| | Winter Season | 1.394 | 1.645 | 1.96 | 2.576 | S(0.1) |
| | Spring Season | 2.413 | 1.645 | 1.96 | 2.576 | S (0.05) |
| | Summer Season | 0.374 | 1.645 | 1.96 | 2.576 | NS |
| | Autumn Season | 0.918 | 1.645 | 1.96 | 2.576 | NS |
| **Linear Regression** | Annual average | 2.243 | 1.699 | 2.045 | 2.756 | S (0.05) |
| | Annual Maximum | 3.27 | 1.699 | 2.045 | 2.756 | S (0.01) |
| | Annual Minimum | 1 | 1.699 | 2.045 | 2.756 | S(0.1) |
| | Winter Season | 1.271 | 1.699 | 2.045 | 2.756 | S(0.1) |
| | Spring Season | 3.164 | 1.699 | 2.045 | 2.756 | S (0.01) |
| | Summer Season | 0.273 | 1.699 | 2.045 | 2.756 | NS |
| | Autumn Season | 1.099 | 1.699 | 2.045 | 2.756 | NS |

NS=Non significant; S=Significant. S 0.01=99% , 0.05=95%, 0.1=90%

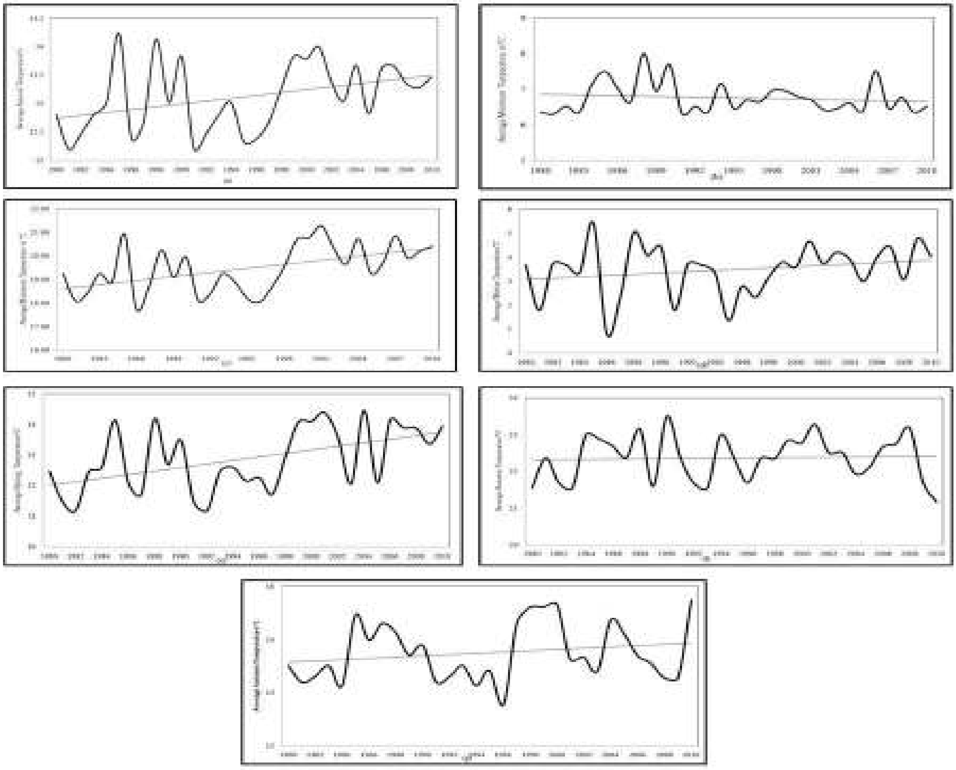

**Fig. 3. Annual and seasonal temperature trends at Srinagar station**

## Pahalgam station

Pahalgam station is located in the Lidder valley of Kashmir at the elevation of 2730 mts between 75° 20' longitude and 34° 00' latitude as shown in Fig 1. The mean Annual temperature at the Pahalgam station is 9ºC. The average temperature at this station showed a significant increasing trend as shown in Table 3 and Fig. 4 at confidence level of 99% using both the tests. The analysis of mean Maximum, mean Minimum and mean Spring and Winter temperature showed a significant increase at a confidence level of 99% using both the test. Summer temperature showed increase at a confidence level of 90% as shown in Table 3 and Fig. 4. The Autumn temperature showed significant increasing trend at confidence level of 95% using both the test.

**Table 3. Annual and seasonal temperature trends at Phalgam station**

| Statistical test | Temperature at Phalgam station in°C | | | | | |
|---|---|---|---|---|---|---|
| | **Name of the Season** | **Test statistic** | **a=0.1** | **a=0.05** | **a=0.01** | **Result** |
| **Mankendall test** | Annual average | 4.119 | 1.645 | 1.96 | 2.576 | S (0.01) |
| | Annual maximum | 3.519 | 1.645 | 1.96 | 2.576 | S (0.01) |
| | Annual minimum | 3.6 | 1.645 | 1.96 | 2.576 | S (0.01) |
| | Winter Season | 3.811 | 1.645 | 1.96 | 2.576 | S (0.01) |
| | Spring Season | 3.438 | 1.645 | 1.96 | 2.576 | S (0.01) |
| | Summer Season | 1.719 | 1.645 | 1.96 | 2.576 | S (0.1) |
| | Autumn Season | 2.416 | 1.645 | 1.96 | 2.576 | S (0.05) |
| **Linear Regression** | Annual average | 5.087 | 1.697 | 2.042 | 2.75 | S (0.01) |
| | Annual Minimum | 3.519 | 1.645 | 1.96 | 2.576 | S (0.01) |
| | Annual Maximum | 4.457 | 1.697 | 2.042 | 2.75 | S (0.01) |
| | Winter Season | 3.856 | 1.697 | 2.042 | 2.75 | S (0.01) |
| | Spring Season | 4.597 | 1.697 | 2.042 | 2.75 | S (0.01) |
| | Summer Season | 1.915 | 1.697 | 2.042 | 2.75 | S (0.1) |
| | Autumn Season | 2.46 | 1.697 | 2.042 | 2.75 | S (0.05) |

NS= Non significant; S=Significant. S= Significance 0.01=99% ,0.05=95%, 0.1=90%

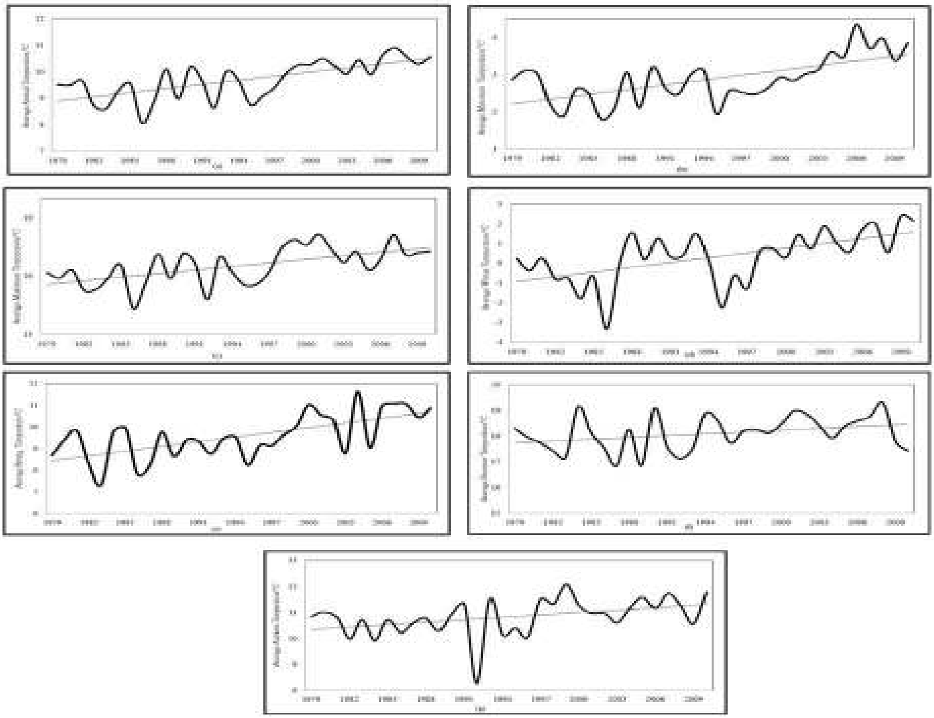

**Fig. 4. Annual and seasonal temperature trends at Phalgam station**

### Kokernag station

The Kokernag is located towards the southern part of the valley at the elevation of 2000mts at the latitude of 33° 40' and longitude of 75° 00'. The mean Maximum and mean Annual temperature at this station showed an increasing trend at confidence level of 99% and the mean Minimum temperature showed an increasing trend from last three decades at the confidence level of 95% as shown in Fig 5 and Table 4. The analysis of temperature in Winter Spring and Autumn season shows a significant increasing trend at confidence level of 99% using both the trend test while the Summer temperature shows insignificant increasing trend.

## Table 4. Annual and seasonal temperature trends at Kokarnag station

| | **Temperature of Kokarnag station in°C** | | | | | |
|---|---|---|---|---|---|---|
| **Statistical tests** | **Names** | **Test statistic** | **a=0.1** | **a=0.05** | **a=0.01** | **Result** |
| **Mankendall test** | Annual average | 3.433 | 1.645 | 1.96 | 2.576 | S (0.01) |
| | Average maximum | 3.246 | 1.645 | 1.96 | 2.576 | S (0.01) |
| | Average minimum | 1.819 | 1.645 | 1.96 | 2.576 | S (0.5) |
| | Winter Season | 1.785 | 1.645 | 1.96 | 2.576 | S (0.01) |
| | Spring Season | -2.176 | 1.645 | 1.96 | 2.576 | S (0.01) |
| | Summer Season | 0.187 | 1.645 | 1.96 | 2.576 | NS |
| | Autumn Season | 2.685 | 1.645 | 1.96 | 2.576 | S (0.01) |
| **Linear regression test** | Annual average | 3.745 | 1.699 | 2.045 | 2.756 | S (0.01) |
| | Average maximum | 3.842 | 1.699 | 2.045 | 2.756 | S (0.01) |
| | Average minimum | 2.331 | 1.699 | 2.045 | 2.756 | S (0.05) |
| | Winter Season | 1.797 | 1.699 | 2.045 | 2.756 | S (0.01) |
| | Spring Season | -2.525 | 1.699 | 2.045 | 2.756 | S (0.01) |
| | Summer Season | -0.154 | 1.699 | 2.045 | 2.756 | NS |
| | Autumn Season | 2.903 | 1.699 | 2.045 | 2.756 | S (0.01) |

NS= Non significant; S=Significant. S= Significance 0.01=99% ,0.05=95%, 0.1=90%

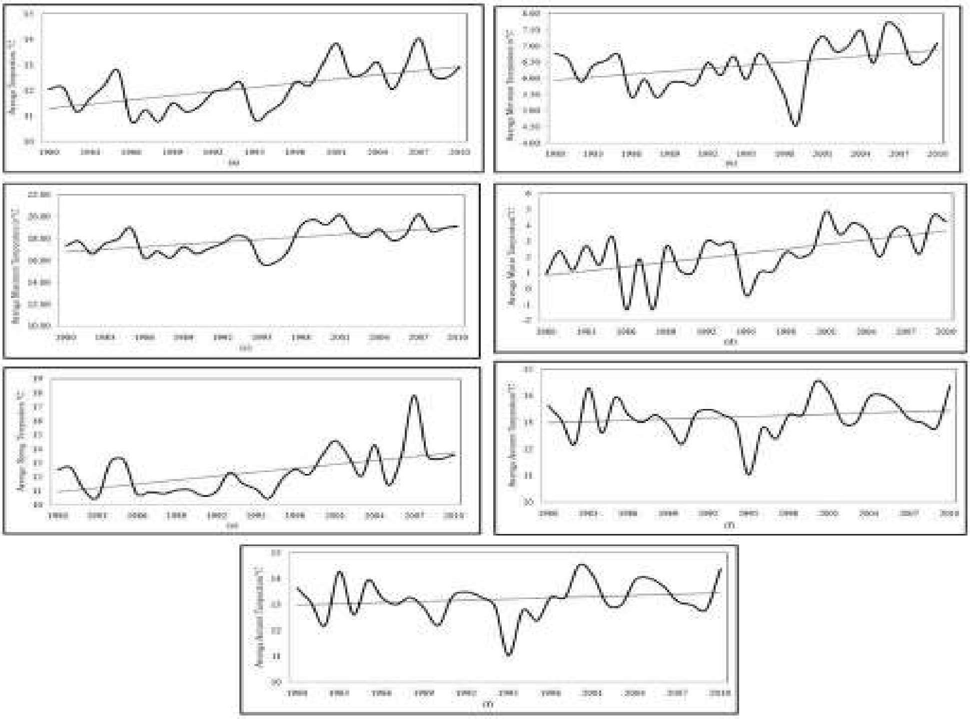

**Fig. 5. Annual and Seasonal temperature trends at Kokarnag station**

**Kupwara station**

The Kupwara station lies at the altitude of 2400 mts at the latitude of 34º 25' and longitude 74º 18'. The average temperature at this station is 12ºC. The analysis of mean Annual, mean Maximum, mean Minimum and Winter temperature from last 30 years showed significant increase at confidence level of 99% using Mann Kendall and Linear regression tests while the mean Summer and Autumn temperature showed insignificant increasing trend as shown in Fig. 6 and Table 5. The mean temperature in Spring season is showing increasing trend at a confidence level of 95% using Mann Kendall test and 99% and 95% using Linear Regression tests.

The result of this study based on observation of the existing data reveal that there has been increasing trend in the seasonal and annual average temperature at all the five stations in particular and in Kashmir valley as a whole. Further analysis also reveals that in Kashmir valley winter and spring seasons have been warming at all the stations (statistically significant at 0.01-0.05 or

95%-99%). Whereas summer and autumn seasons have comparatively increased statistically at lower to insignificant rates. These observations are matching with the findings of other studies on temperature changes, in the Himalaya (Agrawal *et al.,* 1989; Khan 2001; Archer and Flower, 2004; Kumar and Jain, 2010). Shrestha *et al.,* (1999) in his observations also revealed that the Himalayan region as a whole has warmed by about 1.8°F since 1970's. Similar results too have been observed by Fowler and Archer (2006) in Upper Indus basin (North Western Himalayas) where temperature has been found increasing at higher rate in winter season. The Tibetan Plateau region, the Kosi Basin in the Central Himalaya and the Nepal Himalaya in the eastern part of Himalayas have experienced similar positive increasing trend in temperature during the last century (Sharma *et al.,* 2000). Since the Himalayan Mountains are the greatest resources of snow and glaciers after the Polar Regions they are the major sources of water for irrigation, drinking water, hydro project etc for south east Asia. Recent studies revealed that Himalayan glaciers/snow are melting and receding at much faster rate (Kaser *et al.,* 2010; Immerzeel *et al.,* 2010; Schaner *et al.,* 2012; Siderius *et al.,* 2013), which influence the water resources, economy and the tourism in Himalayas, besides snow cover has been shown to exert a considerable local influence on weather variables, so this can be one of the important bases for prediction of enhanced warming in seasonally snow covered regions. The Himalayas receives most of its precipitation in the form of snow by the Western disturbances during Winter months (Karl 1993, Groisman *et al.,* 1994, Robinson and Serreze, 1995). From last few years various researchers have reported decreasing snowfall during winter months due to variations in Western disturbances (Karl, 1993; Groisman *et al*., 1994; Robinson and Serreze, 1995; Hengchun and Mather, 1997; Fallot *et al.,* 1997; IPCC 2001; Ye and Bao, 2001, Raicich *et al.,* 2003; Choi *et al.,* 2010 and Brown and Robinson, 2011). Such decreasing snowfall results in less snow cover/depth in these regions. This less snow cover/ depth melts within a short period of time during winter season and leaves scope for early spring season which results in early increase in temperature and direct heating of earth's surface that has also been established due to early flowering of plants in this region also noted by various workers (Walker *et al*., 1995, Houghton, 2001, Dunne *et al.,* 2003). Early melting of snow has resulted in increasing flow of rivers during spring season and very less flow during summer seasons which has simultaneously affected the irrigation and hydropower sector adversely (Dhanju, 1983; Negi *et al.,* 2005, 2009; Sarthi *et al.,* 2011.)

**Table 5. Annual and seasonal temperature trends at Kupwara station**

| | Temperature of Kupwara station in°C | | | | | |
|---|---|---|---|---|---|---|
| **Statistical tests** | **Names** | **Test statistic** | **a=0.1** | **a=0.05** | **a=0.01** | **Result** |
| **Mankendall test** | Annual average | 3.62 | 1.645 | 1.96 | 2.576 | S (0.01) |
| | Average maximum | 3.11 | 1.645 | 1.96 | 2.576 | S (0.01) |
| | Average minimum | 2.363 | 1.645 | 1.96 | 2.576 | S (0.01) |
| | Winter Season | 2.43 | 1.645 | 1.96 | 2.576 | S (0.01) |
| | Spring Season | 3.195 | 1.645 | 1.96 | 2.576 | S (0.05) |
| | Summer Season | 1.462 | 1.645 | 1.96 | 2.576 | NS |
| | Autumn Season | 0.68 | 1.645 | 1.96 | 2.576 | NS |
| **Linear regression test** | Annual average | 3.998 | 1.699 | 2.045 | 2.756 | S (0.01) |
| | Average maximum | 3.622 | 1.699 | 2.045 | 2.756 | S (0.01) |
| | Average minimum | 2.376 | 1.699 | 2.045 | 2.756 | S (0.01) |
| | Winter Season | 2.259 | 1.699 | 2.045 | 2.756 | S (0.01) |
| | Spring Season | 3.469 | 1.699 | 2.045 | 2.756 | S (0.01) |
| | Summer Season | 1.108 | 1.699 | 2.045 | 2.756 | NS |
| | Autumn Season | 1.023 | 1.699 | 2.045 | 2.756 | NS |

NS= Non significant; S=Significant. S= Significance 0.01=99% ,0.05=95%, 0.1=90%

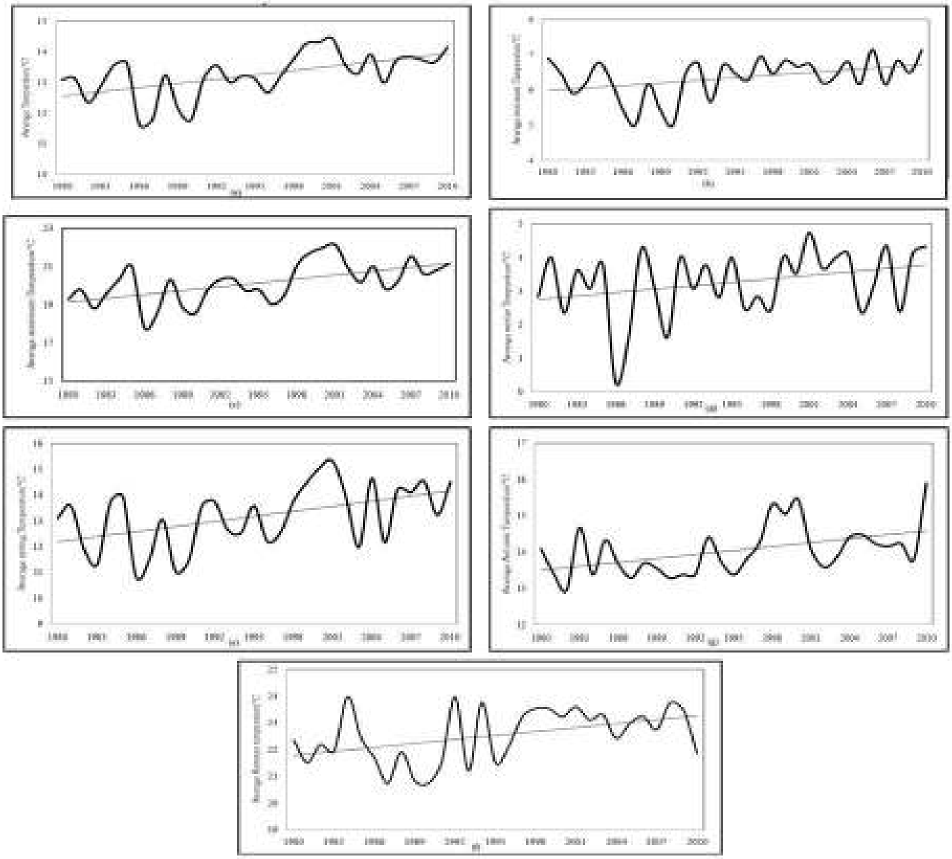

**Fig. 6. Annual and seasonal temperature trends at Kupwara station**

## CONCLUSIONS

The results of the present study based on observation of the existing data reveal that there has been significant increasing trends in the seasonal and the annual surface air temperatures in Kashmir valley as a whole during the period, 1980-2010. Moreover, the winter and spring seasons have been warming more significantly (0.01-0.05) at all stations. The results are in agreement with the findings of other studies on climate change in the Himalaya. Further analysis shows that there has been less snowfall in winter season resulting in less snow cover/depth. This less snow requires less amount of temperature for melting paving way for early springs due to increase in temperature. This increase in temperature throughout the valley with significant increase in spring temperature can have serious consequences on agriculture, hydro power and drinking water supply.

## REFERENCES

Agrawal, D.P., Dodia, R., Kotlia, B.S., Razdan, H. and Sahni, A. 1989. The pliopleistocene geologic and climatic record of the Kashmir valley, India: Areview and new data. *Journal of Palaeogeography, Palaeoclimatology, Palaeoecology* **73**: 267 -286.

Archer, D.R. and Fowler, H.J. 2004. Spatial and temporal variations in precipitation in the Upper Indus Basin, global teleconnections and hydrological implications. *Journal of Hydrology and Earth System Sciences,* **8**: 47–61.

Barnett, T.P., Adam, J.C. and Lettenmaier, D. P. 2005. Potential impacts of a warming climate on water availability in snow dominated regions. *Nature,* **438**: 303–309.

Brohan, P., Kennedy, J. J., Harris, I., Tett, S.F.B. and Jones, P .D. 2006. Uncertainty Estimates in Regional and Global Observed Temperature Changes: A New Dataset from 1850. *Journal of Geophysical Research,* **111**:21-22. D12106. doi: 10.1029/2005J D006548.

Brown, R.D. and Robinson, D.A. 2011. Northern Hemisphere spring snow cover variability and change over 1922–2010 including an assessment of uncertainty, *The Cryosphere*, **5**: 219-229

Choi, Gwangyong., David, A. Robinson., Sinkyu and Kang 2010. Changing Northern Hemisphere Snow Seasons. *Journal of Climate*, **23**:5305-5310.

Dhanju, M.S.1983. Studies of Himalayan snow cover area from satellites. Hydrological Applications of Remote Sensing and Remote Data Transmission. Proceedings of the Hamburg Symposium, August 1983. IAHS Pub. no. 145

Dimiri, A. P., Yasunari, T., Wiltshire, A. J., Kumar, P., Mathison, C. and Ridley, J. 2013. Application of regional climate models to the Indian winter monsoon over the western Himalayas. *Science Total Environment,* doi:10.1016/j.scitotenv. 2013.01.040.

Dunne, J.A., Harte, J. and Taylor, K.J. 2003. Subalpine meadow flowering phenology responses to climate change: Integrating experimental and gradient methods. *Ecological Monographs*, **73**: 69–86

Fallot, J.M., Barry, R.G. and Hoogstrate, D., *et al.,*1997. Variation of mean cold season temperature, precipitation and snow depths during the last 100 years in the former depths during the last 100 years in the former Soviet Union (FSU).*Journal of Hydrological Science,* **42**:301–327.

Fowler, H.J. and Archer, D.R.2006. Conflicting signals of climate change in the upper Indus Basin. *Journal of Climatology,* **19**: 4276–4293.

Groisman, Pavel Ya, Thomas R. Karl, Richard W. Knight, Georgiy L. and Stenchikov. 1994. Changes of snow cover, temperature, and radiative heat balance over the Northern Hemisphere. *Journal of Climate,* **7**:1633–1656.

Hatwar, H.R., Yadav, B.P. and Rama Ravo, Y.V. 2005 Prediction of Western Disturbances and associated Weather in Western Himalayas. *Current Science* **(88) 6**: 913-920.

Hengchun, Y.E. and Mather, J.R., 1997. Polar snow cover changes and global warming. *International Journal of Climatology***,** **17** (2): 155–162

Houghton, J.T., Ding, Y. and Griggs, D.J., *et al.* 2001. *Climate Change 2001: The Scientific Basis*. Third IPCC Report. Cambridge University Press, Cambridge.

Immerzeel, W. W., Van Beek, L. P. H., and Bierkens, M. F. P. 2010. Climate change will affect the asian water towers. *Science*, **328**: 1382–1385.

IPCC. Intergovernmental panel on climate change. 2001. *The IPCC third assessment report*. Cambridge Unive-rsity Press, Cambri-dge and New York I (The Scientific basis), II (Impacts, adaptation and vulnerability) and III (Mitigation).

Jeelani, G., Johannes, J, Feddem., Cornelis, J., van der Veen. and Leigh Stearns.2012. Role of snow and glacier melt in controlling river hydrology in Liddar wate-rshed (western Himalaya) under current and future climate. *Journal of Water Resources*, **48**:1-16.

Joeri, H. R., William, H. L., Jason, D. P., van Vuuren, R. Keywan., B Matthews., H. Tatsuya., J. Kejun and M. Malte., *et al.*, 2011. Emission Pathways Cons-istent with a 2°C Global Temperature Limit. *Natu-re Climate Change*, **1**(1): 413-418. doi:10.1038/nclimate 1258.

Jones P. D and Moberg. A. 2003. Hemispheric and large scale surface air temperature variations: An Extensive Revision and Update to 2001. *Journal of Climate*, **16**: 206-223. doi:10.1175/1520-0442 (2003) 016<0206: HAL-SSA > 2.0.CO.,2

Kaab, A., Berthier, E., Nuth, C., Gardelle, J. and Arnaud, Y. 2012. Contrasting patterns of early twenty-first century glacier mass change in the Himalayas. *Nature*, **488:** 495–498.

Karl, T.R. 1993. Missing pieces of the puzzle. Research and Exploration. *National Geographic Society*, **9:** 234-249.

Kaser, G., Grosshauser, M., and Marzeion, B. 2010. Con-tribution potential of gla-ciers to water availability in different climate regimes. *Proceeding of National. Acadamy Scien-ce*. USA, **107**:20223–20227.

Khan, A, R. 2001. Analysis of Hydro-meteorological Time Series: Searching Evidence for Climate Change in the Upper Indus Basin. International Water Management Institute (IWMI), Pakistan, Lahore. Working Paper 23 In: Inter-governmental Panel on Climate Change (IPCC) Report.

Kulkarni, A. V., Mathur, P., Rathore, B. P., Suja Alex., Thakur ,N and Manoj *et al.,* 2002. Effect of global warming on snow ablation pattern in the Himalaya., *Current Science,* **83**: 120–123.

Kumar, V., Jain and S.K. 2010. Trends in seasonal and annual rainfall and rainy days in Kashmir valley in the last century. *Quarternary International*, **212**: 64–69.

Landscheidt, T. 2000.Solar Wind near Earth: Indicator of Variations in Global Temperature. Proceedings of the 1st Solar and Space Weather Euro conference on the Solar Cycle and Terrestrial Climate, Tenerife. 497- 500.

Namias, J. 1985. Some empirical evidence for the influence of snow cover on temperature and precipitation. *Monitoring Weather Reverses*, **113**: 1542-1553.

Negi. H.S., Mishra, V.D and Mathur, P. 2005. Change Detection Study for Snow Cover Mountains using Remote Sensing and Ground Based Measurements. *Journal of Indian Society of Remote Sensing*, **33**(2): 245–251.

Negi, H.S., Snehmani and Thakur. N. K. 2009. Operational snow cover monitoring in NW-Himalaya using Terra and Aqua MODIS Imageries. *Proceeding of International Workshop on Snow, Ice, Glacier and Avalanches, IIT Bombay, India*.

Negi. H.S., Thakur, N.K., and Sharma, J. K. (2005b). Snowcover Moni-toring using Remote Sensing in NW Himalaya.

Raicich, F., Pinardi,N and Navarra, A., et al 2003. Teleconnections between Indian monsoon and rainfall and the Mediterranean *International Journal of Climatology*, **23**:173-186.

Raza, M., Ahmad, A. and Mohammad. A. 1978. *The Valley of Kashmir: A Geographical Interpretation*: Vikas Publishing House Pvt Ltd, New Delhi. pp 48.

Robinson, D.A., Frei, A. and Serreze, M.C. 1995. Recent variations and regional relationships in northern Hemisphere snow cover. *Annals of Glaciology*, **21**: 71–76.

Sarthi, P.P, Dash, S.K. and Mamgain, A. 2011. Changes in surface temperature and snow over the Western Himalaya under Doubling of Carbon Dioxide $CO_2$ In: (eds) *Challenges and Opportunities in Agrometeorology Springer Berlin Heidelberg* 10.1007/978-3-642-19360-6_11. pp 163 -171.

Schaner, N., Voisin, N., Nijssen, B. and Lettenmaier, D. P. *et al*. (2012). The contribution of glacier melt to Stream flow. *Environmental Research Letter* (7) 034029, doi:10. 1088/ 1748-9326/7/3/ 034029.

Sharma, K.P., Moore, B. III and Vorosmarty, C.J., 2000. Anthro-pogenic, climatic and hydrologic trends in the Kosi Basin, *Himalayan Journal of Climate Change*, **47**:141–165

Shrestha, A.B., Wake, C.P., Mayeski, P.A. and Dibb, J.E. 1999. Maximum temperature trends in the Himalaya and its vicinity. An analysis based on temperature records from Nepal for the period 1971-94.*Journal of Climate*, **12**: 2773-2787.

Siderius, C., Biemans, H., Rao, S., Wiltshire, A. J., Franssen, W. H. P., Kumar, P., Gosain, A. K., van Vliet, M. T. H. and Collins, D. N. 2013. Snowmelt contributions to discharge of the Ganges– amulti-model approach. *Science Total Environment* doi:10.1016/ j. scitotenv. 2013.05.084.

Singh, S. P., Singh, V. and Kutsch, M. S. 2010. Rapid warming in the Himalayas: Ecosystem responses and development options. *Climate and Development*, **2**: 1-13.

Vinnikov, K. Y. and Grody, N, C. 2003. Global Warming Trend of Mean Troposphere Temperature Observed by Satellites. Science, 302, 269-272. doi:10. 1126/science. 1087910

Viviroli, D., Durr, H. H., Messerli, B., Meybeck, M., and Weingartner, R. 2007. Mountains of the world, water towers for humanity: typology, maping, and global signifycance, *Water Resources. Research*, 43, doi:10.1029 /2006 WR005653.

Wadia, D.N.1979. *Geology of India*. Tata McGraw-Hill Publishing Co, New Delhi. p105.

Walker, D.M., Ingersoll, J. and Webber, P.J. 1995. Effects of interannual climate variation on phenology and growth of two alpine forbs. *Ecology*, **76**: 1067–1083.

Wiltshire, A. J. 2013. Climate change implications for the glaciers of the Hindu-Kush, Karakoram and Himalayan region. *Cryosphere*, **7**: 3717–3748.

Ye, H. and Bao, Z. 2001. Lagged teleconnections between snow depth in northern Eurasia, rainfall in southeast Asia and surface temperature over the tropical Pacific Ocean. *International Journal of Climatology,* **21**: 1661-1621.

# ANNUAL FLIGHT PATTERN OF THE ALMOND BARK BEETLE *SCOLYTUS AMYGDALI* GEURIN-MENEVILLE, 1847 (COLEOPTERA: CURCULIONIDAE) IN ALMOND ORCHARDS IN TUNISIA

**Zeiri Asma[1], Abdul A. Buhroo[2]*, Brahem Mohamed[3], Brahem Mohamed[4]**

[1]Department of Biology, Faculty of Sciences of Bizerte, University of Carthage, Bizerte,Tunisia E-mail: asma_zairi@yahoo.fr Tel. +21621676454

[2]P. G. Department of Zoology, University of Kashmir, Hazratbal, Srinagar-190006, India, E-mail: abuhroo@yahoo.com

[3]Laboratory of Entomology, Regional Center of Research on Horticulture and Organic Agriculture, The University of Sousse, 4042 Chott-Mariem, Sousse, Tunisia

[4]Department of Olive tree Physiology, Institute of the Olive Tree Station of Sousse, 40 Street Ibn Khouldoun 4061 Sousse, Tunisia

* Corresponding Author. Email: abuhroo@yahoo.com

**ABSTRACT**

The almond bark beetle *Scolytus amygdali* causes severe damage to some fruit trees in Tunisia. Understanding its seasonal activity is necessary for the development of its management based on mass trapping of the beetles. Therefore, the seasonal flight of *S. amygdali* was studied during two years in two different orchards in the center of Tunisia. The number of flying adults in orchard 2 was higher than the first orchard. It varied significantly between the two orchards ($F = 6.947$; $df = 1$; $P < 0.05$). Three generations were observed in the first orchard. The overwintering generation (November to January) emerges to give a spring generation starting from March and then followed by a summer generation starting from May to June. However, in the second orchard the activity of the almond bark beetle was very accentuated and continued in time. The activity of the pest was almost continuous due to overlapping of generations and availability of suitable trees suffering from poor growing conditions. The beetle flight and parasitism start earlier in orchard 2 than the orchard 1. The attack number (AN), attack density (AD) and multiplication rate (MR) of the beetle pest were also very high in the second orchard. These results reflect the abundance of different host plants available in the second orchard; including *Prunus dulcis*, *Malus domestica*, *Prunus persica*, *Prunus armeniaca* and *Prunus domestica.* However, the orchard 1 contains only *Prunus dulci*. The physiology of trees may also be affected by the soil type which was sandy in the first orchard and clay loam in the second orchard.

***Key words*:** Generations, flight pattern, life cycle, *Scolytus amygdali*, Tunisia.

## INTRODUCTION

In Tunisia, the cultivated almond tree Prunus dulcis (Mill.) D. A. Webb is planted in north, centre and south of Tunisia. It has a great economic importance particularly in the centre and south regions (Demangeon, 1932). Almond tree is the second agricultural product in Tunisia after the olive tree with approximately 22 million trees covering more than 302.0 million hectares (Bahri, 2012). The central and southern agricultural area of the country contributes 45% to the national production. This tree is attacked by many pests and diseases, among them bark beetles are considered as serious pests by destroying phloem of the host tree.

The almond bark beetle *Scolytus amygdali* Geurin-Meneville, 1847 (Coleoptera: Cuculionidae) is a severe pest of stone-fruit trees in the center of Tunisia (Cherif and Trigui, 1990). Only few studies about this beetle were carried out in Tunisia (Cherif and Trigui,1990; Zeiri *et al*., 2010; Zeiri *et al*., 2011a; Zeiri *et al*., 2011b). In Morocco, Benazoun (1983) gave a detailed study on its biology. Picard (1921) in France gives some indication of the tunnel system. According to many authors, *S. amygdali* is considered as a predominant species of bark beetle attacking fruit trees (Janjua and Samuel, 1941; Balachowsky, 1949; Benazoun, 1983; Benazoun and Schvester, 1990; Cherif and Trigui, 1990; Bolu and Legalov, 2008; Mandelshtam and Petrov, 2010). It was reported in all countries around the Mediterranean (Cherif and Trigui, 1990; Russo, 1931; Zeiri *et al*., 2010), the Middle East (Kinawy *et al*., 1991; Youssef *et al*., 2006a; Youssef *et al*., 2006b; Youssef *et al*., 2006c), the Caucasus and Central Asia (Janjua and Samuel, 1941; Choate, 1999). The insect lives on almond, apricot, peach and plum (Benazoun, 1983; Balachowsky, 1949). Plantations of plum, apricot and peach in Israel (Mendel *et al*., 1997), cherry in Spain (Teresa Garcia Becedas, pers. commu.), and almond in Morocco (Mahhou and Dennis, 1992) were severely affected.

Given the established importance of the damage caused by this beetle, the objective of the present study was to investigate the life cycle and some dynamic elements of the pest in different orchards in the center of Tunisia. This may help to assess control strategies and devise an efficient pest management system in the almond orchards.

## MATERIAL AND METHODS

### *Animal collection*

The study was carried out in almond orchards infested by *S. amygdali* at two different localities in the center of Tunisia (Table 1). The first experimental orchard (Orchard 1) is situated under the Professional Training Center of Agricultural Delegation, Souassi Governorat Mahdia. The second orchard (Orchard 2) is situated under the supervision of the Professional Training Center of Agricultural Delegation, Djemmal Governorat of Monastir and 6 km away from the first one. During three years, almond branches were collected from almond orchards and spread all over the experimental orchards under many trees in order to increase the probability of attack by the pest. The largest part of the life cycle of *S. amygdali* occurs under bark, making it difficult to trace its cycle. Hence, fresh branches of almond 30 to 50 cm long were cut twice per month and left open in the orchard, to mimic the natural conditions to allow the infestation of the almond bark beetle. Once the emergence of the beetles began the branches were taken to the laboratory into wooden cages to record emergence of adults and parasites. One face of the cage was with a small door to ensure the daily control of emergence. The cage was kept in the dark.

**Table 1. Experimental orchard characters**

| Orchard | Locality | GPS value | Soil | Vegetation | Climate |
|---|---|---|---|---|---|
| Orch. 1 | Souassi | 35°19'60" N<br>10°25'0" E | Sandy soil | *Prunus dulcis* | Arid |
| Orch. 2 | Djemmal | 35°37'60" N<br>10°46'0" E | Clay loam | *Prunus dulcis*<br>*Malus domestica*<br>*Prunus persica*<br>*Prunus armeniaca*<br>*Prunus domestica* | Semi-arid |

**Enumeration and analysis of the demographic composition of the population**

At the end of the cycle, sample branches were dissected. Each sample was measured for its length and circumference in order to determine its surface area. The number of adult beetles were counted by perforated/exit holes. We have dissected each sample with scalpel and used forceps and brushes to collect beetles. The number of maternal galleries represents the attack number (AN) which also represents the female preferences to lay eggs. The number of galleries per $cm^2$ area represents the attack density (AD) indicating high and low populations of the pest. The multiplication rate (MR) which also represents the intensity of population can be calculated by dividing the number of emerged adults by the number of maternal galleries. The parasitism rate (PR) is calculated by dividing the number of emerged Hymenopteran parasitoids by the number of maternal galleries.

***Statistical analysis***

Calculation of AN, AD and MR were conducted by Excel 2010. The parameters were statistically analyzed with repeated measures using one way ANOVA (SPSS version 17.0). The correlation between parameters was analyzed by Pearson's Correlation Coefficient (SPSS version 17.0). The orchard parameters were considered statistically significant at $P \leq 0.05$.

## RESULTS

The study on the abundance and attack of the beetle *Scolytus amygdali* in the experimental orchards at both the localities was carried out for two years starting from October 2009 until July 2011. Twenty two samples were analyzed for each orchard. The table 2 shows that in the first orchard at Souassi the temperature was higher than in the second orchard at Djemmal. The mean of maximal temperature in the first experimental orchard was 25.1 °C (±7.2 SD); comparing to orchard 2 at Djemmal with a mean of 23.7 °C (±5.1 SD). A minimal temperature in orchard 1 with a mean of 17.2 °C (±5.6 SD) was again higher than mean minimal temperature in orchard 2 (15.6 °C ±5.3 SD). The table 2 also demonstrates the abundance of flying adults in the studied orchards. The orchard 2 was more attacked with mean number of flying adults 73.7 (±76.7 SD) than the first orchard (mean 25.7 ±37.5 SD).

**Table 2. Descriptive statistics of maximal and minimal temperatures in both orchards with the flight of adults**

| | Study sites | N | Mean | SD | SE | Minimum | Maximum |
|---|---|---|---|---|---|---|---|
| Tmax | Orchard 1 | 22 | 25,067 | 7,232 | 1,542 | 16,332 | 46,474 |
| | Orchard 2 | 22 | 23,733 | 5,111 | 1,090 | 16,000 | 32,742 |
| Tmin | Orchard 1 | 22 | 17,198 | 5,605 | 1,195 | 8,858 | 28,416 |
| | Orchard 2 | 22 | 15,564 | 5,306 | 1,131 | 9,290 | 24,355 |
| Adults | Orchard 1 | 22 | 25,703 | 37,478 | 7,990 | 0,000 | 108,000 |
| | Orchard 2 | 22 | 73,661 | 76,676 | 16,347 | 0,000 | 260,200 |

The results of the seasonal flight from 2009 to 2011 are presented in the Fig. 1. Starting from October 2009 about 165.3 flying adults was recorded in the second orchard. During the study period the highest numbers of flying adults were recorded in the second orchard with a peak of 533 in October 2010. In November the same results were observed and the most flying adults were recorded in the second orchard with a high value of 316.7 in 2010. The flight again starts from March to May with high values in the second orchard especially in May 2010 (380.7 flying adults). The summer flight from June to July shows similar pattern in both the years, the highest recorded value was in the second orchard in 2010 (160.3 flying adults).

The one way ANOVA analysis between orchards for studied parameters (Table 3) shows that there was no significant differences between temperatures in both regions (Tmax: $F = 0.499$; $df = 1$; $P = 0.484$ and Tmin: $F = 0.985$; $df = 1$; $P = 0.327$). In contrast, flying adults differed significantly between the two orchards ($F = 6.947$; $df = 1$; $P = 0.012$).

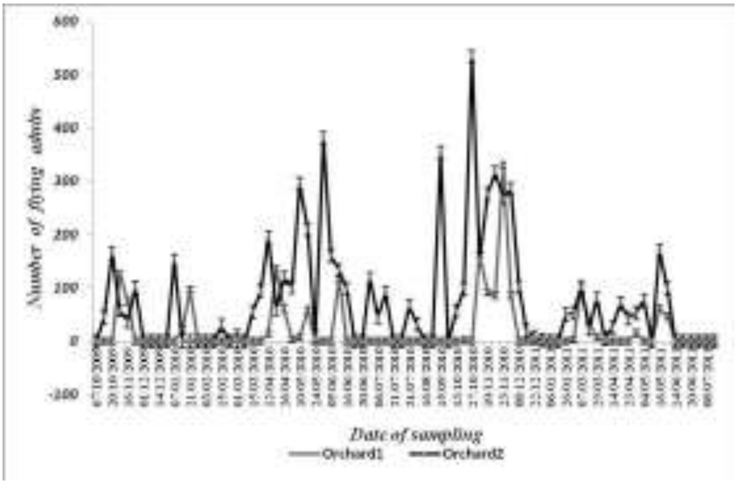


**Fig. 1. Seasonal flight of the beetle in both orchards**

**Table 3. One way ANOVA analysis**

| | | Sum of squares | df | Mean square | F | P |
|---|---|---|---|---|---|---|
| Tmax | Between orchards | 19,571 | 1 | 19,571 | 0.499 | 0.484 |
| | Within orchards | 1646,813 | 42 | 39,210 | | |
| Tmin | Between orchards | 29,335 | 1 | 29,335 | 0.985 | 0.327 |
| | Within orchards | 1251,248 | 42 | 29,792 | | |
| Adults | Between orchards | 25299,486 | 1 | 25299,486 | 6,947 | 0.012 |
| | Within orchards | 152958,098 | 42 | 3641,859 | | |

Pearson Correlation between studied parameters is represented in the table 4. Correlation is significant at the 0.05 level (2-tailed) between date of sampling and adults emergence ($R = 0.377$; $P = 0.012$).

The study of the variation of attack number, the attack density, the multiplication rate and the parasitism rate is shown in the figures (2- 5). The data shows that three generations (last a partial one) were observed in the first orchard. There was an overwintering generation from November to January.

**Table 4. Correlations between temperatures and adult flight**

| | | **Date** | **Tmax** | **Tmin** | **Adults** |
|---|---|---|---|---|---|
| **Date** | Pearson Correlation | 1 | -0.108 | -0.151 | 0.377* |
| | Sig. (2-tailed) | | 0.484 | 0.327 | 0.012 |
| Tmax | Pearson Correlation | -0.108 | 1 | 0.904** | 0.166 |
| | Sig. (2-tailed) | 0.484 | | 0.000 | 0.282 |
| Tmin | Pearson Correlation | -0.151 | 0.904** | 1 | 0.174 |
| | Sig. (2-tailed) | 0.327 | 0.000 | | 0.259 |
| Adults | Pearson Correlation | 0.377* | 0.166 | 0.174 | 1 |
| | Sig. (2-tailed) | 0.012 | 0.282 | 0.259 | |
| | N | 44 | 44 | 44 | 44 |

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

This gives rise to a spring generation starting from March and then followed by a summer generation from May to June. The third generation was observed from September onwards. However, in the second orchard the activity of the almond bark beetle was very accentuated and continued in time. The number of maternal galleries recorded by sampling (Fig.2) varies in both the experimental orchards; it was very high in case of orchard 2. The attack in the second orchard starts before the attack in the first one and continues in similar way. The number of maternal galleries per $cm^2$ area shows similar pattern, the highest number being recorded in the second orchard during September 2010 and November 2010 (Fig. 3). The intensity of population (MR) was almost continued in time and the highest value was recorded in orchard 1 during October in both the years of study (Fig. 4). The pattern of parasitism rate was same in both the orchards with difference in time and the values (Fig.5). The parasitism in orchard 2 starts before the parasitism in orchard 1 that is because the activity of the beetle also starts earlier in orchard 2 than the orchard 1. The values of parasitism rate were highest in orchard 2.

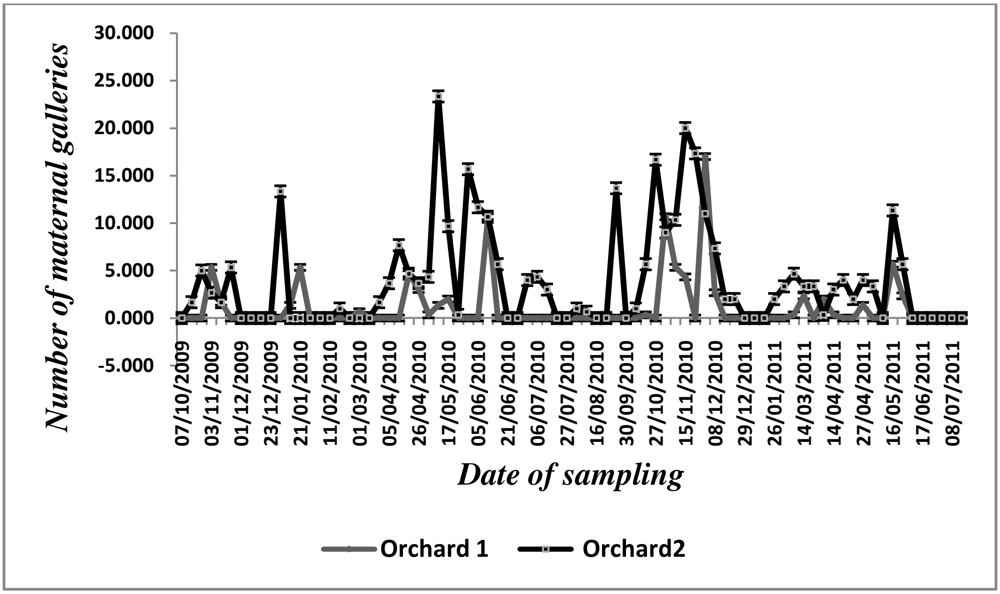


**Fig. 2. Variation of attack number (AN) in both orchards during the years of study**

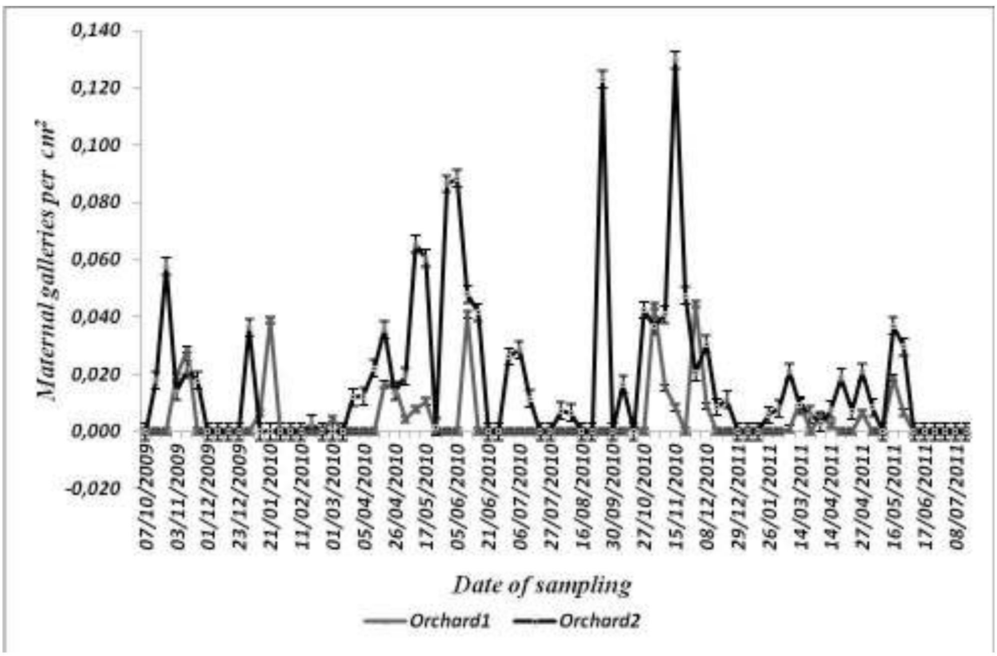


**Fig. 3. Variation of attack density (AD) in both orchards during the years of study**

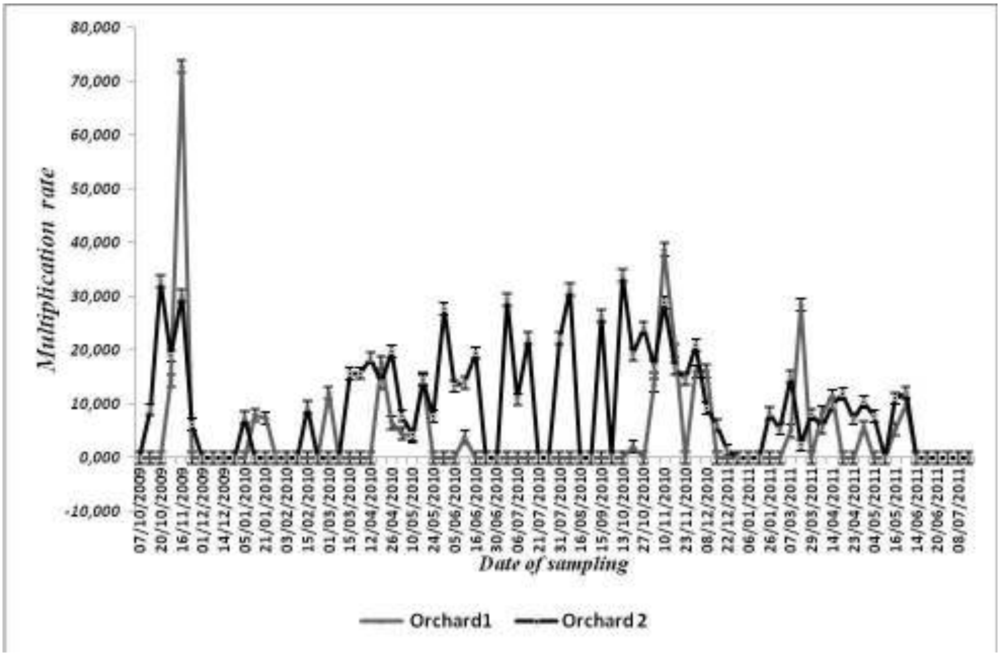


**Fig. 4. Variation of multiplication rate (MR) in both orchards during the years of study**

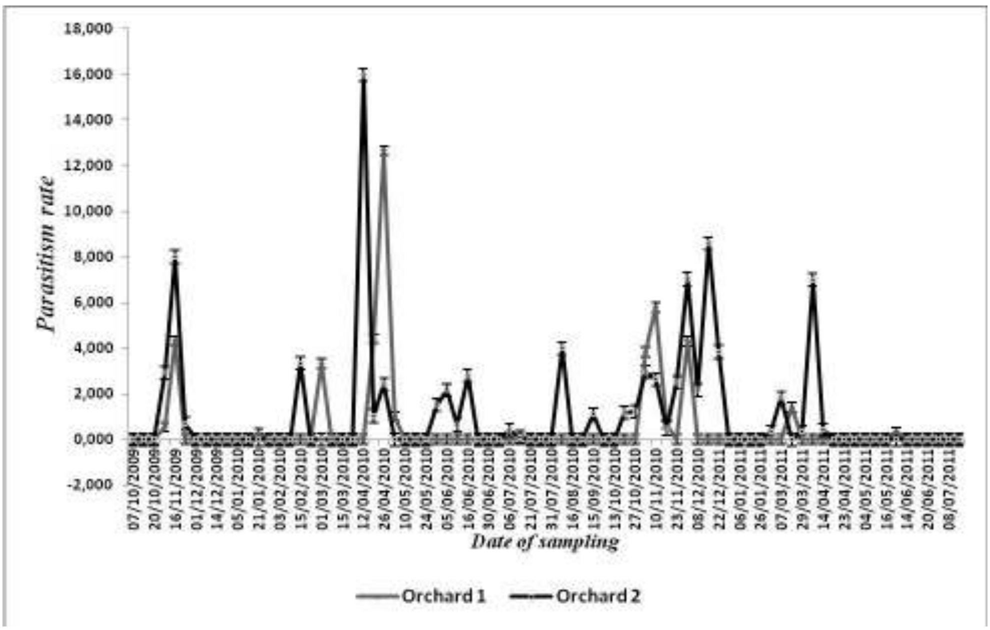


**Fig. 5. Variation of parasitism rate (PR) in both orchards during the years of study**

## DISCUSSION

The data clearly show that the emergence of adults of *Scolytus amygdali* varied greatly between two regions. The climatic conditions were almost same in both the orchards; there was no statistical difference between minimal and maximal temperatures (Table 3). However, the type of soil is different in the experimental orchards; it was sandy in the first orchard and clay loam in the second one. In the second orchard, the vegetation was also rich with different host species including *Prunus dulcis*, *Malus domestica*, *Prunus persica*, *Prunus armeniaca*, *Prunus domestica* (Table 1). The variation in the pattern of adult emergence may be explained by the type of the soil and the different hosts available in the orchard 2 (Almond, Apple, Peach, Plum, Apricot) which make it more suitable to the population of the almond bark beetle.

The activity of *S. amygdali* for three generations was recorded in both orchards. The phenomenon of overlapping of generations has been a real problem for the study of population dynamics. Some generations can't split apart. *S. amygdali* emerge at air temperatures above 10 to 25 °C. The sudden rise of temperature in spring directly influences the flight of beetle and the warm weather will therefore induce the spring generation. If after a period of cold weather, the air temperature suddenly rises up, all adult beetles resulting from the overwintering population waiting under the bark for favorable conditions to return, will suddenly emerge. On subsequent days the number of emerging beetles drops since only new adults that just gained their ability to fly leave the tree. Bark beetles generally fly from release sources in all directions (Unpublished data). They seek suitable and stressed trees for feeding and reproduction. The dispersal flights of the different generations of this beetle species show overlap and cannot be exactly separated in time. The spring generation was recorded starting from March to April; this generation in orchards 2 was mixed with the summer generation which fly around April to May or June. The winter generation started in September to October and hibernates as old larvae under the bark or in tunnels in the wood until they emerge in the spring. The activity of the pest was almost continuous and this may be due to the augmentation of the temperature during the years of study.

Our results are in agreement with the observations of Cherif and Trigui (1990) on *S. amygdali* in Tunisia. Authors noticed that the adult emergence from overwintering forms (first fly) begins in March. The other generations were observed in May, July and in September if weather permits. In Morocco, Benazoun (1983) also recorded three generations per year of the same pest with a generation from mid May - June to late in August and generation was early in August to late September at least with the possibility of extension as conditions permit. The smaller European elm bark beetle, *S. multistriatus* had three distinct periods of adult flight annually in Georgia (James *et al.*, 1984). *Scolytus nitidus* has three generations (the last a partial one) per year in Kashmir (Buhroo and Lakatos, 2007). The author also reported a considerable overlap of 2nd and 3rd generations. Two generations of *S. scolytus* on elm (Beaver, 1967) and also of *S. mali* on apple (Rudinsky *et al.*, 1978) were described under European conditions. However, *S. amygdali* had 4 generations annually on fruit trees of Baluchistan (Janjua and Samuel, 1941) and 5 generations per year on pear trees in Egypt (Kinawy *et al.*, 1991).

Knowing the life cycle of the almond bark beetle helps in its management. Over-wintering and emergence dates, for example, help to determine when one can use chemical control to reduce beetle populations. For example, an insecticide approved for this purpose can be applied to the base of branches in late August or early September to reduce beetle numbers for up to two years. All wood, including infected trees, must be disposed of promptly by burning or burial in a designated disposal site. This limits the spread of the disease outside infected areas, as well as restricting brood material. Fresh pruning cuts also lure the beetle to a tree, and for this reason there is an annual elm tree pruning ban in effect. Accurate disease identification is critical in making smart disease management decisions. Researchers should develop a basic understanding of the pathogen biology and disease life cycles for the major stone fruit diseases. The more you know about a disease, the better equipped you will be to make sound and effective management decisions.

## ACKNOWLEDGMENTS

The authors would like to thank the CRRHAB and the Olive Institute for the valuable help in the field and the laboratory work.

## REFERENCES

Bahri, S. 2012. Lipolytic activity and chilling requirement for germination of some almond cultivars. *Afr. J. Biotechnol.*, **11**: 14096−14101.

Balachowsky, A. S. 1949. *Faune de France*. Coléoptères Scolytides. (Ed. P. Lechevalier) Paris, France, pp 320.

Beaver, R. A. 1967. Notes on the biology of the bark beetles attacking elm in Wytham Wood, Berks. *Entomologist's Monthly Magazine*. **102**: 156-162.

Benazoun, A. and Schvester, D. 1990. Biologie et cycle de *Scolytus* (*Ruguloscolytus*) *amygdali* Guerin au Maroc. *Actes Inst. Agron. Vét. (Maroc)*. **10**: 21-34.

Benazoun, A. 1983. Etude bioécologique sur les scolytes de l'amandier *Ruguloscolytus amygdali* Guerin (Col, Scolytidae) au Maroc. Thèse de doctorat d'état en sciences naturelles. Univ. Paris. VI. pp 140.

Bolu, H. and Legalov, A. A. 2008. On the Curculionoidea (Coleoptera) fauna of Almond (*Amygdalus communis* L.) Orchards in South-eastern and Eastern Anatolia in Turkey, Baltic. *J Coleopterol.*, **8**: 75-86.

Buhroo, A. A. and Lakatos, F. 2007. On the biology of the bark beetle *Scolytus nitidus* Schedl (Coloeoptera: Scolytidae) attacking apple orchards. *Acta Silvatica et Lignaria Hungarica*. **3**: 65-74.

Cherif, R. and Trigui, A. 1990. *Ruguloscolytus amygdali* Guerin [*Scolytus amygdali*], scolytid of fruit trees in Noyau in the mid-southern regions of Tunisia. *Ann Ins. Nat. Rech. Agr. Tun.*, **63**(1): 12.

Choate, P. M. 1999. Introduction to the identification of beetles (Coleo-ptera). Dichotomous Keys to some Families of Florida Coleoptera. Wood, Berks. *Entomo. Mont. Mag.*, **102**: 156-162.

Demangeon, A. 1932. La situation économique de la Tunisie.

In: Annales de Géographie. t. 41, n°231. Pp. 326-327.

James, L H. and Berisford, C. W. 1984. Seasonal flight activity of the smaller European elm bark beetle *Scolytus multistriatus* (Coleoptera: Scolytidae), and associates in Georgia. *The Canadian Entomologist.* **116 (9)**: 1251-1258.

Janjua, N. A. and Samuel, C. K. 1941. Fruit pests of Baluchistan. *Imp Coun. Agric. Res. Bull.*, **42:** 12-28.

Kinawy, M. M., Tadors, A. W. and Abdallah, F. F. 1991. On the biology of the shot-hole bark beetle *Scolytus amygdali* Guer. (Coleoptera: Scolytidae) on pear trees in Egypt. *Bull. Fac. Agr. Univ. of Cairo*, **42**: 119-128.

Mahhou, A. and Dennis, F. G. 1992. The almond trees in Morocco. *Hort-Technology*, **2**: 488–492.

Mandelshtam, M. Y. and Petrov, A. V. 2010. *Scolytus stephani* sp. n. - a new species of bark-beetle (Coleoptera, Curculionidae, Scolytinae) from Northern India with a key to Indian *Scolytus* Geoffroy, 1762 species. *Zookeys*, **56**: 171-178.

Mendel, Z., Ben-Yehuda, S., Marcus, R. and Nestel, D. 1997. Distribution and extent of damage by *Scolytus* spp. to stone and pome fruit orchards in Israel. *Insect Sci Appl.*, **17**: 175–181.

Picard, F. 1921. Sur deux scolytes des arbres fruitiers et leurs parasites. *Bull. Pathol. Veg. Fr.*, **8**: 16-19.

Rudinsky, J. A., Vallo, V. and Ryker, L. C. 1978. Sound production in Scolytidae: Atrraction and stridulation of *Scolytus mali* (Col.: Scolytidae). *Z. angew. Ent.*, **86**: 381-391.

Russo, G. 1931. Contributo alla conoscenza degli Scolytidi II. Lo scolitide del mandorlo: *Scolytus amygdali* (Guèr.). Note biologiche. Bollettino del Laboratorio di Zoologia Generale e Agraria della R. Istituto Superiore d'Agricoltura. *Portici*. **25**: 327-349.

Youssef, N. A., Mostafa, F. F., Okil, A. M. and Khalil, H. R.

2006a. Laboratory studies on shot-hole borer *Scolytus amygdali* Guer, attacking apricot trees and its associated parasitoids at El-Fayoum Governorate. *Annals Agric. Sci*., **51**(2): 523-530.

Youssef, N. A., Mostafa, F. F., Okil, A. M. and Khalil, H. R. 2006b. Certain factors affecting infestation of apricot trees with *Scolytus amygdali* in Fayoum. *Annals Agric. Sci*., **51**(2): 541-550.

Youssef, N. A., Mostafa, F. F., Okil, A. M. and Khalil, H. R. 2006c. Seasonal flight activity of *Scolytus amygdali* Guer on apricot trees by using traps logs at Fayoum Governorate. *Fayoum J. Agric. Res. and Dev*., **12**(1): 186-191.

Zeiri, A., Braham, M. and Braham, M. 2011a. Laboratory studies of the Almond bark beetle *Scolytus amygdali* Geurin-Meneville, (Coleoptera: Curculionidae: Scolytinae) collected in the Center Region of Tunisia. *Intr. Journal of Entomology*, **2**(1): 23-30.

Zeiri, A., Braham, M. and Braham, M. 2011b. First record of *Cephalonomia hypobori* on *Scolytus amygdali* in Tunisia. *Tunisian Journal of Plant Protection*,**6**: 43-47.

Zeiri, A., Mitroiu, M., Braham, M. and Braham, M. 2010. First record of *Cerocephala eccoptogastri* (Hym-enoptera: Pteromalidae) on the Almond bark beetle (*Scolytus amygdali* Guerin) (Coleoptera: Scolytidae) in Tunisia. Analele Ştiinţificeale Universităţii,, Al.I.-Cuza"Iaşi,s. Biologieanimală, Tom LVI. 91-95.

# PHYSICO- CHEMICAL CHARACTERISTICS AND PERIPHYTIC ALGAE OF SINDH STREAM, KASHMIR, HIMALAYA

**Aaliya I. Baba, Tabasum Yaseen, Naseer A. Dar, Sami Ullah Bhat, Ashok K.Pandit and A. R. Yousuf**

P.G. Department of Environmental Science/Centre of Research for Development, University of Kashmir, Srinagar-190006, J & K, India

**ABSTRACT**

A limnological investigation was carried out in Sindh stream, Kashmir Himalaya (Jammu and Kashmir) from July 2009 to December 2009. Water quality parameters like temperature, pH, dissolved oxygen, free carbon dioxide, total alkalinity, total hardness, calcium hardness, chloride, phosphate, ammonical- nitrogen, nitrite-nitrogen, and nitrate-nitrogen and periphytic algal composition were investigated during the study period. A perusal of data on physico-chemical characteristics showed that the stream was hard water type with high dissolved oxygen. The ionic composition of stream water revealed the predominance of bicarbonate and calcium. A total of 49 species were identified belonging to Cyanophyceae, Chlorophyceae, Bacillariophyceae and Xanthophyceae. The taxa belonging to different classes, were Cyanophyceae (07 taxa), Chlorophyceae (09), Bacillariophyceae (32) and Xanthophyceae (01). Both qualitatively and quantitatively, Bacillariophyceae was the most dominant algal class at all the sites being followed by Chlorophyceae, Cyanophyceae and Xanthophyceae. In the present study, the species diversity (Shannon) was relatively high most of the time, fluctuating between 2.102 and 2.698, accompanied by high species richness (2.511-2.961). There was a good coincidence in the temporal variation in the number of species, diversity index, evenness and species richness. Correlation coefficients were calculated among the various physicochemical variables and algal groups. Chlorophyceae was found to bear positive correlation with nitrite. Bacillariophyceae showed positive correlation with chloride. However, Xanthophyceae was found to bear negative correlation with alkalinity and hardness. While, the correlation between the algal groups depicted positive correlation between Xanthophyceae and Cyanophyceae.

***Key words:*** Sindh stream, Bacillariophyceae, Xanthophyceae, Cyanophyceae.

## INTRODUCTION

Periphyton in streams and rivers are an important component of aquatic eco-systems, providing food for invertebrates, fish and downstream ecosystems (Finlay *et al*., 2002; Chick *et al.,* 2008; Liston *et al.,* 2008). They are the primary producers in freshwater bodies where different forms are present in various locations viz: epilithic (rock), epipsamic (mud), epiphytic (plant), epipelic (sediments) and epizoic (animals) forms (Kadiri, 2002). Periphyton growth can be light-limited or nutrient-limited, or both, and is influenced by temperature (Perrin and Quinn *et al*., 1997a; Quinn *et al*., 1997b; Francoeur *et al*., 1999; McCormick and Stevenson, 1998; Morin *et al*., 1999; Robinson *et al*., 2000; Weckstroem and Korhola, 2001; Cascallar *et al*., 2003). Periphyton composition is believed to be governed by water quality parameters. The relationship water quality share with periphyton is reciprocal as the later strongly influence water quality through carbon-dioxide uptake, oxygen production, calcite precipitation and co-precipitation of phos-phorus. Phosphorus limitation radically alters periphyton structure and composition (Quall and Richardson, 1995). Various factors controlling loss of periphyton include high shear stress/turbulence (in both temporal and spatial dimensions), sediment instability, and invertebrate grazing (Biggs, 1996). Periphytic algae are very responsive to degradation of water quality, often changing in both taxonomic composition and biomass where even slight contamination occurs (Lavoie *et al*., 2003). Researches on them have contributed significantly to the understanding of the impact of anthropogenic activities on them. It is therefore proper that their spatio-temporal occurrence, composition and abundance be matched with opportunities provided in their environment. This accounts for the array of periphyton species displayed in each trophic spectrum along with the taxonomic composition of periphyton which reflects local water quality and hydrological conditions.

The present study is an attempt to reduce the information gap and contribute to our current knowledge of the limnology and periphyton diversity of Sindh stream, Kashmir, Himalaya. The need for such study became important especially to provide opportunity for monitoring changes in the chemical content and algae composition of the stream water system. These will go a long way, as it would influence the socio-economic well being of the communities found in the immediate vicinity of the stream and beyond.

## MATERIAL AND METHODS

### Study area and sites

Sindh stream locally known as 'Sendh' originates from the Panjtarni glacial fields at an altitude of 4,250 m (a.s.l) at the base of Saskut, a peak (4,693 m a.s.l) in the Ogput Range running parallel to the North-West to South-East. Sindh stream drops steeply north westward to reach the main strike valley. Gathering momentum, the river runs towards Sonamarg between steeply towering mountain areas, over a boulder stream bed, emerging into the pleasant upland serenity of the Sonamarg, as if to rest before it plunges roaring headlong torrent sharply to the southwest through the Gagangir gorge, 4000 ft (1,230 m) deep. It has a catchment area of 1,556 $km^2$ which extends between the geographical co-ordinates of $34^0$ 07' 40" to $34^0$ 27' 46" N latitude and $74^0$ 40' 37" to $75^0$ 35' 15" E longitude. There is abundant Triassic limy shale and slaty limestones in the headwater region of the Sindh valley, while as in the middle granite and sandstone replace them as a dominant rock type.

Four sampling sites were selected to carry out sampling. The sites varied in altitude, temperature of water body, current velocity, depth and many other characteristics. Site I was located at Baltal. Site II was located at Yashmarg. Site III was located at Sonamarg, a famous hill station and site IV was located at Thajwas Grar, a left bank tributary of Sindh stream (Figure 1). Geographical attributes and substratum quality of the sites are given in Table 1.

**Table 1.General characteristics of four study sites.**

| Sites | Code | Altitude (a.s.l) | Latitude | Longitude | Substrate Type |
|---|---|---|---|---|---|
| Baltal | I | 2,850 m | $34^0$ 15' N | $75^0$ 24' E | Cobble, Gravel, Pebbles |
| Yashmarg | II | 2,712 m | $34^0$ 17' N | $75^0$ 19' E | Cobble, Sand |
| Sonamarg | III | 2,705 m | $34^0$ 18' N | $75^0$ 15' E | Mud, Sand and Pebbles |
| Thajwas Grar | IV | 2,617 m | $34^0$ 17' N | $75^0$ 12' E | Gravel, Pebbles, Sand and Leaf Litter |

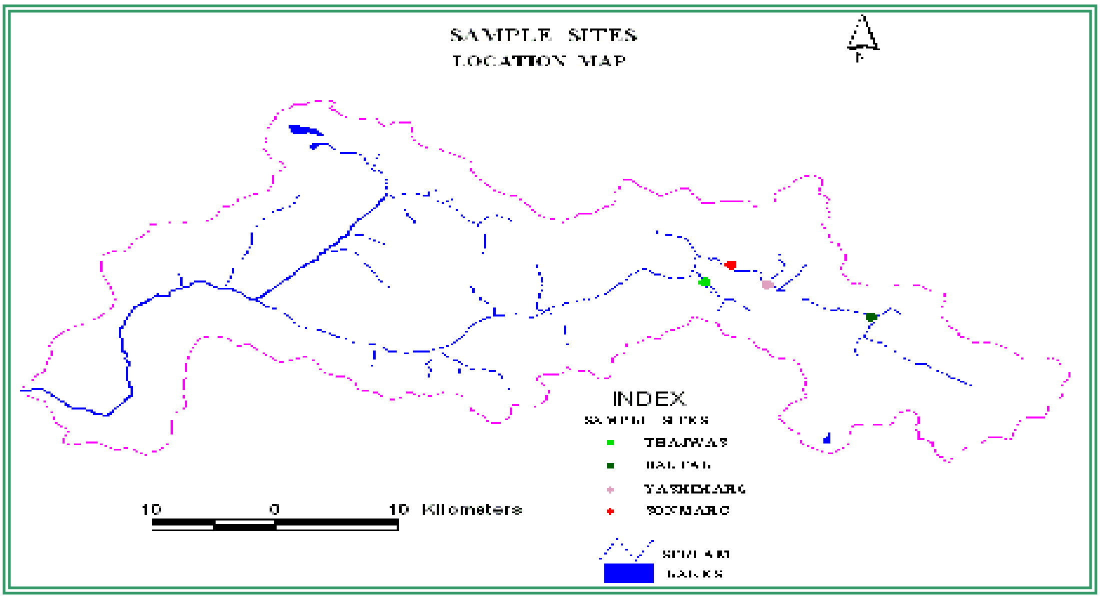


**Fig. 1. Map of study area showing location of sampling sites**

Baltal located 14 km upstream from Sonamarg, lies between geographical co-ordinates of $34^0$ 15' 23" N latitude and $75^0$ 24' 29" E longitude and at an altitude 2,850 m (a.s.l). Being located at the Zoji La pass, it has a sacred cave in the upper reaches dedicated to Lord Shiva. This site is surrounded by rocky barren area. Yashmarg is famous picnic spot located near Sonamarg, known for its pastures, ponies and firs. Sonamarg is located 14 km downstream of Baltal, at an altitude 2,705 m (a.s.l).Thajwas Grar is located 3 km away from Sonamarg. Thajwas Grar is known for the glaciers, the miniature plateaus, snowfields, pines and islets.

## Physico-chemical analysis

Water samples were collected at monthly intervals in an acid washed polyethylene container, between 0900 and 1300hrs on each sampling day from July to December 2010. Temperature was deter-mined *in-situ* with mercury in glass thermometer, measuring 0-50°C. The hydrogen-ion-concentration (pH) was determined by using digital pH meter. Conductivity was determined using conductivity meter. While as dissolved oxygen was determined by Winkler's titrimetric method (APHA, 2005). The parameters like carbon dioxide (Titrimetric), chloride (Argentometric), total alkalinity (Titrimetric) and hardness (EDTA titrimetric) were measured by titrimetry methods. Other parameters were measured spectrophotometrically such as ammonia-nitrogen ($NH_3$-N) and nitrite-nitrogen ($NO_2$-N) were determined with Phenate method and Sulphanilamide method respectively (APHA, 2005), while as nitrate-nitrogen ($NO_3$-N) was determined with Salicylate method (CSIR, 1974). Phosphates ($PO_4^{3-}$) were determined following Stannous Chloride method (APHA, 2005).

## Periphyton collection

Stream periphytons have distinct seasonal cycles, with peak abundance and diversity typically occurring in late summer or early fall (Bahls, 1993). High flows may scour and sweep away periphyton. For these reasons, the index period for periphyton sampling is usually late summer or early fall, when stream flow is relatively stable (Bahls, 1993). The present study was carried over a period of four months starting from late June to the early December.

Periphyton were collected from a 20-30 m stream reach using a multi-habitat collection method that targets snags, roots, leaf packs, vegetation, rock, and algal mat in proportion to their occurrence in the reach (Bahls, 1993). Ten sample aliquots were collected and combined into a single final sample. Wide mouth jars were used to collect 100 ml of sample water. A piece of substrate approximately the size of the surface area of the jar was selected and rubbed into the jar. No sediment was collected. The algal and water slurry was stirred and a pipette was used to remove 4 ml of the algal slurry and then transfer it into a 50 ml centrifuge tube. The process was repeated for a total of 10 substrate types for a final total volume of 40 ml. The sample was then preserved with 4 ml of full strength buffer formalin for further analysis (APHA, 2005). Identification was carried out with the help of standard keys (Edmondson, 1963; Prescott, 1969; Whitford and Schumacher,1973; Palmer, 1980; Cox, 1996; Ward and Whipple, 1996).

### Statistical analysis

Diversity (H) (Shannon and Wiener, 1963), Dominance (D) (Simpson, 1949) and Richness (R) (Margalef, 1951) indices were used to describe the numerical structure of the algal community. Simple correlation coefficient was used to examine the relationships among the different water parameters and periphytic algae by using SPSS statistical software program.

## RESULTS AND DISCUSSION

Algal species dominance pattern changes in a cyclic pattern, known as algal succession**,** driven by the changes in season, temperature, wind, precipitation patterns, and nutrient cycles (Moore and Thornton, 1988; Kortmann and Henry, 1990). Physical and chemical parameters make possible the existence of biotic diversity and various phenomena of biological activity (Welch, 1948; Moss, 1988).

A perusal of data on physico-chemical characteristics showed that the stream was hard water type with high dissolved oxygen. The ionic composition of stream water revealed the predominance of bicarbonate and calcium. Physicochemical characteristics of the stream were found within the desirable and maximum permissible limits (Table 2).

**Table 2. Physico-chemical characteristics of water at four study sites**

| Sites | Statistics | AT | WT | pH | Cond. | DO* | $CO_2$* | Alka.* | Cl* | Hard.* | Ca* | $NH_3$* | $NO_2$** | $NO_3$** | P** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baltal | Mean | 14 | 7.25 | 7.45 | 243 | 8.8 | 13 | 69.5 | 5.25 | 169 | 28.5 | 28 | 9 | 42 | 35 |
| | SD | 4.24 | 2.47 | 0.21 | 32.53 | 0.57 | 4.24 | 6.36 | 0.35 | 43.8 | 7.07 | 2.83 | 1.45 | 5.66 | 7.07 |
| | Mini. | 11 | 5.5 | 7.3 | 220 | 8.4 | 10 | 65 | 5 | 138 | 23.5 | 26 | 8 | 38 | 30 |
| | Max. | 17 | 9 | 7.6 | 266 | 9.2 | 16 | 74 | 5.5 | 200 | 33.5 | 30 | 10 | 46 | 40 |
| Yashmarg | Mean | 12.75 | 7 | 7.35 | 312.5 | 8.48 | 7.05 | 75 | 5.88 | 177 | 39.3 | 31 | 10 | 43.5 | 31.75 |
| | SD | 7.35 | 3.34 | 0.25 | 128.4 | 2.62 | 1.75 | 33.2 | 1.11 | 28.9 | 14 | 4.69 | 3.27 | 9.98 | 14.22 |
| | Mini. | 4 | 2.5 | 7.1 | 210 | 7 | 5.2 | 40 | 5 | 140 | 28.5 | 26 | 6 | 35 | 18 |
| | Max. | 20 | 10 | 7.48 | 500 | 12.4 | 9 | 120 | 7.5 | 200 | 59 | 37 | 14 | 57 | 51 |
| Sonamarg | Mean | 12.25 | 6.5 | 0.45 | 315 | 8.6 | 6.5 | 75 | 6.75 | 193 | 35.8 | 27.8 | 16.5 | 70.5 | 31.5 |
| | SD | 7.71 | 3.7 | 7.1 | 123.4 | 2.1 | 2.38 | 36.8 | 1.19 | 37.3 | 6.04 | 6.85 | 16 | 7.37 | 14.18 |
| | Mini. | 4 | 2 | 7.7 | 250 | 7.1 | 4 | 30 | 5.5 | 150 | 28.6 | 20 | 4 | 62 | 22 |
| | Max. | 20 | 10 | 8 | 500 | 11.6 | 9 | 120 | 8 | 228 | 42.5 | 36 | 40 | 80 | 52 |
| Thajwas Grar | Mean | 14.67 | 7.83 | 7.27 | 193.3 | 8.33 | 7.33 | 50 | 5.83 | 109 | 19.5 | 26.3 | 11.7 | 26 | 28.33 |
| | SD | 6.33 | 2.02 | 0.31 | 86.22 | 1.3 | 2.31 | 26.5 | 1.01 | 38.9 | 4 | 4.04 | 6.51 | 10.5 | 4.73 |
| | Mini. | 7.5 | 5.5 | 7 | 100 | 7 | 6 | 20 | 5.2 | 76 | 15.5 | 22 | 5 | 16 | 23 |
| | Max. | 19.5 | 9 | 7.6 | 270 | 9.6 | 10 | 70 | 7 | 152 | 23.5 | 30 | 18 | 37 | 32 |

*=mg $L^{-1}$; **=μg $L^{-1}$

AT= Air temperature; WT= Water temperature; Cond.= Conductivity; DO= Dissolved oxygen; $CO_2$= Free Carbon dioxide, Alka.= Alkalinity; Cl= Chloride, HARD.= Total hardness; Ca= Calcium hardness; $NH_3$= Ammonia; $NO_2$= Nitrite; $NO_3$= Nitrate; P= Total phosphorus

Periphytic algae in the present study exhibited a modest diversity in species number across different sampling sites. The present study shows Bacillariophyceae and Chlorophyceae are dominant over other two groups. During the period of study 49 taxa of periphytic algae were recorded across four different sites during the period of invest-tigation. Those taxa present in different divisions, were Cyanophyceae (07), Chlorophyceae (09), Bacillariophyceae (32) and Xanthophyceae (01). The number of common species recorded from all the sites were 11 while as taxa like *Vaucheria* sp., *Navicula appendiculata, Meridion* sp., *Fragillaria* sp., *Brachysira virea, Rhi-zoclonium* sp., *Oedogonium capillare*, *Mougeotia* sp., *Oscillatoria* sp., *Merismopedia* sp., *Leptolyngbya* sp., *Ceolospharum* sp., *Calothrix* sp. were restricted to only one particular site (Table 3). Amongst 49 genera, the highest numbers of taxa (31) were found at site II, followed by site III (30), site I (28) and site IV (28). Comparative analysis revealed that Cyanophyceae, Chlorophyceae and Bacillariophyceae contributed 3, 3, and 22 respectively at site I. At site II, 3 genera belonged to Cyanophyceae, 4 to Chlorophyceae and 24 to Bacillariophyceae. At site III, 2 genera belonged to Cyanophyceae, 5 to Chlorophyceae and 23 to Bacillariophyceae. However, a similar pattern in terms of contribution to algal taxa was observed at site IV with 3 taxa belonged to Cyanophyceae, 6 to Chlorophyceae, 18 to Bacillariophyceae and 1 to Xanthophyceae (Table. 3). Both qualitatively and quantitatively Bacillariophyceae was the most dominant algal class at all the sites being followed by Chlorophyceae, Cyanophyceae and Xanthophyceae in a decreasing order. The most numerically dominant genera found during the entire study period were: *Coelospharum* sp, *Lyngbya* sp., *Oscillatoria* sp., and *Phormedium* sp., *among* Cyanophyceae; *Closterium* sp, *Diadesmis* sp, *Ulothrix zonata and Zygnema* sp. among Chlorophyceae; *Amphora ovalis, Amphora pediculus, Amphora veneta, Cymbella aspera, Cymbella kappi, Cymbella lanceolata, Diatoma mesodon, Epithemia sorex, Gomphonema germinatum, Gomphonema truncatum, Hannaea arcus, Navicula* sp. *and Tabellaria* sp. among Bacillariophyceae.The sriking feature of the present study was the presence of *Vaucheria* sp. being restricted to site IV (Thajwas Grar) only (Table 3). Lowest percentage of diverse Cyanophyceae, Chlorophyceae and Bacillariophyceae and were taken 2, 3 and 18 respectively (Table 4). Analysis of species–environment relationships found that the concentrations of major ions to be the most important factor explaining variation in periphyton taxonomic composition within the River Sindh.

**Cyanophyceae**

The population density of Cyanophyceae reached its highest peak (5504 ind./cm$^2$) at Site IV in September while as the lowest population density (32 ind. /cm$^2$) was obtained at site II in September. However on spatial basis the group depicted maximum mean population (1877 ind./cm$^2$) at site IV against its minimum (38 ind. /cm$^2$) at site II. In case of Cyanophyceae, genera like *Phormidium* sp. *Lyngbya* sp. and *Coelospharum* sp. were the most dominant species contributing the major portion to the overall density of Cyanophycean group (Table 3). The increase in Cyanophyceae at Site IV is the result of low level of $CO_2$ and alkalinity. Alkalinity range of 50 to 110 mg/L has been reported as optimum and low level of $CO_2$ for the growth of Cyanophyceae (Boyd, 1981). They are normally found in oligo mesotrophic zone (Round, 1969).

**Chlorophyceae**

Although they occurred most of the year, they contributed with less species to the total flora. However, chlorophytes contributed well to the total number of species. Most of the green algae (Chlorophyceae) could be found in all seasons and all sites. Among the sites studied the population density of Chlorophyceae fluctuated from a minimum of 96 ind. /cm$^2$ at site IV in October to a maximum of 8480 ind./cm$^2$at site III in December. The highest mean population density of Chlorophyceae was noticeable at site III (2958 ind./cm$^2$) and minimum density at site I (214 ind./cm$^2$). The life-forms which contributed their major share in the overall density of Chlorophyceae were *Zygnema* sp., *Closterium* sp., *Diadesmis* sp. and *Ulothrix zonata* (Table 3). Higher contribution of Chlorophyceae at site-III is due to the higher levels of alkalinity and hardness probably because of the association with bicarbonate ions that provide a supplemental supply of carbon dioxide for photosynthesis and the importance of the carbonate-bicarbonate buffering system that controls pH (Smith, 1950; Zafar, 1964; Hutchinson, 1967; Patrick, 1977; Singh and Swarup 1979). It may be also due to due high alkalinity and pH. High alkalinity and pH favours the growth of algae (Zafar, 1959).

**Bacillariophyceae**

Diatoms contributed considerably to the overall species composition. The population density of Bacillariophyceae varied from a low of 159 ind. /cm$^2$at site II in July to a high of 65920 ind. /cm$^2$ at site III in December. Pronounced mean population density was noted at site I with values ranging from a minimum of 4261 ind./cm$^2$ to a maximum of 31258 ind./cm$^2$ at site III. Different genera like *Amphora ovalis, Amphora pediculus, Amphora veneta, Diatoma mesodon, Gomphonema germinatum, Gomphonema trunkatum, Hannaea arcus, Navicula* sp. and *Tabellaria* sp. were the major contributors to the overall density (Table 3). Algal communities, particularly diatoms, are known to respond specific conductance (conductivity) gradients (Kolbe, 1927; Patrick, 1948; Lowe, 1974; Blinn, 1993; Van Dam *et al*., 1994). Therefore, high variation in mean population density at site-III is the product of slight increase in conductivity compared to the other sites. According to Palmer 1980, poor quality of water supports only few numbers of species, where as high number of species denotes the high quality of water.

Dominance of Chlorophyceae and Bacillariophyceae at site-III is the consequence of higher values of nitrate-nitrogen and phosphorus. Nitrogen (N) and phosphorus regulates the growth of periphyton and phosphorus is limiting nutrient in oligotrophic systems (McCormick and O'Dell, 1996; McCormick *et al*., 1996, 1998; Pan *et al*., 2000; Gaiser *et al*., 2004, 2005).

**Xanthophyceae**

*Vucheria* sp. (Xanthophyceae) in the present study was found to be restricted at site IV. It normally grows in slightly polluted stream and rivers. However, in the present it was found to be restricted to site IV only. On monthly basis, the maximum density of periphytic algae in the Sindh stream was obtained in the month of December which can be attributed to the factors like low temperature and less amount of water available during this month, thus providing more stability in terms of variation of discharge and also less turbidity both of which provide a stable habitat for the growth of periphytic algae. The peak population of periphytic algae during December gains support from the studies on Kashmir Himalayan Lakes, observed diatoms to develop profusely during relatively low temperatures (Pandit, 1993). Reisen (1976), Albay and Aykulu (2002), Uehlinger *et al.* (2003) have also suggested similar reasons. However, in July, the density of periphytic algae was observed to be very low at all the sites. It may be because of high discharges during summer that cause higher shear stress thereby preventing periphytic algae to grow (Pandit, 1980; Biggs, 1996; Nikora *et al.*, 1997).

**Table 3. Mean density (Ind/cm$^{-2}$) of various families of periphytic algae at different sites in the Sindh river from July to December 2009**

| S.No. | Genera | Sites | Months | | | | Mean | S.D |
|---|---|---|---|---|---|---|---|---|
| **Cyanophyceae** | | | | | | | | |
| | | | **July** | **Sep** | **Oct** | **Dec** | | |
| **1** | *Calothrix* sp. | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 16 | 0 | 0 | **4** | **8** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **2** | *Coelospharum* sp. | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 0 | 0 | 0 | **0** | **0** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 0 | 640 | 0 | n.s | **213** | **369** |
| **3** | *Leptolyngbya* sp. | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 16 | 0 | 0 | **4** | **8** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **4** | *Lyngbya* sp. | Baltal | n.s | 36 | 0 | n.s | **18** | **25** |
| | | Yashmarg | 0 | 0 | 0 | 120 | **30** | **60** |
| | | Sonamarg | n.s | 32 | 0 | 0 | **11** | **18** |
| | | Thajwas Grar | 27 | 2176 | 40 | n.s | **748** | **1237** |
| **5** | *Merismopedia* sp. | Baltal | n.s | 144 | 0 | n.s | **72** | **102** |
| | | Yashmarg | 0 | 0 | 0 | 0 | **0** | **0** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **6** | *Oscillatoria* sp. | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 0 | 0 | 0 | **0** | **0** |
| | | Sonamarg | n.s | 64 | 133 | 240 | **146** | **87** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **7** | *Phormedium* sp. | Baltal | n.s | 18 | 0 | n.s | **9** | **13** |
| | | Yashmarg | 0 | 0 | 0 | 0 | **0** | **0** |
| | | Sonamarg | n.s | 0 | 0 | 120 | **40** | **69** |
| | | Thajwas Grar | 27 | 2688 | 32 | n.s | **916** | **1535** |
| | **Total** | **Cyanopyceae** | **54** | **5830** | **205** | **480** | | |
| **Chlorophyceae** | | | | | | | | |
| **8** | Unknown green unicells | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 540 | 0 | 0 | **135** | **270** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **9** | *Closterium* sp. | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 53 | 640 | 665 | 360 | **429** | **287** |
| | | Sonamarg | n.s | 32 | 0 | 8120 | **2717** | **4679** |
| | | Thajwas Grar | 0 | 64 | 12 | n.s | **25** | **34** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **10** | *Diadesmis* sp. | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 0 | 0 | 0 | **0** | **0** |
| | | Sonamarg | n.s | 0 | 0 | 360 | **120** | **208** |
| | | Thajwas Grar | 27 | 256 | 24 | n.s | **102** | **133** |
| **11** | *Geminella* sp. | Baltal | n.s | 0 | 114 | n.s | **57** | **80** |
| | | Yashmarg | 0 | 0 | 0 | 0 | **0** | **0** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 0 | 128 | 0 | n.s | **43** | **74** |
| **12** | *Maugeotia* sp. | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 0 | 0 | 0 | **0** | **0** |
| | | Sonamarg | n.s | 0 | 133 | 0 | **44** | **77** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **13** | *Oedogonium capillare* | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 0 | 0 | 0 | **0** | **0** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 0 | 0 | 16 | n.s | **5** | **9** |
| **14** | *Rhizoclonium* sp. | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 0 | 0 | 0 | **0** | **0** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 0 | 32 | 4 | n.s | **12** | **17** |
| **15** | *Ulothrix zonata* | Baltal | n.s | 0 | 40 | n.s | **20** | **28** |
| | | Yashmarg | 106 | 16 | 133 | 0 | **44** | **60** |
| | | Sonamarg | n.s | 0 | 100 | 0 | **33** | **58** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **16** | *Zygnema* sp. | Baltal | n.s | 216 | 57 | n.s | **136** | **112** |
| | | Yashmarg | 26 | 16 | 133 | 0 | **44** | **60** |
| | | Sonamarg | n.s | 128 | 0 | 0 | **43** | **74** |
| | | Thajwas Grar | 826 | 4096 | 40 | n.s | **1654** | **2151** |
| | **Total** | **Chlorophyceae** | **1038** | **6164** | **1638** | **8840** | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bacillariophyceae** | | | | | | | | |
| **17** | *Amphipleura* sp. | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 0 | 1 | 0 | **0.25** | **0.5** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 0 | 0 | 8 | n.s | **3** | **5** |
| **18** | *Amphora ovalis* | Baltal | n.s | 306 | 113 | n.s | **210** | **136** |
| | | Yashmarg | 0 | 256 | 533 | 2520 | **827** | **1149** |
| | | Sonamarg | n.s | 544 | 460 | 2520 | **1175** | **1166** |
| | | Thajwas Grar | 0 | 32 | 12 | n.s | **15** | **16** |
| **19** | *Amphora pediculus* | Baltal | n.s | 0 | 50 | n.s | **25** | **35** |
| | | Yashmarg | 53 | 0 | 0 | 0 | **13** | **26** |
| | | Sonamarg | n.s | 320 | 0 | 0 | **107** | **185** |
| | | Thajwas Grar | 53 | 0 | 0 | n.s | **18** | **31** |
| **20** | *Amphora veneta* | Baltal | n.s | 234 | 0 | n.s | **117** | **165** |
| | | Yashmarg | 0 | 0 | 400 | 0 | **100** | **200** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 0 | 0 | 76 | n.s | **25** | **44** |
| **21** | *Astrionella ralfsii* | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 0 | 0 | 240 | **60** | **120** |
| | | Sonamarg | n.s | 0 | 0 | 240 | **80** | **138** |
| | | Thajwas Grar | 0 | 0 | 12 | n.s | **4** | **7** |
| **22** | *Bacillaria paradoxa* | Baltal | n.s | 18 | 0 | n.s | **9** | **13** |
| | | Yashmarg | 0 | 18 | 0 | 0 | **4** | **9** |
| | | Sonamarg | n.s | 32 | 33 | 0 | **22** | **19** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **23** | *Brachysira virea* | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 0 | 0 | 0 | **0** | **0** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 27 | 96 | 116 | n.s | **80** | **47** |
| **24** | *Cocconeis placentula* | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 0 | 0 | 120 | **30** | **60** |
| | | Sonamarg | n.s | 32 | 0 | 120 | **51** | **62** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **25** | *Cymbella aspera* | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 0 | 0 | 3600 | **900** | **1800** |
| | | Sonamarg | n.s | 0 | 66 | 0 | **22** | **38** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **26** | *Cymbella kappi* | Baltal | n.s | 0 | 567 | n.s | **283** | **401** |
| | | Yashmarg | 0 | 864 | 2667 | 1440 | **1243** | **1119** |
| | | Sonamarg | n.s | 1280 | 100 | 4440 | **1940** | **2244** |
| | | Thajwas Grar | 133 | 896 | 52 | n.s | **360** | **466** |
| **27** | *Cymbella lanceolata* | Baltal | n.s | 270 | 113 | n.s | **191** | **111** |
| | | Yashmarg | 26 | 336 | 0 | 0 | **90** | **164** |
| | | Sonamarg | n.s | 96 | 766 | 360 | **407** | **337** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **28** | *Diatoma ehenbergii* | Baltal | n.s | 0 | 113 | n.s | **56** | **80** |
| | | Yashmarg | 0 | 0 | 0 | 0 | **0** | **0** |
| | | Sonamarg | n.s | 0 | 132 | 0 | **44** | **76** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **29** | *Diatoma hyemalis* | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 0 | 0 | 0 | **0** | **0** |
| | | Sonamarg | n.s | 0 | 396 | 0 | **132** | **229** |
| | | Thajwas Grar | 0 | 96 | 80 | n.s | **59** | **51** |
| **30** | *Diatoma mesodon* | Baltal | n.s | 144 | 736 | n.s | **440** | **419** |
| | | Yashmarg | 0 | 32 | 1199 | 480 | **428** | **559** |
| | | Sonamarg | n.s | 96 | 766 | 360 | **407** | **337** |
| | | Thajwas Grar | 0 | 128 | 48 | n.s | **59** | **65** |
| **31** | *Diatoma vulgaris* | Baltal | n.s | 0 | 57 | n.s | **28** | **40** |
| | | Yashmarg | 0 | 0 | 1599 | 0 | **400** | **799** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **32** | *Epithemia prostatum* | Baltal | n.s | 16 | 0 | n.s | **8** | **11** |
| | | Yashmarg | 0 | 0 | 700 | 0 | **175** | **350** |
| | | Sonamarg | n.s | 32 | 0 | 0 | **11** | **18** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **33** | *Epithemia sorex* | Baltal | n.s | 20 | 170 | n.s | **95** | **106** |
| | | Yashmarg | 0 | 0 | 2330 | 120 | **612** | **1146** |
| | | Sonamarg | n.s | 32 | 62 | 0 | **31** | **53** |
| | | Thajwas Grar | 0 | 32 | 264 | n.s | **99** | **144** |
| **34** | *Fragilaria capucina* | Baltal | n.s | 0 | 57 | n.s | **28** | **40** |
| | | Yashmarg | 0 | 16 | 0 | 0 | **4** | **8** |
| | | Sonamarg | n.s | 160 | 66 | 0 | **75** | **80** |
| | | Thajwas Grar | 0 | 256 | 0 | n.s | **85** | **148** |
| **35** | *Fragilaria* sp. | Baltal | n.s | 0 | 849 | n.s | **424** | **600** |
| | | Yashmarg | 0 | 0 | 0 | 0 | **0** | **0** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **36** | *Fragilariforma virescens* | Baltal | n.s | 90 | 0 | n.s | **45** | **64** |
| | | Yashmarg | 0 | 16 | 0 | 0 | **4** | **8** |
| | | Sonamarg | n.s | 0 | 0 | 120 | **40** | **69** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **37** | *Gomphoneis* sp. | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 352 | 0 | 0 | **88** | **176** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 0 | 0 | 92 | n.s | **31** | **53** |
| **38** | *Gomphonema germinatum* | Baltal | n.s | 540 | 397 | n.s | **468** | **101** |
| | | Yashmarg | 80 | 1920 | 10400 | 1440 | **3460** | **4692** |
| | | Sonamarg | n.s | 832 | 13298 | 4320 | **6150** | **6431** |
| | | Thajwas Grar | 80 | 4896 | 3756 | n.s | **2911** | **2517** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **39** | *Gomphonema truncatum* | Baltal | n.s | 360 | 170 | n.s | **265** | **134** |
| | | Yashmarg | 0 | 2880 | 5066 | 840 | **2196** | **2263** |
| | | Sonamarg | n.s | 352 | 6100 | 1440 | **2631** | **3053** |
| | | Thajwas Grar | 53 | 3424 | 3344 | n.s | **2274** | **1923** |
| **40** | *Hannaea arcus* | Baltal | n.s | 1008 | 963 | n.s | **985** | **32** |
| | | Yashmarg | 0 | 0 | 6000 | 9000 | **3750** | **4500** |
| | | Sonamarg | n.s | 1216 | 300 | 40000 | **13839** | **22661** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **41** | *Meridion* sp. | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 0 | 0 | 360 | **90** | **180** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **42** | *Navicula appendiculata* | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 0 | 0 | 240 | **60** | **120** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **43** | *Navicula* sp. | Baltal | n.s | 72 | 397 | n.s | **234** | **230** |
| | | Yashmarg | 0 | 208 | 0 | 0 | **52** | **104** |
| | | Sonamarg | n.s | 128 | 100 | 480 | **236** | **212** |
| | | Thajwas Grar | 81 | 3360 | 56 | n.s | **1166** | **1900** |
| **44** | *Neidium iridis* | Baltal | n.s | 18 | 0 | n.s | **9** | **13** |
| | | Yashmarg | 0 | 0 | 0 | 0 | **0** | **0** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 0 | 32 | 0 | n.s | **11** | **18** |
| **45** | *Nitzschia* sp. | Baltal | n.s | 0 | 56 | n.s | **28** | **40** |
| | | Yashmarg | 0 | 0 | 0 | 0 | **0** | **0** |
| | | Sonamarg | n.s | 0 | 33 | 3600 | **1211** | **2069** |
| | | Thajwas Grar | 0 | 0 | 36 | n.s | **12** | **21** |
| **46** | *Surirella* sp. | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 0 | 0 | 120 | **30** | **60** |
| | | Sonamarg | n.s | 0 | 100 | 0 | **33** | **58** |
| | | Thajwas Grar | 0 | 0 | 0 | n.s | **0** | **0** |
| **47** | *Synedra ulna* | Baltal | n.s | 0 | 113 | n.s | **56** | **80** |
| | | Yashmarg | 0 | 0 | 0 | 0 | **0** | **0** |
| | | Sonamarg | n.s | 0 | 100 | 480 | **193** | **253** |
| | | Thajwas Grar | 0 | 0 | 52 | n.s | **17** | **30** |
| **48** | *Tabellaria fenestrata* | Baltal | n.s | 504 | 0 | n.s | **252** | **356** |
| | | Yashmarg | 0 | 352 | 267 | 5640 | **1565** | **2721** |
| | | Sonamarg | n.s | 256 | 366 | 7440 | **2687** | **4116** |
| | | Thajwas Grar | 27 | 1280 | 160 | n.s | **489** | **688** |
| | **Total** | **Bacillariophyceae** | **613** | **30786** | **67491** | **92080** | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Xanthophyceae** | | | | | | | | |
| **49** | *Vaucheria* sp. | Baltal | n.s | 0 | 0 | n.s | **0** | **0** |
| | | Yashmarg | 0 | 0 | 0 | 0 | **0** | **0** |
| | | Sonamarg | n.s | 0 | 0 | 0 | **0** | **0** |
| | | Thajwas Grar | 0 | 0 | 4 | n.s | **1** | **2** |
| | **Total** | **Xanthophyceae** | **0** | **0** | **4** | **0** | | |
| | **Grand total** | **Cyanophycea + Chlorophyceae+ Bacillariophyceae+ Xanthophyceae** | **1705** | **42780** | **69338** | **101400** | | |

Species diversity is a reliable parameter in biology to determine how healthy an environment is (Ogbeibu and Edutie, 2002). In the present study, the diversity index was relatively high most of the time, fluctuating between 2.012 and 2.698 (Table 4), accompanied by high species richness (2.511-2.961). There was a good coincidence in the temporal variation of species number, diversity index, evenness and species richness, but each site sustained a characteristic temporal pattern which was different from the other sites. Sorensen's similarity index (Table 4) revealed maximum similarity in terms of taxonomic composition of periphytic algae between Baltal and Sonamarg (0.77) and lowest between Yashmarg and Thajwas grar (0.55) (Table 6).The statistical analysis indicated significant negative correlation between Cyanophyceae and alkalinity. Chlorophyceae bears positive correlation with nitrite. Bacillariophyceae bears positive correlation with chloride. However, Xanthophyceae was found to bear negative correlation with alkalinity and hardness. While, correlation within the algal groups depicted positive correlation between Xanthophyceae and Cyanophyceae (Table. 5)

**Table 4**. **Species number and diversity indices of Cyanophyceae, Chlorophyceae, and Bacillariophyceae at four sites of Sindh stream**

| Sampling site | Cyan | Total Pop. | Chlo | Total Pop. | Bacil | Total Pop. | Shannon (H) | Simpson (1-D) | Margalef (R) |
|---|---|---|---|---|---|---|---|---|---|
| S-I | 3 | 198 | 3 | 427 | 22 | 8521 | 2.698 | 0.905 | 2.961 |
| S-II | 3 | 152 | 4 | 2688 | 24 | 65530 | 2.327 | 0.863 | 2.704 |
| S-III | 2 | 589 | 5 | 8873 | 23 | 93773 | 2.014 | 0.785 | 2.511 |
| S-IV | 3 | 6569 | 6 | 5525 | 18 | 23146 | 2.102 | 0.829 | 2.609 |

**Table 5. The coefficient of correlation between physico-chemical parameters of water and different dominant major groups of periphytic algae**

| | AT | WT | pH | COND | DO | $CO_2$ | TA | Cl | Ca | TH | $NO_3$ | $NH_3$ | $NO_2$ | $PO_4$ | CYA | CHLO | BACC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WT | 0.935 | | | | | | | | | | | | | | | | |
| pH | -0.53 | -0.761 | | | | | | | | | | | | | | | |
| COND. | -.976(*) | -0.919 | 0.445 | | | | | | | | | | | | | | |
| DO | -0.125 | -0.454 | 0.667 | 0.202 | | | | | | | | | | | | | |
| $CO_2$ | 0.485 | 0.199 | 0.081 | -0.35 | 0.762 | | | | | | | | | | | | |
| TA | -0.848 | -0.903 | 0.51 | 0.927 | 0.521 | 0.026 | | | | | | | | | | | |
| Cl | -0.712 | -0.638 | 0.597 | 0.541 | -0.18 | -0.75 | 0.279 | | | | | | | | | | |
| Ca | -0.911 | -0.847 | 0.308 | .979(*) | 0.215 | -0.247 | 0.945 | 0.363 | | | | | | | | | |
| TH | -0.863 | -.954(*) | 0.655 | 0.912 | 0.585 | 0.024 | .984(*) | 0.381 | 0.898 | | | | | | | | |
| $NO_3$ | -0.871 | -.968(*) | 0.879 | 0.807 | 0.457 | -0.226 | 0.773 | 0.747 | 0.692 | 0.865 | | | | | | | |
| $NH_3$ | -0.585 | -0.44 | -0.217 | 0.729 | -0.006 | -0.126 | 0.726 | -0.084 | 0.847 | 0.594 | 0.204 | | | | | | |
| $NO_2$ | -0.563 | -0.557 | 0.691 | 0.372 | -0.077 | -0.622 | 0.151 | .968(*) | 0.174 | 0.286 | 0.718 | -0.314 | | | | | |
| $PO_2$ | -0.191 | -0.438 | 0.388 | 0.344 | 0.903 | 0.759 | 0.67 | -0.378 | 0.433 | 0.658 | 0.332 | 0.382 | -0.367 | | | | |
| CYA | 0.697 | 0.803 | -0.459 | -0.815 | -0.654 | -0.256 | -.971(*) | -0.061 | -0.114 | -0.944 | -0.659 | -0.712 | 0.044 | -0.822 | | | |
| CHLO | -0.391 | -0.353 | 0.549 | 0.18 | -0.24 | -0.673 | -0.075 | 0.923 | -0.022 | 0.059 | 0.538 | -0.453 | .973(*) | -0.552 | 0.272 | | |
| BACC | -0.894 | -0.827 | 0.633 | 0.775 | -0.037 | -0.675 | 0.559 | .950(*) | 0.632 | 0.633 | 0.871 | 0.195 | 0.869 | -0.14 | -0.356 | 0.761 | |
| XAN | 0.719 | 0.837 | -0.522 | -0.823 | -0.676 | -0.243 | -.976(*) | -0.114 | -0.861 | -.962(*) | -0.708 | -0.669 | -0.02 | -0.816 | .997(**) | 0.211 | -0.4 |

**Table 6. Similarity coefficient (Sorenson index) between different selected sites on the basis of periphytic algae**

| | Yashmarg | Sonamarg | Thajwas Grar |
|---|---|---|---|
| Baltal | 0.66 | 0.77 | 0.66 |
| Yashmarg | | 0.73 | 0.55 |
| Sonamarg | | | 0.63 |

## CONCLUSIONS

The present study reveals the importance of physicochemical parameters and their effect on algal biodiversity in selected fresh water stream of Kashmir Himalaya. Dominance of Bacillariopyceae taxa owing to a healthy trophic status of the stream. Slightly, higher values of physico-chemical parameters and higher algal diversity density were recorded at the site-II and III whereas low value of physico-chemical parameters and low algal diversity and density was recorded at site-I and IV respectively. The above study clearly points to the fact that only eurytopic species that have the capability of resisting wide range of fluctuations in environmental factors have been able to colonize this very cold ecosystem of Kashmir Himalaya.

## REFERENCES

Albay M. and Aykulu, G. 2002. Invertebrate grazer – epiphytic algae interactions on submerged macrophytes in a mesotrophic Turkish lake. *TrJFAS*, **19**(1-2): 247-258

APHA. 2005. *Standard Methods for the Evaluation of Water and Waste Water.* 21st Edn., Washington DC.

Bahls, L.L. 1993. *Periphyton Bioassessment Methods for Montana Stream.* Montana Water Quality Bureau, Department of Health and Environmental Science, Helena, Montana.

Biggs, B. 1996. *Patterns in Benthic Algae in Streams. In Algal Ecology: Freshwater Benthic Ecosystems*. Academic Press. NY. London.

Blinn, D.W. 1993. Diatom community structure along physiochemical gradients in saline lakes. *Ecology*, **74**(4): 1246–1263.

Boyd, C.E. 1981. Water quality in warm water fish ponds. Auburn University Press. Alabama, U.S.A. p.59-71.

Cascallar, L., Mastranduono, P., Mosto, P., Rheinfeld, M., Santiago, J., Tsoukalis, C. and Wallace, S. 2003. Periphytic algae as bioindicators of nitrogen inputs in lakes. *Journal of Phycology,* **39**(1): 7-8.

Chick, J.H., Geddes, P. and Trexler, J.C. 2008. Periphyton mat structure mediates trophic interactions in a subtropical wetland. *Wetlands,* **28**:378–389.

Cox, E.J. 1996. *Identification of Freshwater Diatom Live Material*. Chapman and Hall, London, p. 158.

Edmondson, W. T. 1963**.** *Fresh water Biology*. 2nd Edition, John Wiley & Sons, Inc. p. 1248.

Finlay, J. C., Khandwala, S. and Power, M.E. 2002. Spatial scales of carbon flow in a river food web. *Ecology*, **83**(7): 1845-1859.

Francoeur, S.N., Biggs, B.J.F., Smith, R.A. and Lowe, R.L. 1999. Nutrient limitation of algal biomass accrual in streams: Seasonal patterns and a comparison of methods. *Journal of the North American Benthological Society*,**18**:242-260.

Gaiser, E.E., Scinto, L.J., Richards, J.H., Jayachandran, K., Childers, D.L., Trexler, J.D. and Jones. R.D. 2004. Phosphorus in periphyton mats provides best metric for detecting low-16 level P enrichment in an oligotrophic wetland. *Water Research.,* **38**:507-516.

Gaiser, E.E., Trexler, J.C., Richards, J.H., Childers, D.L., Lee, D., Edwards, A.L., Scinto, L.J., Jayachandran, K., Noe, G.B. and Jones. R.D. 2005. Cascading ecological effects of low- level phosphorus enrichment in the Florida Everglades. *Journal of Environmental Quality,* **34**:717-723.

Hutchinson, G.E. 1967. A treatise on limnology, Vol. II, *Introduction to Lake Biology and the Limno-plankton*, New York, John Wiley and Sons, 1115 p.

Kadiri, M.O. 2002. *Periphyton of Ikpoba River*. B. Sc dissertation, University of Benin, Benin City 84pp.

Kolbe, R.W. 1927. Zur okologie, morphologie und systematike der brackwasser-diatomeen. *Pflanzen-forschung (Jena)*. **7**:1–146.

Kortmann, R.W. and Henry. D.D. 1990. *Mirrors on the*

*Landscape: An Introduction to Lake Management*. Connecticut Institute of Water Resources. University of Connecticut, Storrs, CT.

Lavoie, I., Vincent, W.F., Pienitz, R. and Painchaud, J. 2003. Effect of discharge on the temporal dynamics of periphyton in an agriculturally influenced river. *Journal of Water Science,* **16**(1):55-77.

Liston, S.E., Newman, S. and Trexler, J.C. 2008. Macroinvertebrate community response to eutrophication in an oligotrophic wetland: An *in situ* mesocosm experiment. *Wetlands,* **28**:686-694.

Lowe, R.L. 1974. Environmental requirements and pollution tolerance of freshwater diatoms Cincinnati, Ohio, U.S. Environmental Protection Agency, National Environmental Research Center, Office of Research and Development, EPA-670/4-74- 005, 334 p.

Margalef, R. 1951.*Species diversity in natural community*. Publ. *Inst. Biol. Apl*.,**11**: 246-247.

McCormick, P.V. and O'Dell, M.B. 1996. Quantifying periphyton responses to phosphorus enrichment in the Florida Everglades: A synoptic-experimental approach. *Journal of the North American Benthological Society,* **15**: 450- 468.

McCormick, P.V. and Stevenson, R.J. 1998. Periphyton as a tool for ecological assessment and management in the Florida Everglades. *Journal of Phycology,* **34**:726-733.

McCormick, P.V., O'Dell, M.B. Shuford III, R.B.E.. Backus, J.G. and Kennedy, W.C. 2001. Periphyton responses to experimental phosphorus enrichment in a subtropical wetland. *Aquatic Botany***,** **71**:119-139.

McCormick, P.V., Rawlik, P.S., Lurding, K. Smith, E.P. and Sklar, F.H. 1996. Periphyton-water quality relationships along a nutrient gradient in the northern Everglades. *Journal of the North American Benthological Society*,**15**:433-449.

McCormick, P.V., Shuford III, R.B.E., Backus, J.G. and Kennedy, W.C. 1998. Spatial and seasonal patterns of periphyton biomass and productivity in the northern Ever-glades, Florida, USA. *Hydrobiologia,***362**:185-208.

Moore, L. and Thornton, K. 1988. *The Lake and Reservoir Restoration Guidance Manual*. First Edition. EPA 440/5-88-002.

Morin, A., Lamoureux, W. and Busnarda, J. 1999. Empirical models predicting primary productivity from chlorophyll a and water temperature for stream periphyton and lake and ocean phytoplankton. *Journal of the North American Benthological Society.* **18**(3): 299-307.

Moss, B. 1988. *Ecology of Freshwaters: Man and Medium*. 2nd ed., Oxford, Blackwell Scientific Publ., London, UK

Nikora, V.I., Goring, D. G. and Biggs. B.J.F. 1997. On stream periphyton-turbulence interactions. *New Zealand Journal of Marine and Freshwater Research,* **31**(4): 435-448.

Ogbeibu, A.E. and Edutie, L.O. 2002. Effects of brewery effluents on water quality and Rotifers of Ikpoba river, Southern Nigeria. *Afr. J. Pollut. Hlth.*, **1**:1-12.

Palmer, C. M.1980. *Algae and Water Pollution*. Castle House Publications, England

Pan, Y., Stevenson, R.J., Vaithiyanathan, P., Slate, J. and Richardson, C.J. 2000. Changes in algal assemblages along observed and experimental phosphorus gradients in a subtropical wetland, U.S.A. *Freshwater Biology*, **44**:339-353.

Pandit, A.K. 1980. *Biotic factor and food chain structure in some typical wetlands of Kashmir*. Ph.D thesis, University of Kashmir, Srinagar.

Pandit A. K. 1993. Dal lake ecosystem in Kashmir Himalaya: Ecology and management. p. 131-202. In: *Ecology and Pollution of Indian Lakes and Reservoirs* (P. C. Mishra and R. K. Trivedy, eds.). Ashish

Publishing House, New Delhi, India.

Patrick, R. 1948. Factors affecting the distribution of diatoms. *Botanical Review.* **14**:473–524.

Patrick, R. 1977. Ecology of freshwater diatoms and diatom communities. In: Werner, Dietrich, (ed)., *The Biology of Diatoms, Botanical Monographs*,V. 13, Berkeley, Calif., University of California Press, 284–332p.

Perrin, C.J. and Richardson, J.S. 1997. N and P limitation of benthos abundance in the Nechako River, British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences,* **54**(11): 2574-2583.

Prescott, G.W. 1969. *The Freshwater Algae.* W.M.C. Brown Co., Publ. Dubuque. 258 pp

Qualls, R.G. and Richardson, C.J. 1995. Forms of soil phosphorus along a nutrient enrichment gradient in the Northern Everglades. *Soil Science,* **160**:183-198.

Quinn, J.M., Cooper, A.B., Davies-Colley, R.J., Rutherford, J.C., Williamson, R.B. 1997a. Land use effects on habitat, water quality, periphyton, and benthic invertebrates in Waikato, New Zealand, hill-country streams. *New Zealand Journal of Marine and Freshwater Research,* **31**(5): 579-597.

Quinn, J.M., Cooper, A.B., Stroud, M.J. and Burrell, G.P. 1997b. Shade effects on stream periphyton and invertebrates: An experiment in streamside channels. *New Zealand Journal of Marine and Freshwater Research*, **31**(5): 665-683.

Reisen, W. 1976. The ecology of Honey Creek: Temporal patterns of the travertine periphyton and selected physico-chemical parameters and *Myriophylium* community produc-tivity. *Proc. Okla. Acad. Sci*., **56**: 69-74.

Robinson, C. T., Rushforth, S. R. and Burgherr, P. 2000. Seasonal effects of disturbance on a lake outlet algal assemblage. *Arch. Hydrobiol*., **148**: 283–300.

Round, F. E.1969. *Introduction to the Lower Plants.* London Butterworth & Co Ltd.

Shannon, C.E. and Wiener, W. 1963. *The Mathematical Theory of Communications*. University of Illinois, Urbana. 117 pp.

Simpson, E.H. 1949. Measurement of diversity. *Nature,* **163**: 688.

Singh, B. N. and Swarup, K. 1979. Limnological studies of Suraha lake. *J. Inland .Bot. Sco.,* **58**: 319-329.

Smith, M. 1950. *The Freshwater Algae of the United States*. McGraw-Hill, New York.

Uehlinger, U., Malard, F. and Ward, J. V. 2003. Thermal patterns in the surface waters of a glacial river corridor (Val Roseg, Switzerland). *Fresh-water Biology,* **48**: 284–300.

Van Dam, H., Mertens, A. and Sinkeldam, J. 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Nether-lands. *Netherlands Journal of Aquatic Ecology,* **28**(1): 117–133.

Ward, H. B. and Whipple, G.C. 1996. *Fresh water Biology,* 3rd Edn. John Wiley and Son's Inc., New York.

Weckstroem, J. and Korhola, A. 2001. Patterns in the distribution, composition and diversity of diatom assemblages in relation to ecoclimatic factors in Arctic Lapland. *Journal of Biogeography,* **28**(1): 31-45.

Welch, E.B., Jacoby, J.M., Horner, R.R. and Seeley, M.R. 1988. Nuisance biomass levels of periphytic algae in streams. *Hydrobiologia*, **157**(2):161-168.

Whithford, L.A. and Schumacher, G.J.1995. *A Manual of the Fresh-water Algae in North Carolina, North Carolina*, Agriculture Experiment Sta-tion. U.S.A

Zafar, A. R. 1959. An apparatus for sampling water and mud from the deeper strata of lakes. *J. Indian Bot. Sci.,* **38** (1):109-113.

Zafar, A. R. 1964. On the Ecology of the Algae in certain fish ponds of Hyderabad, India, I. Physico-chemical complexes. *Hydrobiologia,* **23:** 179-195.

# ECOLOGY OF PERIPHYTON (ILLIOPHGIC FISH FOOD) IN LIDDER STREAM OF KASHMIR HIMALAYA

**F. A. Bhat, A. R. Yousuf*, M.H. Balkhi, F. A. Shah, A. M. Najar and Imran Khan**

Faculty of Fisheries, Rangil, Ganderbal, SKUAST-K -190006

*Member Expert, National Green Tribunal, Faridkot House 1, Copernicus Marg, New Delhi-110001

**ABSTRACT**

Lidder stream throughout was found rich in periphyton which is an important food of the illiophagic fishes. A progressive change in water quality and the species diversity and density along the altitudinal gradient in the downstream was observed. Downstream the diversity and density of most of the algal classes increased except the Diatoms which showed the reverse trend. A total of 58 taxa were recorded the river, out of which 38 belonged to Bacillariophyceae, 12 to Chlorophyceae, 5 to Cyanophyceae, 2 to Chrysophyceae, 1 to Euglenophyceae and 3 to Protozoa. Temperature, Dissolved oxygen and nutrient influx were found the major constituents responsible for the abundance and distribution of the algae as they formed significant correlations with the abundance of the algae (P<0.05). Pollution tolerant species like *Euglena, Oscillatoria* and *Microcystis* were recorded downstream only. The species diversity index H´ was high towards the mouth (downstream) and moderate pollution downstream was found responsible for the high Shannon Diversity Index (H´).

***Keywords**:* Lidder stream, water quality, periphyton, diatoms, upstream, downstream, shannon diversity index

## INTRODUCTION

In hill streams periphyton forms an important component of aquatic ecosystems, providing food to invertebrates and fishes (Finlay *et al.,* 2002). In hill streams periphyton are the primary producers; play an integral part of aquatic food chain where number of plankton is comparatively low due to fast water current, steep gradient and low nutrient content (Wetzel, 2005; Dutta, 2012). Periphyton is an important component of many lotic systems, influencing nutrient and carbon cycling, invertebrate composition and other aspects of system character and dynamics (Lock *et al.,* 1984; Meyer *et al.,* 1988). The diversity and density of an organism in an aquatic ecosystem is affected mostly by environmental factors such as oxygen content, temperature, turbidity, feeding conditions, predator pressure and reproduction period (Moore, 1980; Kajak, 1986, 87).

River Jhelum is the lone drainage water body of Kashmir and Lidder is an important right bank tributary of it, being massive with huge catchment and harbors indigenous riverine fishes and forms an excellent habitat for the exotic brown trout (*Salmo trutta fario*). Most of the studies on lotic water bodies and attached algae in Kashmir were restricted to lentic waters and the lotic environs have received less attention except for few reports e.g. Kumar and Bhagat (1978), Qadri *et al.* (1981), Bhat and Yousuf (2002), Bhat and Yousuf (2004), Yousuf *et al.* (2003), Yousuf *et al.* (2006), Bhat *et al.* (2011) and Bhat *et al.* (2013). In view of importance of such an aquatic bioresource on one hand and scarcity of information about them on the other, the present study was undertaken in order to assess the species composition, distribution pattern and abundance of macrozoobenthos in relation to several physico-chemical parameters in the Lidder stream.

## STUDY AREA

Lidder valley, with an area of 1246 $km^2$, lies to the north of Anantnag district of Jammu and Kashmir state. The valley is 50 km long and has a varied topography with the altitudinal extremes of 1588 – 5215m ASL. Lidder River has its origin from the high altitude Sheshnag and Tarsar lakes and the Kolhai glaciers. All along from its origin up to the mouth, its bottom is rocky with gravel and sand. Three study zones were selected along the course of the combined Lidder. Zone I (upstream zones) is located 7 km below the confluence of east and west Lidder (Pahalgam) near Langanbal Bridge. The Latitude and Longitude of this zone are $33^\circ\ 58'\ 08.2''$ and $75^\circ\ 18'\ 37.7''$ respectively with an altitude of 2035m. Zone II (midstream) is 14 km downstream of the Zone I, near the Kathsoo village. The Latitude and Longitude of this zone are $33^\circ\ 05'\ 26.2''$ and $75^\circ\ 15'\ 54.0''$ respectively with an altitude of 1768m. Zone III (downstream) is located near the Akura Bridge; about 10 km downstream of Zone II and about 4 km above the place, were Lidder joins the Jhelum River. The Latitude and Longitude of this zone are $32^\circ\ 45'\ 32.6''$ and $75^\circ\ 08'\ 33.0''$ respectively with an altitude of

1594m. This zone gets the additional water from the downstream tributaries and thus holds good amount of water during winter season also.

## MATERIAL AND METHODS

### Physico-chemical parameters

Temperature, pH, conductivity, depth and transparency were recorded on the spot. Dissolved oxygen was determined as per Winkler's method. Free $CO_2$, hardness, alkalinity and chloride were determined by titrimetric methods (Mackereth *et al*., 1978). Phosphate (Stannous chloride method) and ammonia (Phenate method), nitrate (Salicylate method), and nitrite (Brucine method) were analyzed with the help of Systronics 106 spectrophotometer in accordance with APHA (1998), CSIR Pretoria (1974) and EPA (1976) respectively.

### Periphyton

The periphyton was collected by scratching 2 $cm^2$ of the substratum in triplicate. The scratched material was preserved in 4% formalin (APHA, 1998). The algal count was done with the help of Sedgwick counting chamber. The unicellular algae and protozoans were counted as Individuals while the filamentous forms were recorded as cells and in colonial forms; colony was taken as a unit. Identification of the periphyton was done with the help of standard taxonomical works of Edmondson (1959), Heurek (1896), Randhawa (1959), Pal *et al*., (1962) and Eaton *et al.* (1995). The results were calculated as Individuals (units) per square meter.

### Statistical Analysis:

The diversity Indices were computed with the help of Shannon Diversity Index (1963), i.e. $H' = - \Sigma$ pi $\log^2$ pi; [Where, pi = the importance of probability of each species (*ni*/N), N = total no. of Individuals in "S" species and *ni* = no. of Individuals in *ith* species]. Data was analyzed using one-way analysis of variance (ANOVA) and correlation coefficient was calculated by using Pearson's correlation (SPSS, 13).

## RESULTS

### A. Physico-chemical Parameters

The Physico-chemical characteristics of Lidder stream are presented in Table 1. The water temperature in the stream varied from 2°C (February) to 18 °C (August) with an average value of 11°C. However, the air temperature in the study area fluctuated from 4°C (January and February) to 25°C (July). The stream showed significant variation in its depth vis-à-vis the volume of water throughout the year. The maximum depth (high volume) in the stream was recorded in the month of July (0.93m), while the minimum depth (low volume) was recorded during December and January (0.25 m). The average values of transparency in the river at Zones I, II and III were 0.35m, 0.26m and 0.27 m respectively. Upstream the velocity of the water of the stream was high as compared to downstream and the mean velocity varied between the Zones and was 201cm/sec at Zone I (upstream), 155cm/sec at Zone II (midstream) and 137cm/sec at Zone III (downstream). Dissolved oxygen concentration in the Lidder stream was very close to saturation. The minimum saturation of 70% was recorded at Zone III and Zone II (June and August) and maximum saturation of 128% was recorded at Zone I (February). Mean pH in the stream varied from 7.77 (Zone I) to 8.09 (Zone III). $CO_2$ in the river fluctuated from 8mg/l to 22mg/l. At Zone III, $CO_2$ was absent in the summer months. Total alkalinity of the stream at Zone I, Zone II and Zone III was present with a mean value of 54 mg/l, 51 mg/l and 53 mg/l respectively.

The conductivity in the stream ranged from 85µS (April, Zone II) to 428µS (August, Zone III). The mean values of chloride at Zone I, Zone II and Zone III were 8 mg/l, 9 mg/l and 12 mg/l respectively. Total hardness increased downstream and the average values being 77 mg/l, 86 mg/l and 100 mg/l at Zone I, Zone II, Zone III respectively. Calcium, magnesium, sodium and potassium concentrations increased significantly downstream and their mean concentration was 25 mg/l, 6 mg/l, 4 mg/l and 2 mg/l respectively. The average Ammonical-N concentra-tion in the stream at different zones was as 13µg (Zone I), 14µg (Zone II) & 29µg (Zone III). The average concentration of Nitrate-N at Zone I, Zone II and Zone III was 252 µg/l, 260 µg/l and 314 µg/l respectively. Mean concentration of T.P.P and O.P.P at Zone I, Zone II and Zone III was 12µg, 14μg & 26g and 3μg, 5μg & 8μg respectively.

**B. Periphyton diversity and density**

A total of 58 species of periphyton were recorded in the Lidder River. Of these 38 belonged to Bacillariophyceae, 12 to Chlorophyceae, 5 to Cyanophyceae, 2 to Chrysophyceae and 1 to Euglenophyceae. Periphytic animalcules were represented by only three species, all belonging to class Protozoa (Fig. 1). The most dominant taxa of periphyton obtained during the present investigation were:

**Bacillariophyceae:** *Achnanthes longi-pins, Achnanthes* sp., *Amphora* sp., *A. ovalis, Bidulphia* sp., *Cymbella* sp., *Coconeis* sp., *Cyclotella* spp, *Diatoma elongatum, Diatoma* sp., *Epithemia* sp., *E. hyndamini, Fragillaria capucina, F.careteninsis, Gomphonema germinatum, G.constriticum, Hantzschia* sp., *Gyrosigma kutzangi, Pleurosigma* sp., *Melosira* sp., *Meriodon* sp., *Navicula* sp., *Navicula cuspidata, N. radiosa, N. alpine, N. nobilis, Stauroneis* sp., *Synedra ulna, Surirella* sp., *Eunotia* sp., *Staurastrum* sp.

**Chlorophyceae:** *Cladophora* sp., *Chlorella* sp., *Cosmarium* sp., *Desmidium* sp., *Mougetia* sp., *Oedogonium* sp., *Rhizoclonium* sp., *Scenedesmus* sp., *Staurodesmus* sp., *Ulothrix* sp. *Zygnema* sp.; **Cyanophyceae:** *Anabaena* sp., *Micro-cystis* sp., *Oscillatoria* sp., *Synechococus* sp., *Synechocystis* sp. **Chrysophyceae:** *Dinobryon* sp. and *Ceratium* sp., **Euglenophyceae:** *Euglena acus* and **Protozoa:** *Arcella* sp., *Difflugia* sp. and *Centropyxis* sp.

In Zone I, forty nine (49) taxa in all were recorded from the Lidder, which belonged to only four classes Bacillariophyceae (38 taxa), Chlorophyceae (9 taxa), Cyanophyceae (1 taxa) and Protozoans (1 taxa). In Zone II and Zone III, fifty five (55) taxa each were recorded. However, at Zone II, Bacillariophyceae was represented by 36 taxa, Chlorophyceae by 11 taxa, Cyanophyceae by 3 taxa, Chrysophseae by 3 taxa and Protozoans by 3 taxa and at Zone III, the contribution of various classes like Bacillariophyceae was 32 taxa, Chlorophyceae 12 taxa, Cyano-phyceae 5 taxa, Euglenophyceae 1 taxa and Protozoans 3 taxa. Bacillariophyceae in all Zones was the dominant class and on annual mean basis formed 77.55%, 65.45% and 58.18% at Zone I, Zone II and Zone III respectively. Chlorophyceae was the second dominant class and formed 18.37%, 20% and 21.82% followed by Cyanophyceae and formed 2.04%, 5.45% and 9.09% at Zone I, II and III respectively. Chrysophyceae were absent in upper reaches (Zone I) and formed 3.64% both at midstream and downstream. Euglenophyceae was present in the downstream only and on mean basis formed 1.82% of the total taxa. Protozoans were recorded at all reaches. However, their diversity increased downstream and formed 2.04%, 5.45% and 5.45% at Zone I, II and III respectively.

As Bacillariophyceae was the most dominant group of periphyton and was represented by 38 taxa in the river. *Achnanthes* sp. showed higher density during December-March when water was cool. *Cymbella* sp. was present throughout the year and showed the highest density during March to May. *Coconeis* sp. was dominant during April, May, September and October. *Diatoma* sp. were dominant in the months of September-December. *Gomphonema* sp. was dominant during August, September and December - March. *Melosira* sp. was maximum in the months of April and May. *Navicula* sp. also recorded their higher density in the months of April, May and October-January. *Synedra ulna* population was present in significant numbers during March-May, October and November. *Surirella* sp. was recorded higher in number in September. At Zone I, the highest density of Bacillariophyceae was recorded in the months of January-March and October, with the highest density (15152x$10^4$ Ind./$m^2$) in February. At Zone II, Bacillariophyceae also recorded the highest density in February (11362x$10^4$ Ind./$m^2$). At zone III, three peaks were observed, one in May (10288 x$10^4$ Ind./$m^2$), second in October (9932 x$10^4$ Ind./$m^2$) and third in February (9626 x$10^4$ Ind./$m^2$).

Among Chlorophyceae, no taxa of the group occurred throughout the year at any zone. On an average the density of Chlorophyceae increased downstream. *Cladophora* sp. was recorded at all stations. *Chlorella* sp. was present only at Zone III while at Zone I and II it was absent. Density of *Cosmarium* sp. increased downstream. At Zone I *Oedogonium* sp. was present only in the month of March and its density decreased downstream (Zone III). *Mougetia* taxa showed increasing trend. *Rhizoclonium* sp. density increased downstream (Zone II & III) and at Zone I was present only in the months of August-November. *Scenedesmus* sp. and *Staurodesmus* sp. were absent at Zone I while at Zone II low population was recorded and at Zone III the density increased. *Ulothrix* sp. and *Zygnema* sp. were present throughout the stream. The highest density of Chlorophyceae was in Zone I in the month of October ($685x10^4$ Ind./$m^2$). At Zone II, Chlorophyceae high density was recorded during October ($1754x 10^4$ Ind./$m^2$). At Zone III, the highest density of the group was recorded in the month of October ($2414 x10^4$ Ind./$m^2$).

Cyanophyceae was represented by 5 taxa. *Microcystis* sp. showed their presence downstream only (Zone III) and was present in May, August-November only. *Synechocystis* sp. and *Synechococus* sp. showed their presence only at Zones II and III in the months of August-November. The density of both the taxa increased downstream (Zone III). *Anabaena* sp. was recorded in downstream (Zone III) only during August-October. *Oscillatoria* sp. was present upstream during April and May and in mid stream and downstream it was absent during December & January and January respectively. The density of this group on an average at Zone I was $5 x 10^4$ Ind./$m^2$, at Zone II was $204 x 10^4$ Ind./$m^2$, and at Zone III it was $721 x 10^4$ Ind./$m^2$.

Chrysophyceae was represented by only two taxa, *Dinobryon* and *Ceratium*. Both these taxa were present at Zone II and III only during August to November and August to December respectively. The density of this group at Zone II and III on an average was $23 x 10^4$ Ind./$m^2$ and $108 x 10^4$ Ind./$m^2$ respectively. Euglenophyceae was represented by only one species i.e., *Euglena acus* which was present only at Zone III in the months of September and October. The density of this group on an average was 5 x $10^4$ Ind./$m^2$. The protozoa was represented by only 3 taxa i.e., *Arcella* sp., *Difflugia* sp. and *Centropyxis* sp. *Arcella* and *Difflugia* were absent at Zone I. At Zone II and III they were present only during July-October and July-November respectively. *Centropyxis* was present at Zone I in July-October with an average density of 19 x$10^4$Ind./$m^2$. At Zone II and III, Protozoans were present in July to November and their average density in these Zones was 118x$10^4$Ind./$m^2$ and 354 x $10^4$ Ind./$m^2$ respectively (Fig. 2).

Shannon diversity index in the Zone I was recorded minimum (4.45) in the month of August and maximum (4.91) in the month of October, with an average value of 4.74. In Zone II, minimum (4.45) and maximum (5.02) Shannon diversity index values were recorded in the month of December and Sept-ember respectively, the average value at this Zone being 4.79. In Zone III, the Shannon diversity index was recorded minimum (4.36) and maximum (5.22) in the month of January and August respectively and the average value at this Zone was 4.77 (Fig. 3).

## DISCUSSION

Periphyton has a great limnological significance and is one of the main contributors to the primary productivity of running waters. It constitutes the base of the food chain and the principal food items to the fishes, especially bottom feeders and omnivores. In the present study the occurrence and seasonal abundance of periphyton in the river showed much variation between the study zones. The Lidder stream showed a substantial variation in water quality with the decrease in altitude, as there is a fall of about 441m from upstream to downstream. The velocity of water has been found to be one of the important parameters which plays a significant role in the distribution and abundance of the attached algae. The varied velocity of the water and altitude had their influence on the range of temperature difference between air and water, with higher difference in fast flowing Zone (upstream) and less difference in slow flowing Zone (downstream). Dissolved oxygen concentration in the Lidder stream was very close to saturation. The dissolved oxygen showed negative correlation with water temperature at all zones, which was significant at $P<0.01$ level.

Singh (1964) and Vasisht and Sharma (1975) found the temperature to be one of the important factors influencing the distribution and production of plankton. Upstream the low temperature and high Dissolved Oxygen of the water has lead to the abundance of Diatoms. Patric (1950), Paramasivam and Sreenivasan (1981) reported that a healthy portion of a stream contains mostly diatoms and the contribution of green algae in such habitats is insignificant. Rao (1955) and Sarwar and Zutshi (1988) reported the colder water to be more suitable for the growth of diatoms. Similar conditions seemed to prevail in the present river as the Bacillariophyceae exhibited its highest peak during winter period which was characterized by low water temperature, low velocity, high transparency, high dissolved oxygen and moderate concentration of nutrients (Vasisht andSharma, 1975; Nautiyal, 1986 and Nautiyal *et al.*, 1997). Diatoms are the most important colonizers of the river stones (Lowe and Gale, 1980). Bacillariophyceae contributed more than 70% of the total periphyton and as such the seasonal trend depicted by the total periphyton was reflected by it as well. This is confirmed by the significant negative correlation of Diatoms with water temperature ($P<0.05$) and positive with dissolved oxygen ($P<0.05$). As the Diatom density decreased downstream and this decrease in species density and diversity downstream may be attributed to marked fluctuations in water depth, water temperature, water current, type of substratum, sunshine-hours, transparency levels and increase in nutrient load mostly during autumn and winter season (Phillopose *et al.*, 1976; Kumar, 1995). Similar results were found by Bhat and Yousuf (2004) while working on several lotic systems of Kashmir.

The dominance of Chlorophyceae, Cyanophyceae, Chrysophyceae and Euglenophyceae downstream can be related to increased organic wastes and higher temperature as these showed positive significant correlation (p

$\leq$0.05) with water temperature, conductivity, ammonia, and total phosphate phosphorus. Singh *et al.,* 1994 reported the occurrence of Chrysophyceae and Euglenophyceae with the mild pollution (both organic and inorganic matter downstream) and seems true for the present study also. In the lower stretches the river receives maximum sewage, agricultural runoff and domestic effluents which enhance the growth of the Chlorophyceae and Chrysophyceae. Zutshi (1976) and Khan *et al.* (1998) have also emphasized that pollution leads to the development of green and blue green algae. Venkateswarlu *et al.* (1981) found that the blue greens grow abundantly in waters with high pH, more chloride, very high organic matter. Our results are in conformity with the results of these workers. The high density of Chlorophyceae in the months of May to October, dominated by the *Cladophora, Closterium, Cosmarium* and *Ulothrix* and their presence seems to be related to the high water temperature and high dissolved oxygen. Cyanophyceae population, which increased downstream, especially during warmer periods, was favoured by higher temperature, pH, chloride and nutrient influx. This is in conformity with Wanganeo and Wanganeo (1991), Bhat & Yousuf (2002, 2004) who have reported that during summer when the temperature conditions are favourable and the nutrient influx is more due to human pressure, large populations of tolerant species such as *Euglena, Oscillatoria* and *Microcystis* show quick increase in their population. The dominant taxa of Cyanophyceae in lower stretches of Lidder were *Oscillatoria, Anabeana* followed by *Microcystis, Synnechocystis,* and *Synnechocus.*

On the whole the Lidder water quality was well within the permissible limits especially in the upper reaches and was very conducive for the growth of periphytic communities. Although downstream mild pollution has lead to the occurrence of pollution tolerant species like *Oscillatoria, Anabeana*, *Microcystis, Synnechocystis* and *Synnechocus.* However, the presence of species likes *Cosmarium* and *Ulothrix* sp. throughout the stream confirms that the water of Lidder is still almost pollution free.

**Table 1. Mean physico – chemical characteristics of Lidder stream in Kashmir, Himalaya**

| **Parameters** | **Zone I** | **Zone II** | **Zone III** |
|---|---|---|---|
| Water temperature (˚C) | 8.92(4.94)$^{a}$ | 10.50(4.95)$^{a}$ | 12.50(5.32)$^{a}$ |
| Water depth (m) | 0.69(0.29)$^{b}$ | 0.47(0.29)$^{ab}$ | 0.40(0.15)$^{a}$ |
| Transparency (m) | 0.35(0.09)$^{b}$ | 0.26(0.07)$^{a}$ | 0.27(0.09)$^{ab}$ |
| Velocity (cm/sec) | 201(94.17)$^{a}$ | 155(83.83)$^{a}$ | 137(48.42)$^{a}$ |
| pH | 7.77$^{a}$ | 7.90$^{a}$ | 8.09$^{a}$ |
| $CO_2$(mg/l) | 17(5.95)$^{b}$ | 15(5.35)$^{b}$ | 8(5.68)$^{a}$ |
| Dissolved oxygen (mg/l) | 12.17(2.89)$^{a}$ | 10.00(2.30)$^{a}$ | 9.83(2.08)$^{a}$ |
| Conductivity (µS) | 149(65.62)$^{a}$ | 175(79.36)$^{a}$ | 221(117.01)$^{a}$ |
| Chloride (mg/l) | 8(2.93)$^{a}$ | 9(4.02)$^{a}$ | 12(4.74)$^{a}$ |
| Total hardness (mg/l) | 77(12.61)$^{a}$ | 86(14.39)$^{ab}$ | 100(20.01)$^{b}$ |
| Calcium (mg/l) | 22(5.63)$^{a}$ | 24(6.63)$^{ab}$ | 29(6.84)$^{b}$ |
| Magnesium (mg/l) | 5(1.38)$^{a}$ | 6(1.93)$^{a}$ | 6(1.86)$^{a}$ |
| Sodium (mg/l) | 3(1.60)$^{a}$ | 4(2.44)$^{a}$ | 5(2.54)$^{a}$ |
| Potassium (mg/l) | 1(0.74)$^{a}$ | 2(1.14)$^{a}$ | 2(1.16)$^{a}$ |
| Ammonical-nitrogen (µg/l) | 13(6.34)$^{a}$ | 14(5.96)$^{a}$ | 29(10.97)$^{b}$ |
| Nitrate-nitrogen (µg/l) | 252(47.02)$^{a}$ | 260(45.24)$^{a}$ | 314(59.91)$^{b}$ |
| Total Phosphate phosphorus (µg/l) | 12(5.43)$^{a}$ | 14(7.47)$^{ab}$ | 26(18.36)$^{b}$ |

**Note:** Values within parenthesis are standard deviation values and alphabets a, b shows Tukeys variation within sites.

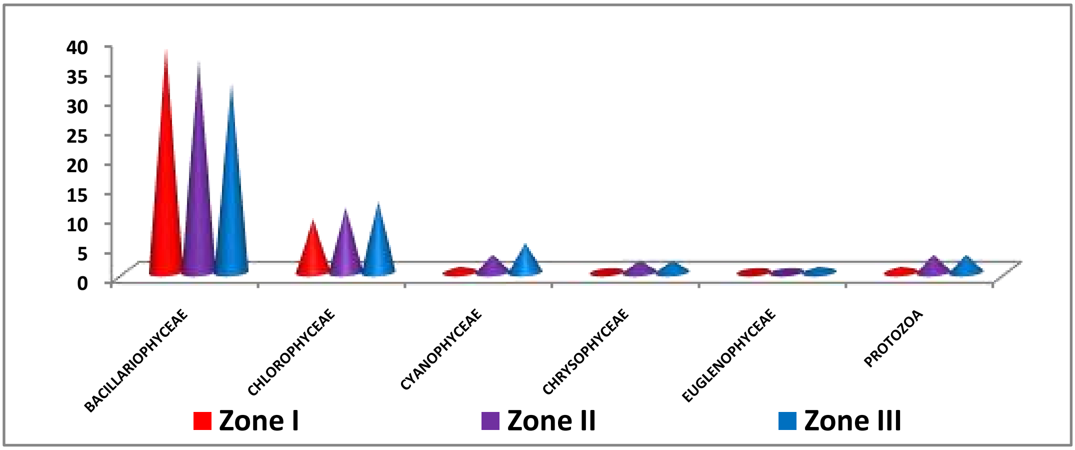


**Fig. 1. Number of taxa of different classes of periphyton in the study zones in Lidder River**

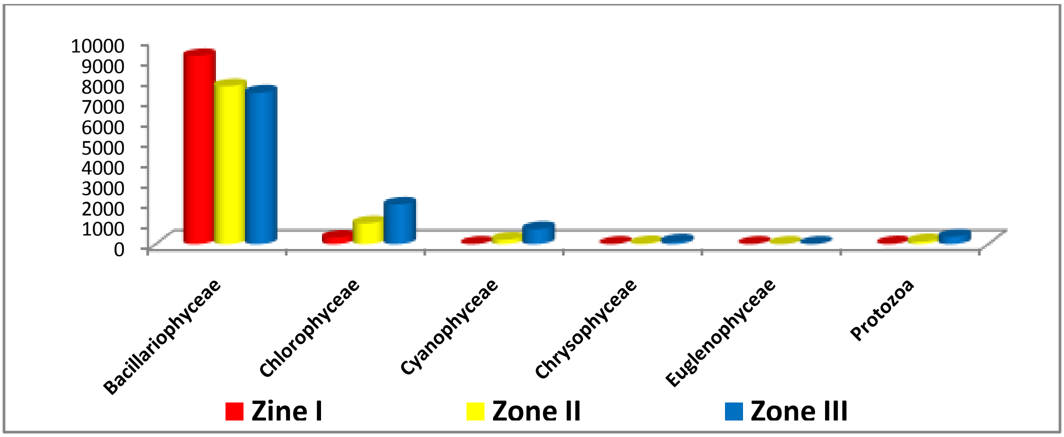


**Fig. 2. Mean population Density (Individuals x$10^4$/$m^2$) of different classes of periphytic community in the study zones in Lidder stream**

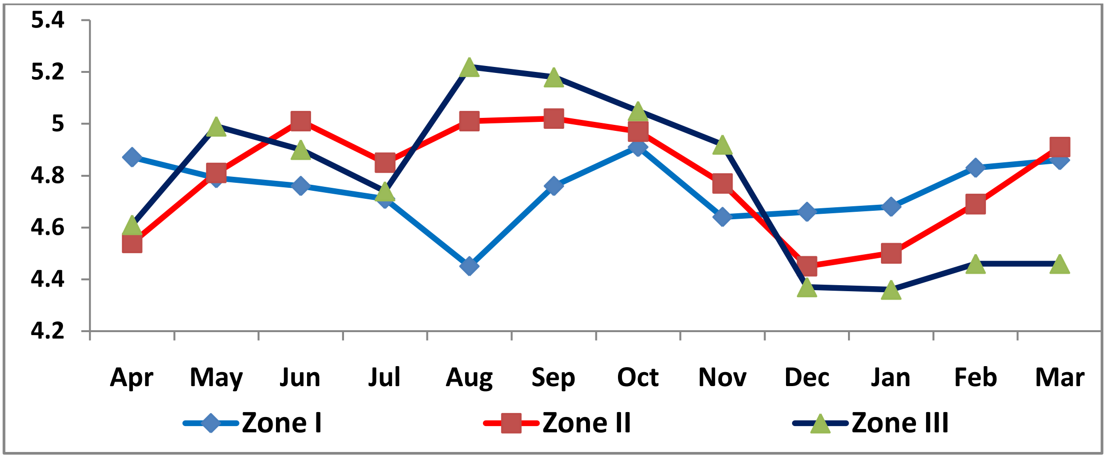


**Fig. 3. Shannon Diversity Index of periphyton in the study zones in Lidder River.**

## REFERENCES

APHA. 1998. *Standard Methods for the Examination of Water and Wastewater*. A.P.H.A., A.W.W. A., W. E.F., Washington DC.

Bhat, F. A. and Yousuf, A.R. 2002. Ecology of periphytic community of Seven Springs of Kashmir. *J. Res. Dev.* **2**: 47-59.

Bhat, F. A. and Yousuf, A. R. 2004. Limnological Features of Some Lotic Systems of Kashmir. pp. 57-70.In: *Bioresources Concerns and Conservation* (Eds. Azra N. Kamili and A. R. Yousuf), Centre of Research for Development, University of Kashmir.

Bhat, S. U., Sofi, A. H., Yaseen, T., Pandit, A. K. and Yousuf, A. R. 2011. Macro-invertebrate community from Sonamarg streams of Kashmir Himalaya. *Pakistan Journal of Biological Sciences*, **14** (3): 182 - 194.

Bhat, F. A., Yousuf, A. R., Balkhi, M. H. and Najar, A. M. 2013. Occurrence of Macrozoobenthos Against the Varied Altitudinal Gradient and Ecology in a Trout Stream (Lidder) of Kashmir Himalaya, India. *Proc. Natl. Acad. Sci., India, Sect. B Biol. Sci.,* DOI 10.1007/ s40011-013-0217-3.

Bhat, F. A., Yousuf, A. R., Balkhi, M. H., Mahdi Dilgeer and Shah, F. A. 2010.Length-weight relationship and morphometric characteristics of *Schizothorax* spp. in the River Lidder of Kashmir. *Indian J. Fish,* **57**(2): 73-76.

CSIR. 1974. *Analytical Guide* (Laboratory Techniques) CSIR, Pretoria, South Africa.

Dutta, R. 2012. *Hydrobiology and Fishery Potential of Namsang (Chatju) Stream in Arunachal Pradesh.* Unpublished Ph.D thesis, Gauhati University.

Edmondson, W.T. 1959. *Freshwater Biology,*John Wiley, N.Y.

EPA. 1976. Methods for chemical analysis of water and wastes. Environmental Monitoring and support laboratory, ERC, Lincinati, Ohio, USA.

Finlay, J. C., Khandwala, S. and Power, M. E. 2002. Spatials scales of carbon flow in a river food web. *Ecology.* **83**(7):1845-1859.

Heurek, H.V. 1896. *A Treatise on Diatomaceae*. William Wisley and Son, Essex street, strand, W.C.

Kajak, Z. 1987. Determinants of maximum biomass of benthic chironomidae (Dipetra). *Ent. Scand.*, **29**: 303–308.

Kajak, Z. 1996. Abundance and production of benthos and factors influencing them. *Zesz. Probl. Kosomosu.,* **13**: 69–92.

Khan, Asif. A., Alam, Aftab and Gaur, Rajeev,V. 1998. Seasonal variations in the abundance and composition of phytoplankton in the River Gangas at Narora, U.P. *J.Inland Fish. Soc.,* **30**(1): 79-86.

Kumar, K. and Bhagat, M.J. 1978. Observation on the ecology of two trout streams in Kashmir and its possible effect on Brown trout (*Salmo trutta fario*) Catches. *J. Inland Fesh. Sci. Ind.,* **10**: 1-8.

Kumar, Dhirendra. 1995. Study on periphyton of Ravishankar Sagar Reservior. *J. Inland. Fish. Soc.India,* **27**(1): 13-20.

Lock M. A., Wallace R. R., Costerton J. W., Venullo R. M., Charlton S. E. 1984. River epilithon. Toward a structural-functional model. *Oikos,* **42**:436-443.

Lowe, R.L. and Gale, W.F. 1980. Monitoring river periphyton with artificial benthic substrates. *Hydrobiologia,* **69**(3): 235-244.

Mackereth, F.J., H. Haron, J. and Talling, J.F. 1978. *Water analysis. Fresh Wat. Biol. Assoc. Sct. Publ. No. 36.*

Meyer, J. L. McDowell, W. H., Bott, T.L., Elwood, J.W., Ishizaki, C., Melack, J.M., Pckarsky, B.L., Peterson, B.J.and Rublee, P.A. 1988. Elemental dynamics in streams. *J. N. Am. Benthol. Soc*., **7**: 410-432.

Moore, J. W. 1980. Factors influencing the composition, structure, and density of population of benthic vertebrates. *Arch. Hydrobiol*., **88**: 202- 218.

Nautiyal, P., Bhatt, J.P., Kishor, B., Rawat, V.S., Nautiyal, R., Badoni, K. and Singh, H.R. 1997. Altitudinal variations in phytobenthos density and its components in the coldwater mountain River Alkananda—Ganga. *Phykos.,* **36** (1-2): 81-88.

Nautiyal, P. 1986. Studies on the river ecology of torrential waters in the Indian uplands of the Garhwal region. III. Floristic and faunastic survey. *Trop. Ecol.,* **27**: 157-165.

Pal, B.P., Kundu, B.C., Sundaralingam, V.S. and Venkataraman, G.S. 1962. *Charophyta.* ICAR, New Delhi.

Paramasivam, M. and Sreenivasan, A.1981. Changes in algal flora due to pollution in Cauvery Rivers. *Indian. J. Environ. HIth.,* **23**(3): 222-238.

Patrick, R. 1950. Biological measure of stream conditions. *Sew. Indust. Wastes.,* **22**: 926.

Phillopose, M.T., Nandy, A.C., Chakraborthy, D.P. and RamaKrishna, K.V. 1976. Studies on the distribution in time and space of the periphyton of the perennial pond at Cuttack India. *Bull. Cet. Inl. Fish. Res. Inst. Barrackpore,* **21**: 1-43.

Qadri, M.Y., Naqash, S.A., Shah, G.M. and Yousuf, A.R. 1981. Limnology of two streams of Kashmir. *J. Indian Inst. Sci*. **63**: 137-141.

Randhawa, M.S. 1959. *Zygnemaceae.* ICAR Publ. pp. 91-437. New Delhi.

Rao, K. 1955. Plankton ecology of the river Hoogly at Palta, W.B. *Ecology,* **36**: 169-175.

Sarwar, S.G. and Zutshi, D.P. 1988. Species distribution and community structure of periphytic algae on artificial substrate. *Tropical Ecology*. **29**(2): 116-120.

Shannon, C. E. and Weiner, W. 1963. The mathematical theory of communication. University of Illionis Press, Urbana and regional scales. *Annu. Rev. Entomol.,* **43**: 271–293.

Singh, C.S. 1964. Seasonal fluctuation in diatom diatom population I. *J. Sci. Res.,* B.H.U. **16**: 201-211.

Singh, H. R., Nautiyal, P., Dobriyal, A. K., Pokhriyal, R. C., Negi, M., Baduni, V., Nautiyal, R., Agarwal, N. K., Nautiyal, P. and Gautam. A. 1994. Water quality of the River Ganga (Garhwal Himalayas). *Acta Hydrobiologia,* **36**:3-15.

Vasisht, H.S. and Sharma, B.K. 1975. Ecology of a typical urban pond in Amabala city of the Haryana State. *Indian J. Ecol.,* **2**(1): 79-86.

Venkateswarlu, V. 1981. Algae as indicators of river water quality and pollution. pp. 93-100. In: *WHO Workshop on Biological Indicators and Indices of Environmental Pollution.* Osma-nia University.

Wanganeo, A. and Wanganeo, R. 1991. Algal population of Kashmir Himalaya. *Arch. Hydrobiol.,* **121**(2): 219-233.

Wetzel, R. G. 2005. Periphyton in the aquatic ecosystem and food webs. In Periphyton: Ecology, Exploitation and Management (Eds., Azim, M. E., Verdegen, M. C. J. Van Dam, A.A. & Beveridge, M. C. M.). Cabi Publishing, Wallingford, UK. : 51-70.

Yousuf, A. R., Bhat, F. A., Mehdi, D., Ali, S. and Ahangar, M. A. 2003. Food and feeding habits of *Glyptosternon* *reticulatum* McClelland & Griffith in torrential streams of Kashmir Himalayas. *J. Res. Dev.,* **3**: 123 – 133.

Yousuf A. R., Bhat, F. A. and Mehdi, D. 2006. Limnological features of River Jhelum and its important tributaries in Kashmir Himalaya with a note on fish fauna. *J. Himalayan Ecol. Sustain. Dev.,* **1**: 37 – 50.

Zutshi, D.P. 1976. Phytoplankton productivity, algal dynamics and trophic status of Lake Mergozzo (Northern Italy). *Mem. Ist. Ital. Idriobiol. Pallanza.* **33**: 221-256.

# INVESTIGATING DRAINAGE RESPONSE TO THE BALAPUR FAULT INTERACTION ON THE NORTHEASTERN PIR PANJAL FLANK, KASHMIR VALLEY, INDIA

**Shabir Ahmad* and M. I. Bhat**
Department of Earth Sciences, University of Kashmir, Srinagar-190006
*Correspondence author: shabirgeo79@gmail.com.

**ABSTRACT**

Soft terrain lithology like Karewa deposits are mostly dominated by the erosional activity thereby quickly vanish recent fault traces. Kashmir Valley being tectonically active and specially its west-southwest Karewa dominant terrain, we used geomorphic features chiefly drainage analysis for indications of active deformation. Drainage anomalies such as sudden drainage deflections, and stream captures are used to infer zones of remnant and recent tectonic activity. Though our initial interpretation is based on remote-sensing observations, however, all the relevant features have been equally verified with field evidences. The study demonstrates the usefulness of drainage features in exploring the extension of the Balapur fault together with a few paleoseismic sites for future programme. The exercise can be useful for soft rock terrain in other deforming parts of the world.

***Key words:*** active tectonics, geomorphic and drainage anomalies, Balapur fault, field mapping, Kashmir valley

## INTRODUCTION

The precise drainage features predominantly stream capture and beheaded streams are considered to identify recently active fault traces (Schumm, 1977; Bloom, 1979). Additionally, drainage features are not only useful tools for identification of fault traces but their gross character is evident on topographic maps and aerial photographs (Howard, 1967; Kurz *et al.,* 2007; Gloaguen *et al.,* 2007, 2008). Depending upon various variables such as relief, slope, structure, climate and vegetation characteristics the nature of drainage pattern can vary greatly from one type of terrain to another. It can also provide important clues toward understanding the Quaternary tectonic activity of a region at both regional and local scales (Goldsworthy and Jackson, 2000). Thus, an integrated observation from general landform topography together with the characteristics of the drainage features of main channels (e.g., sharp deflections, and braided bar deposits) and the behavior of their adjacent tributaries (e.g., stream captures, beheaded streams, and stream deflections) can reveal recent tectonic activity.

Bounding on the east-north east by the Great Himalaya and west-south west by the Pir Panjal Ranges, Kashmir valley is located on the eastern limb of the Kashmir-Hazara syntaxial bend (Fig. 1). In tectonic terms, two well established, parallel, sequential faults such as Panjal thrust (=MCT) and Murree thrust (=MBT) are bounded on its Southwestern end (Thakur *et al.,* 2010), and Zanskar thrust on its Northeastern end (Agrawal and Agrawal, 2005). Furthermore, several out-of-sequence faults have been identified south of Panjal thrust such as Riasi thrust (RT), Kotli thrust (KT), and Balakot-Bagh fault (BBF), the latter was the source of 2005 Mw 7.6 Muzzafarabad earthquake. Kashmir Valley has been devastated by earthquakes as suggested by its historical record (Oldham, 1883; Jones, 1885; Iyanger and Sharma, 1996; Iyanger *et al.,* 1999; Ambraseys and Jackson, 2003; Ahmad *et al.,* 2009) which includes 1555 and 1885 mega events but which of the faults have produced these devastated events is yet unknown. Evidently, a few studies are available in literature such as lineament analysis (Ganju and Khar, 1984), observations of southward-facing fault scarp segments (Yeats *et al.,* 1992) and severe northward trajectory deflections in the tributaries of Jhelum (Bhat *et al.,* 2008) which are however, devoid of any field derived data. The identification of fault begins with a NW-SE trending reverse Balapur fault (BF). The fault (BF) was identified recently in southwest of the Kashmir Valley (Ahmad, 2010) and later confirmed by paleoseismic trench study (Madden *et al.,* 2010), substantiated by other studies (Madden *et al.,* 2011; Ahmad and Bhat, 2012; Ahmad *et al.,* 2013). Thus, the present study examines drainage characteristics of a segment of the Balapur fault interaction in the west-southwest of the Kashmir Valley (Fig. 1).

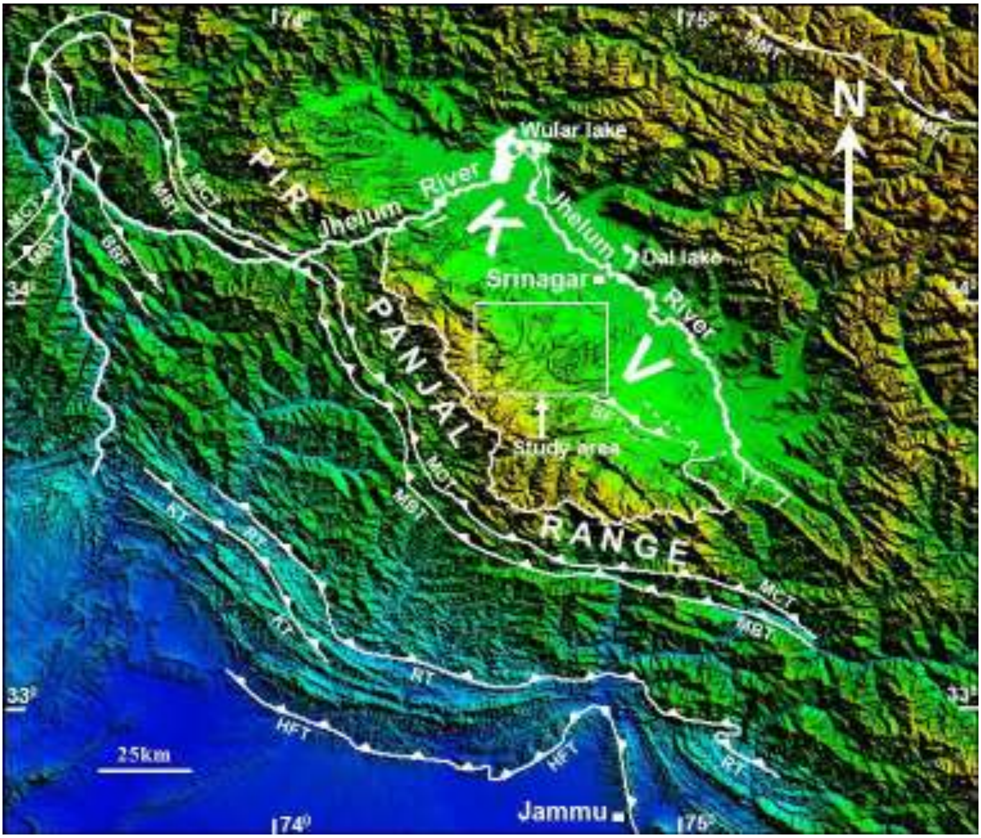


**Fig. 1. Showing Kashmir and its adjoining major Himalayan structures.** The figure is a SRTM-90m base; sequential mapped faults (MCT, MBT and HFT) and some out-of-sequence faults (RT, KT and BBF) are adapted from Thakur *et al.,* (2010). Mapped MMT is adapted from Hussain *et al.,* (2009). Little is known in Kashmir Valley faults where field, trench and terrace deformation studies (Ahmad, 2010, Madden *et al.*, 2010; Madden *et al.,* 2011; Ahmad and Bhat, 2012; Ahmad *et al.,* 2013) depict northeast dipping Balapur fault (BF) together with two inferred faults (shown as dashed lines). KV = Kashmir Valley; MCT = Main Central thrust; MBT = Main Boundary thrust; HFT = Himalayan Frontal thrust; MMT = Main Mantle thrust; BBF = Balakot-Bagh fault; RT = Riasi Thrust; KT = Kotli thrust BF = Balapur fault.

## Geological Setting

The exposed bedrock and surficial units in and around the study area are shown in Figure 2 and the stratigraphic succession is given in Table 1. The oldest rocks exposed in the upper reaches of the study area are Panjal Volcanic Series (Middlemiss, 1910) (Upper Carboniferous-Permian) and Triassic limestone together with some basement inliers. However, most of the area is covered by fluvioglacial sediments, collectively known as the Karewas or *wudr* in Kashmiri dialect (Plio-Pleistocene), which has been assigned group status (Farooqi and Desai, 1974; Bhatt, 1989). These consist of unconsolidated clays, sands, and conglomerates with lignite beds unconformably lying on the bedrock and are overlain by the recent river alluvium (Bhatt, 1975, 1976; Wadia, 1975; Burbank and Johnson, 1982; Singh, 1982). The Karewa Group has been subdivided into the progressively younger Hirpur, Nagum, and Dilpur Formations, respectively (Bhatt, 1989).

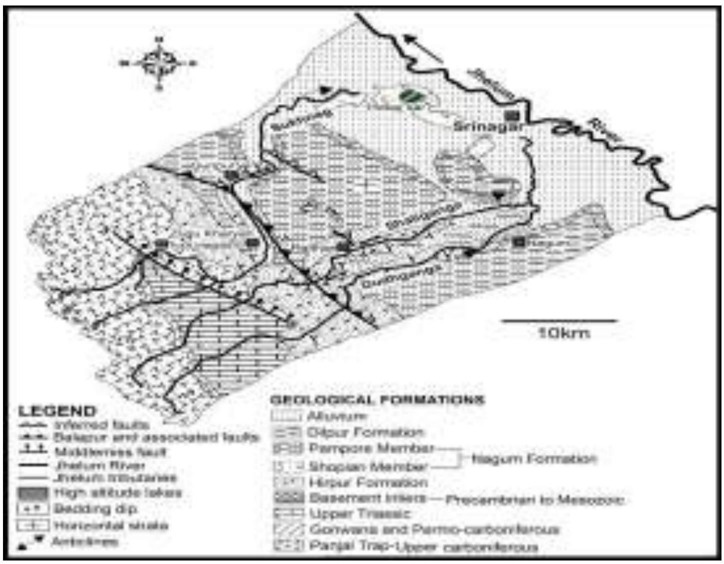


**Fig. 2. Geological Formations of the part of Northeastern Pir Panjal Range (modified after Middlemiss, 1911; Bhatt, 1989)**

 ISSN 0973-7502

**Table 1. Geological succession of southwest Kashmir Valley (After Wadia, 1975; Bhatt, 1976, 1989)**

| Formation/Group | | | Lithology | Age |
|---|---|---|---|---|
| Alluvial deposits | | | Clay, sandy clay, silt with occasional gravel | Recent to Sub-recent |
| Loess-paleosol succession of Dilpur formation | Dilpur Formation | **KAREWA GROUP** | Layers of brown silt vary from calcareous to non-calcareous types | Upper Pleistocene |
| Krungus Member<br>Pampur Member<br>Shupiyan Member | Nagum Formation | | Gravels, sand, sandy clay, marl and silt | Middle Pleistocene |
| ---Angular unconformity--- | | | ---Angular unconformity--- | |
| Methawoin Member | Hirpur Formation | | Clay, sandy clay, conglomerate, varve sediment, liginite and sand | Pliocene to Pleistocene |
| Rambiara Member | | | | |
| --Er.Unconformity-- | | | | |
| Dubjan Member | | | | |
| ---------Unconformity--------- | | | | |
| Triassic Formation | | | Limestones, shales etc. | Triassic |
| Panjal Trap | Panjal volcanic series | | Andesite, Basalts etc. | Permian |
| Agglomeratic slate | | | Slates | Carboniferous |

## Drainage characteristics of the study Area

The study area contains three sub-basins of the Jhelum basin such as Dudhganga, Shaliganga and Sukhnag (Fig. 3) and their brief drainage features are discussed below:

**Dudhganga:** Rising between the Katsgalu (4704m) and Tatakutti peaks (4745m) together with other tributaries in Magru Sar as Sangsafed nar and Sainmarg and Kharmarg nars from numerous high altitude lakes of the Pir Panjal Range, Dudhganga comes into existence from Frasnag village downstream. It shows general transverse (NE) flow regime from source to Wahathor village despite some right and left deflections between Liddarmarg and Brenawar locations. At Wahathor, Dudhganga is joined by Shaliganga (discussed next), which actually contributes maximum volume of discharge to Dudhganga. At Barzul, Dudhganga is diverted into the Spill channel; only a littlevolume of water exits from the Spill channel to follow original stream course until its confluence with the Jhelum at Chhatabal. From Wahathor village to Jhelum, it flows due north. It has total length of 50.15km.

**Shaliganga:** Rising below the Tattakuti (4745m) and Asdhar Gali (4188m) peaks as Asdhar nala, Shaliganga derives its name after receiving numerous small tributaries in source region along with Razdain Nar on left bank. In terms of volume/discharge and size, it exclusively comes into existence near Dudhpathri. Numerous, huge glacial erratics are found in the Shaliganga valley at different places. It has laid down the only small braided bar deposit in the middle of the channel at Lanyalab village. Shaliganga generally maintains average NE transverse flow; however, it shows anomalous behavior between Lanyalab and Guravet Kalan villages where flow direction changes between east and north. From source up to its confluence with Dudhganga at Wahathor, it has total length of 37.35km.

**Sukhnag:** Numerous high altitude small lakes such as Gurwan Sar, Pam Sar, Bodh Sar, Damam Sar between the Chinamarg (4386m) and the Pathri ki Gali (4132m) peaks, give rise to two small streams -- Godtar nala and Sirwan nala -- which unite on the southern side of Zugu Kharyan forest region to form a sizable stream known as Sukhnag. Besides, several tiny streams north of Tosh maidan to Sugan forest region directly joining Sukhnag. While descending from the northeastern Pir Panjal Range at Tosh maidan it passes through a sand choked plain across the Karewa terrain only to strike against Triassic limestone outcrop at Guripur village to Qasba Biru and to assume a narrow course. It shows a significant anomalous flow regime among all the three streams. It disappears in marshes of Rakh Aral, west of Hokarsar. It has total length of 87.15km.

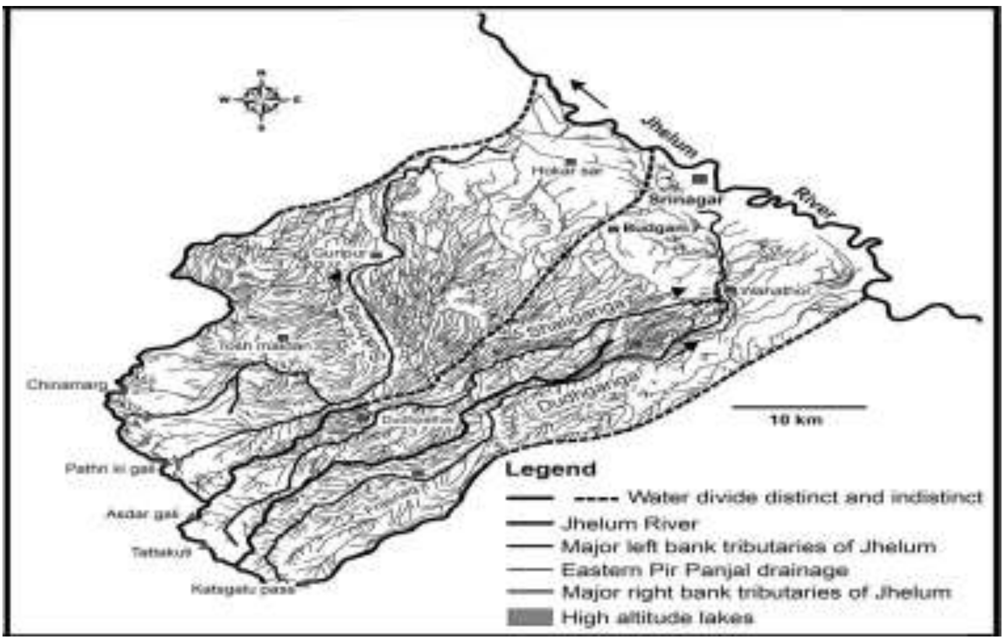


**Fig. 3. Showing drainage characteristics of the study area. Solid and dashed lines reflect hard rock, distinct and soft rock, indistinct sub-basin boundaries. Notice the drainage pattern changes its look once the streams enter soft rock or Karewa terrain**

## MATERIAL AND METHODS

At the initial stage, we conducted a systematic survey to compile the existing information related to the Balapur fault (Ahmad, 2010; Madden *et al.,* 2010; Madden *et al.,* 2011; Ahmad and Bhat, 2012; Ahmad *et al.,* 2013) and other fault relevant studies in the area (Ganju and Khar, 1984; Yeats *et al.,* 1992; Bhat *et al.,* 2008). After compiling the relevant information from published literature we subsequently, consult topographic maps derived from Survey of India (SoI) 1:50,000 scales followed by 90m resolution DEM derived from SRTM (Shuttle Radar Topographic Mission) with the help of software 'Global Mapper' to finalize the interaction of recent Balapur fault traces using drainage signatures together with field observations.

## RESULTS AND DISCUSSION

To specifically notice drainage interaction (e.g., streams captures, beheaded streams, sharp drainage deflections etc.) along the strike of the Balapur fault, we analyze one of its segment from Kelar village, runs through Yusmarg to Takibal village and covers parts of Romushi, Dudhganga, Shaliganga basins and Sukhnag basins (Fig. 4).

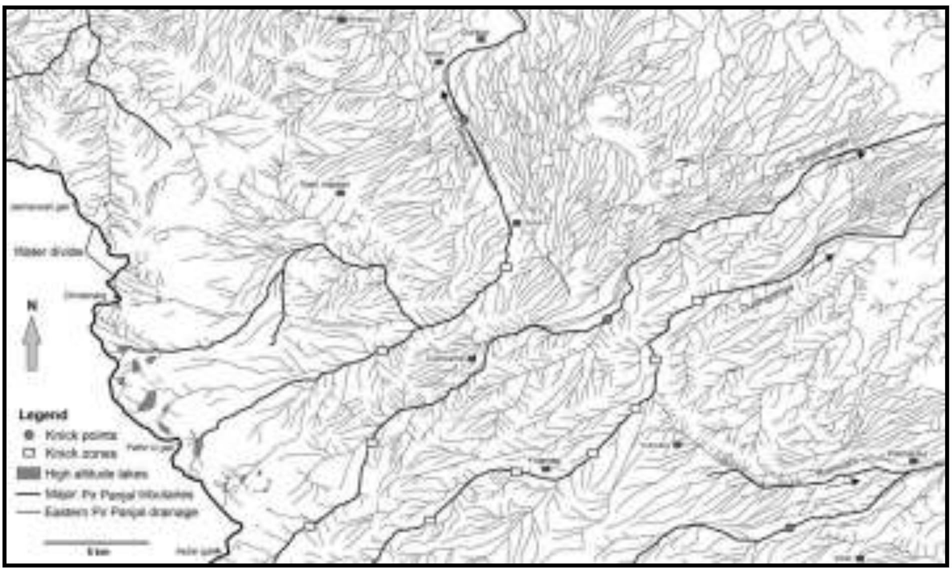


**Fig. 4. Drainage features of the study area along the strike of the Balapur fault**

Drainage analysis begins with very weak drainage evidence (e.g. stream capture) of the Balapur fault from Kelar village to Romushi stream. However, Romushi long profile shows a sharp knick point (Fig. 4) which could be evidence of the concealed segment of the Balapur fault here (Bhat *et al.,* 2008). Further NW from this point, another small, NW branch of the Romushi, originating between Dargahtolan and Cherakhol villages and flowing a general NE direction, to deflect right at Yusmarg to take SE direction for about 1.4 km with prominent stream capture. Middlemiss (1911) has observed a monoclinal fold at Yusmarg where lower Karewa bedding planes has completely changes their attitude from a general NE to anomalous SW directions (Fig. 5). Moreover, Bhatt (1978) while discussing the lower and higher level margs also observed reversal of bedding due to asymmetrical anticline at Yusmarg (Fig. 6). The sudden drainage deflection together with monoclonal fold (Middlmiss, 1911) or asymmetrical anticline (Bhatt, 1978) could suggest the presence of a hidden segment of the Balapur fault here.

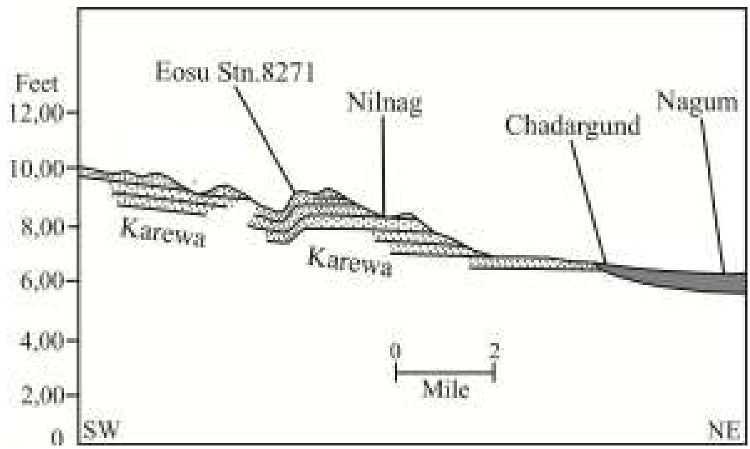


**Fig. 5. Cross-section of a monoclinal fold extracted from Middlemiss (1911) cross-section of Nilnag-Tatakuti across Pir Panjal Range**

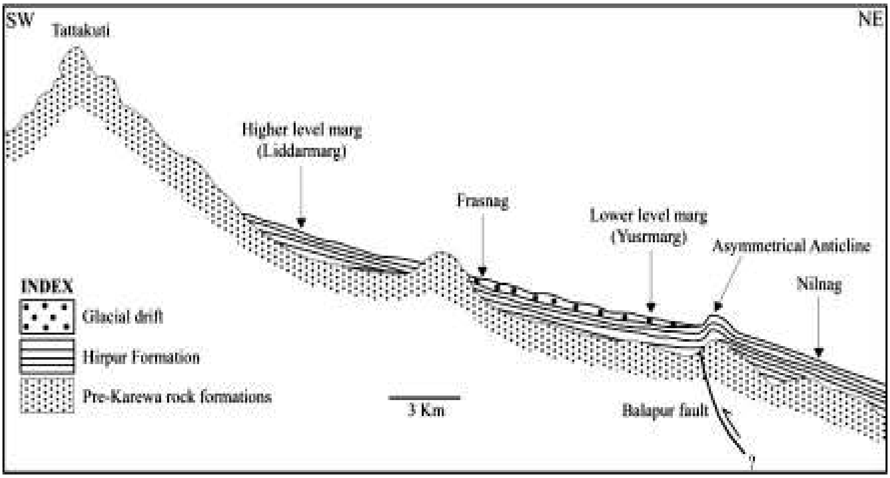


**Fig. 6. Cross-section showing impact of the Balapur fault on lower level margs which have been uplifted, deformed, reversed bedding attitude and preserved asymmetrical anticline near Yusmarg on the Northeastern Pir Panjal Range (modified after Bhatt, 1978). Basement depth of the Balapur fault is unknown**

Further NW from Yusmarg, the Balapur fault is dissected by Dudhganga and Shaliganga streams however, retains prominent stream captures all along, especially between Romushi to Dudhganga streams. The Balapur fault deforms mostly older terraces of Dudhganga, Shaliganga and Sukhnag streams. Although stream capture is not evident between Dudhganga and Shaliganga streams but both streams marked prominent gradient fluctuations in the form of knick zones and knick points, extremely suggests existence of Balapur fault (Fig. 7). Further northwest-ward, the area surrounding Gojathaj village is marked by prominent stream capture evidence along the Balapur fault (Fig. 8). Sukhnag channel generally flows NE but near Arzal village takes sharp left turn to flow a straight NW course for ~7.5 km along the foot of suddenly rising Karewas on its west. This deflection appears fault-controlled that alone could force such a sharp deflection of the Sukhnag stream itself. Additionally, the long profile of the stream develops a sharp knick point within this reach (Bhat *et al.,* 2008).

Further northwestward from Takibal to Shekhapur villages, we notice stream captures (Fig. 9), drainage deflections, alignment of some springs, and attitude of beds (i.e. SW dipping) all support the existence of the Balapur fault in this segment.

The Balapur fault is associated with a 0.7km long asymmetrical anticlinical fold and is exposed on the left bank of Rambiara. The fault is sub-vertical with an average dip of $60^{o}$ NE. Close to the fault, the bedding dip measures 40-$45^{o}$ SW; however, away from the fault the amount of dip decreases immediately until it is just $5^{o}$ NE at the northeastern end of the anticline. On the basis of structural data such as dip and/strike of bedding planes, similar fault-associated anticlines mostly asymmetrical in nature are observed in the field along the strike of the Balapur fault on the banks of the several streams, like Veshav near Kulgam, Sasara near Manshiwor, Romushi near Abhom, Shaliganga near Lanyalab and Sukhnag near Gurpur village. However, unlike in the Rambiara asymmetrical anti-clinical fold area, intense agricultural activity and/or plantation has masked stratigraphic cross-section of fault of all the latter asymmetrical fold structures.

Field investigations also reveal numerous evidences along the strike of Balapur fault where Karewa terrace deposits have been clearly deformed in latest by Quaternary and these locations would certainly provide suitable stratigraphic relations for paleoseismic analysis especially nearby Lanyalab (locally called Wusan Wudar) and Gojathaj villages.

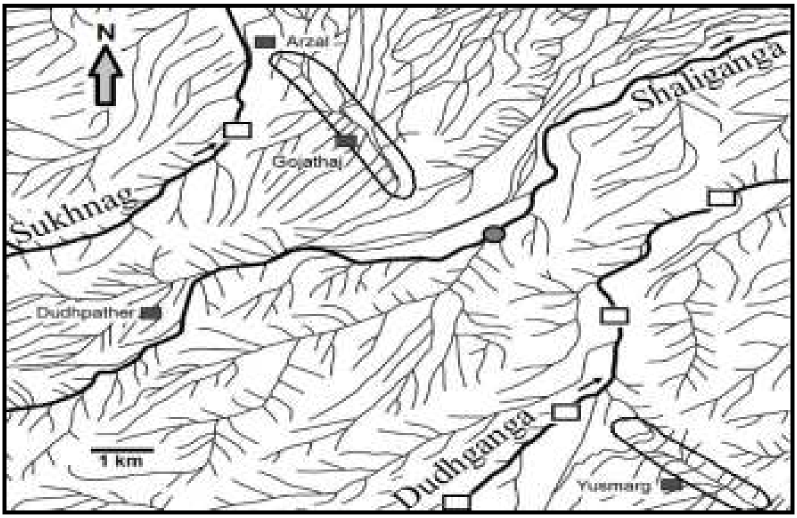


**Fig. 7. Stream capture evidences along the strike of the Balapur fault. Notice stream captures are highlighted by polygons, white rectangles are knick zones and a grey circle is knick point**


**Fig. 8. Field photo showing clear stream capture due to the Balapur fault near Gojathaj village (for locations refer Fig. 7). White dashed line traces the Balapur fault**

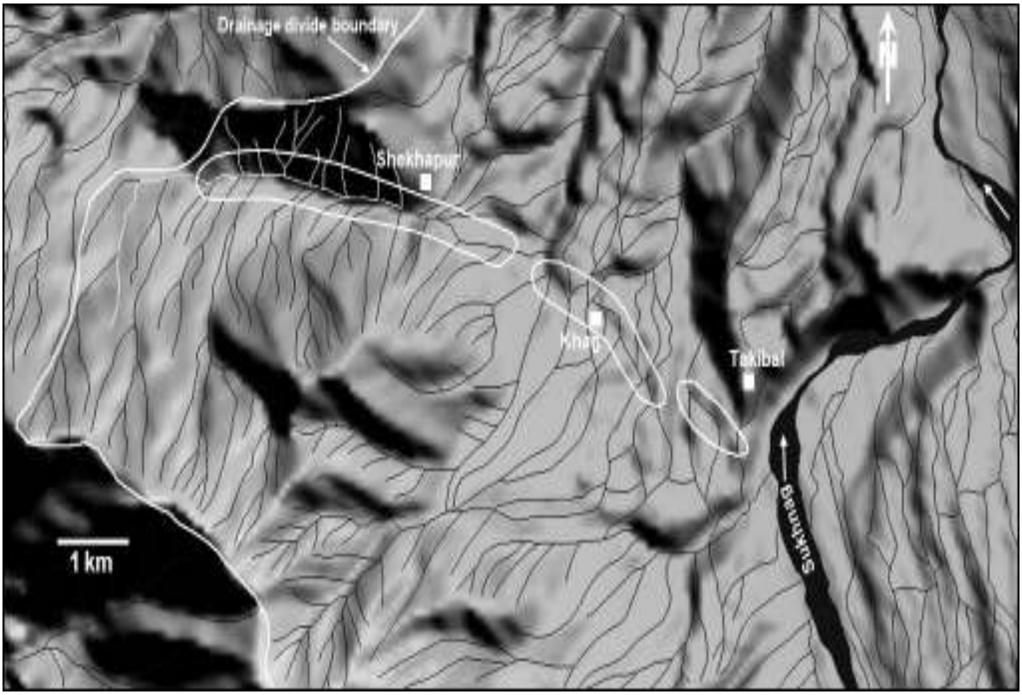


**Fig. 9. Part of the drainage map of the Sukhnag basin. White-polygons highlight areas of stream capture and drainage deflections. Based on stream captures, white-polygons mark the NW-ward expression of the Balapur fault between Takibal and Shekhapur villages**

## CONCLUSIONS

The soft rock terrains such as Karewas are exceptionally dominated by the erosional activity as a result, wiping of recent faults traces. However, recent fault traces can be revealed through geomorphic features specifically by drainage analysis. To decipher active deformation along an unknown segment of the Balapur fault, we accordingly, employ the technique on the dominant soft rock Karewa terrain in west-southwest side of the Kashmir Valley. Drainage anomalies such as sudden drainage deflections, and stream captures are used to infer zones of remnant and recent tectonic activity. Though our initial interpretation is based on remote-sensing observations, however, all the relevant features have been equally verified with field evidences. The study demonstrates the usefulness of drainage features in exploring the extension of the Balapur fault together with a few paleoseismic sites for future program. The exercise can be useful for soft rock terrain in other deforming parts of the world.

## ACKNOWLEDGEMENT

We are thankful to department of earth sciences for providing necessary laboratory facilities.

## REFERENCES

Ahmad, B., Bhat, M. I. and Bali, B. S. 2009. Historical record of Earthquakes in the Kashmir valley. *Himalayan Geology*, **30** (1): 75-84.

Ahmad, S. 2010. Tectonic Geomorphology of the Rambiara basin, southwest Kashmir Valley. Unpublished M. Phil Thesis, University of Kashmir, Srinagar.

Ahmad, S. and Bhat, M. I. 2012. Tectonic geomorphology of the Rambiara basin, SW Kashmir Valley reveals emergent out-of-sequence active fault system. *Himalayan Geology*, **33**(2): 162-172.

Ahmad, S., Bhat, M. I. Madden, C. and Bali, B. S. 2013. Geomorphic analysis reveals active tectonic deformation on the eastern flank of the Pir Panjal Range, Kashmir Valley, India. *Arabian Journal of Geosciences*, DOI 10.1007/s12517-013-0900-y

Agarwal, K. K. and Agrawal, G. K. 2005. A genetic model of thrust bounded intermontane basin using scaled sandbox analogue models: an example from the Karewa Basin, Kashmir Himalayas, India. *International Journal of Earth Science*, **94**(1): 47–52.

Ambraseys, N. and Jackson, D. 2003. A note on early earthquakes in northern India and Southern Tibet. *Current Science*, **84**: 540-582.

Bhatt, D. K. 1975. On the Quaternary geology of the Kashmir valley with special reference to stratigraphy and sedimentation. *Geological Survey of India, Misc Pub.,* **24** (1): 188-203.

Bhatt, D. K. 1976. Stratigraphical status of Karewa Group of Kashmir, India. *Himalayan Geology*, **6**: 197-208.

Bhatt, D. K. 1978. Geological observations of the margs of Kashmir Valley, India. *Himalayan Geo1ogy*, **8**:769-783.

Bhatt, D. K. 1989. Lithostratigraphy of the Karewa Group, Kashmir valley, India and a critical review of its fossil record. *Geological Survey of India, Mem*, **122**: 1-85.

Bhat, M. I., Malik, M. A. and Bali, B. S. 2008. Tectonic Geomorphology of the Pir Panjal range. *Workshop on October 8, 2005 Kashmir Earthquake and After. Jam Univ*: 39-42.

Bloom, A. L. 1979. *Geomorphology. Prentice-Hall* Pvt. Ltd., India, New Delhi.

Burbank, D. W. and Johnson, G. D. 1982. Intermontane-basin development in the past 4 Myr in the north-west Himalaya. *Nature,* **298**: 432-436.

Farooqi, I. A. and Desai, R. N. 1974. Stratigraphy of Karewas, India. *Journal of Geological Survey of India*, **15**(3): 299-305.

Ganju, J. L. and Khar, B. B. 1984. Tectonics and hydrocarbon prospects of Kashmir valley – possible exploratory targets. Petroleum *Asia Journal*, **4**: 207-216.

Gloaguen, R., Marpu, P. R. and Niemeyer, I. 2007. Automatic extraction of faults and fractal analysis from remote sensing data. Nonlinear Processes in *Geophysics* **14** (2): 131–138.

Gloaguen, R., Kaessner, A., Wobbe, F., Shahzad, F. and Mahmood, S. A. 2008.

Remote sensing analysis of crustal deformation using river networks. In: *IEEE International Geosciences and Remote Sensing* Symposium, Boston, USA, pp. IV-1–IV-4.

Goldsworthy, M. and Jackson, J. 2000. Active normal fault evolution in Greece revealed by geomorphology and drainage pattern. *Journal of Geological Society of London*, **157**: 967-981.

Howard, A. D. 1967. Drainage analysis in geologic interpretation, a summation. *American Association of Petroleum Geology*, **51**: 2246-2259.

Hussain, A. Yeats, R. S. and MonaLisa. 2009. Geological setting of the 8th October, 2005 Kashmir 518 earthquake. *Journal of Seismology*, **13**(3): 15-325.

Iyenger, R. N., and Sharma, D. 1996. Some earthquakes of Kashmir from historical sources. *Current Science*, **71**: 330-331.

Iyenger, R. N., Sharma, D. and Siddiqui, J. M. 1999. Earthquake history of India in Medieval times. *Indian Journal of History of Science*, **34**(3): 181-237.

Jones, E. J. 1885. Notes on the Kashmir earthquake of 30th May 1885. Records, *Geological Survey of India*, **18**: 153-156.

Kurz, T. Gloaguen, R., Ebinger, C., Casey, M. and Abebe, B. 2007. Deformation distribution and type in the Main Ethiopian Rift (MER): a remote sensing study. *Jour Afr E Sc* **48** (2–3): 100–114.

Madden, C., Trench, D. Meigs, A., Ahmad, S., Bhat, M. I. and Yule, J. D. 2010. Late Quaternary Shortening and Earthquake Chronology of an Active Fault in the Kashmir Basin, Northwest Himalaya. *Seismological Research Letters*, **81**(2): p. 346.

Madden, C., Ahmad, S. and Meigs, A. 2011. Geomorphic and paleoseismic evidence for late Quaternary deformation in the southwest Kashmir Valley, India: Out-of-sequence thrusting, or deformation above a structural ramp? (Abstract-ID T54B--

07) *American Geophysical Union Fall Meeting*.

Middlemiss, C. S. 1910. A revise of the Silurian-Trias sequence in Kashmir. *Geological Survey of India, Records*, **40**: 206-260.

Middlemiss, C. S. 1911. Sections in Pir Panjal and Sindh valley, Kashmir. *Geological Survey of India, Records,* **41**(2): 115-144.

Oldham, T. 1883. A Catalogue of Indian earthquakes. In: Oldham RD (ed), Memoir, *Geological Survey of India*, **19**: 163-215.

Schumm, S. A. 1977. *The Fluvial System*. John Wiley, New York, pp 338.

Singh, I. B. 1982. Sedimentation pattern in the Karewa basin, Kashmir valley, India and its geological signific-ance. *Journal of Palaeontological Society of India*, **27**: 71-110.

Thakur, V. C. Jayangondaperumal, R. and Malik, M. A. 2010. Redefining Medlicott–Wadia's main boundary fault from Jhelum to Yamuna: An active fault strand of the main boundary thrust in northwest Himalaya. *Tectonophysics*, DOI: 10.1016/j.tecto. Cited 14 Mar 2010.

Wadia, D. N. 1975. *Geology of India*. 4th edition, Tenth reprint, Tata McGraw-Hill, New Delhi.

Yeats, R. S., Nakata, T., Farah, A., Fort, M., Mizra, M. A., Pandey, M. R. and Stein, R. S. 1992. The Himalayan frontal fault system. *Annales Tectonicae,* **6**: 85-98.

# RESI DENTIAL ENVI RONMENT AND RELATED HEALTH PROBLEMS IN COLD DESERT LADAKH, J&K-INDIA

**G. M. Rather, Rouf A. Dar and M .S. Bhat**
P.G. Department of Geography & Regional Development, University of Kashmir, Srinagar- 190006, J&K, India

**ABSTRACT**

More recently, environmental geographers have begun to take an even wider-angle view, as investigators using ecological approaches to explore the multifaceted interrelationships between the residential environment and human health. The present research work, an attempt in the same direction examines various aspects of residential environment and related health problems in Ladakh - a high altitude cold desert region of Jammu and Kashmir. The investigation reveals that traditional residential adjustment because of harsh climatic conditions leads to various aspects of poor housing such as overcrowding and bad sanitation, that in turn, have been identified as contributing to the impact of housing on health. Majority of households are lacking behind when compared with recommended housing standards and are suffering from both respiratory and infectious diseases. The study seeks to assess and quantify the health impact of housing conditions and attempts to formulate a planning strategy that shall be helpful for future health care planning

***Key words:*** Residential environment, housing standards, health, bad sanitation, overcrowding, Cold desert Ladakh

## INTRODUCTION

Residential environment, defined as the physical structure that man uses and the environs of the house including facilities (Aldrich, and Sandhu, 1990; Akhtar, 1991). Residential environment is one of the priority issues because people spend more than 90 percent of their time indoors (Broun, 2011), because of the influence of housing conditions on the people's health (Cairneros, 1990), and is necessary for sustainable health (Dever, 1972). Housing fulfills a basic human need for shelter. It protects us from the weather and from hostile intruders. Often, it is an expression of personal identity and social status (JuanIgnacio, 2001).Health depends on the environment in which one is born and brought up. Environment can be both a cause and cure of many diseases. Environmental surroundings both natural and buildup is important to human health. The nature of soil, water, air, temperature, wind, cloud, rainfall, humidity etc. determine the man's health and welfare. Pollution of the environment result from a wide range of human activities like uncontrolled disposal of human excreta and industrial discharges.

The age old issues of access to safe water, poor domestic hygiene and dependence on traditional low grade fuels for cooking and heating, continue to pose particular problems to the health of underprivileged in both developed and developing world. Many health problems are still related to bad housing conditions and it is a matter of concern that despite the developmental planning and technological gain in health research, the developing countries continue to suffer from poverty, insanitary conditions and related health problems (Akhtar, 1998). Some health problems related to bad housing conditions are; respiratory infections like common cold, tuberculosis, influenza, bronchitis, measles and whooping cough; skin infections like scabies, ring worm and leprosy; arthropod infections; high morbidity and mortality and psychosocial effects (Gilg, 1985 and Park, 2010). Substantial scientific evidences in the past decade have shown that various aspects of residential environment can have profound, directly measurable effects on both physical and mental health. Therefore, there is a cardinal relationship between poor housing, poverty and health (Martin, 1967).

The United Nations Habitat Report affirmed that a large proportion of the world population live and work in poor housing conditions. According to WHO, bad housing is one of the important factors contributing to the spread of infectious diseases, the biggest killer throughout the world leading to about 13 million deaths every year. (WHO, 1999).

The approach of housing problem in India was introduced with focus on improvement of living conditions since early 1970's (Martin, 1967) but it was only during the last few years that the problem of housing received increasing attention from Government. Very good housing policies under National Development Planning process are developed for urban housing but rural areas remain neglected (Mc Granahan, 1991). A number of studies have been carried out on housing environment in different parts of the world. The eminent scholars have emphasized how does and how much the residential environment of a place influences the human health. Sagwal, S.S. (1991) and McGranahan (1991), carried out a study on environmental problems and the urban household in third world countries. Singh and Rahman (1997) Hardony (1992)

| Category | Recommended Standard | Category | Recommended Standard |
|---|---|---|---|
| **Site** | Free from floods | Set Back | Open for Sunlight and Ventilation |
| **Floor** | Pucca | Cattle shed | Outside house at a distance of > 25 ft. |
| **Water Supply** | Adequate and clean | Location | at a distance of > 25 ft. |
| **Height of room** | Not less than 10 feet | Latrine if dry | 90 – 100 sq. ft. for 1 person |
| **Rooms** | 1 room for 2 persons, 2 rooms for 3 persons, 3 rooms for 5 persons | Floor Space | 110 sq. ft. or more for 2 persons |

- **Excluding Kitchen, Store and Bathroom including latrine that is compulsory for each house**
- **A baby under 12 months is not counted and for 2 persons age above 9 years is counted**
- **Standards are higher in urban areas**

worked on environmental problems in third world cities. Srivastava and Srivastava (1991); Singh and Rahman (1997), carried out a research on indoor air quality and respiratory diseases in Aligarh city. Some other notable contributions in this direction are that of Martin and Singh (1967), Griffiths (1971), Dever (1972), Martin (1967), Rahman (1998) and Jacobi (1994). Residential environment and human health has been the topic of great concern in WHO reports of (1961, 1965, 1997, (2005), 2006 and 2010).

Certain standards have been evolved to create sound houses in almost every country and in India. The Environmental Hygiene Committee, Ministry of Health, recommended the following standards for rural areas (Gilg, 1985).

Traditional rural geographers were mainly concerned with architecture of rural housing, but it was only in recent years, concern has shifted towards quality of housing (Misra, 2000). In the present research work an attempt has been made not only to assess the

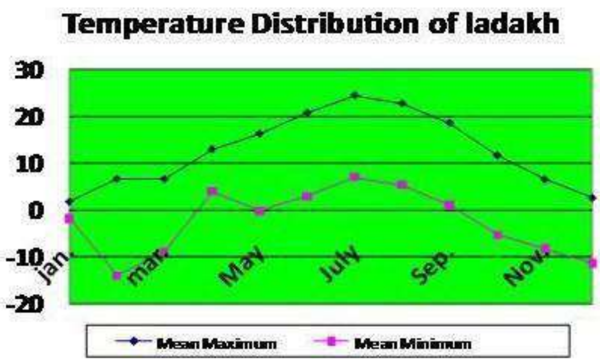


**Fig.1.2 Distribution of Temperature round the year**

magnitude of bad housing conditions and its impact on health by employing various relationship techniques but also to suggest some remedial measures that will aid in future health planning in this high altitude area.

## STUDY AREA

Ladakh, the northern most part of India with an area of 96701 sq.km in the Trans –Himalayan region of India lies between 32˚-15' to 35˚-55'north latitude and 75˚- 15' to 80˚ 15' east longitude (Fig.1.1), with an average altitude of 3500 meters. It is deprived of vegetation and often been termed as the "Roof of the world" where people live at a height ranging between 2,800 to 5,000 meters above mean sea level. The area is inhabited by 1, 85,000 population as per 2011 Census with a record of India's lowest sex ratio of 583. Although the literacy rate is 63.99 percent. Buddhist and Muslim population dominate the area. The Buddhists and Muslims are found equal in number with preponderance of Buddhist in north and east, and Muslims to south and west.

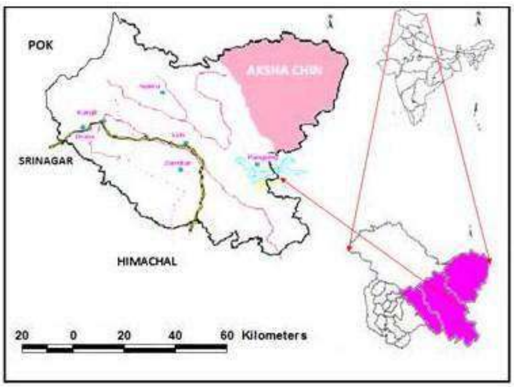


**Fig.1.1: Location Map of Ladakh.**

The climate of Ladakh is very cold, arid and dry. In winter, temperatures are extremely low. The mean maximum temperature is 12.27˚C and the mean minimum temperature is -4.24˚C.Average annual rainfall 3.15 cms (Husain, 1998 and Raza, 1978).

**Data Base and Methodology:**

The present research work was based mainly on primary data and partly on secondary data. The methodology adopted involves the following steps;

**Step -1: Selection of Sample villages and Sample Households**

The study area was divided into six geographical regions, Three in Kargil district and three in Leh district. Stratified random sampling technique was applied for the selection of sample villages and households. 9 sample Villages from Kargil and 9 from Leh Districts of Ladakh were selected but keeping in view that all the regions should have equal representation so 3 sample villages were selected from each region. 200 households from 18 sample villages in proportion to total number of households were selected for field survey.

**Step -11 : Housing Standards Survey**

Survey of 200 households was carried out with a structured questionnaire to collect data regarding housing conditions. Number of rooms for personal use especially for sleeping and the number of persons residing were noted in order to calculate over-crowding index. The overcrowding index was then compared with one recommended by Ministry of Health, Government of India.

**Step – 111 : Health survey**

During households survey, all the patients suffering from various diseases in general and diseases related to bad housing conditions in particular were noted, based on prescriptions they had, having obtained from different medical practitioners and Health care facilities in order to examine regional incidence of diseases related to bad housing conditions in Ladakh.

**Step- IV : Statistical Analysis and Map Work**

Relationship techniques like correlation and regression were employed to find out impact of bad housing on health.

Weavers combinational analysis was employed for determination of bad housing related disease combinations and Kandls ranking method was used for ranking of different bad housing related diseases.

Map work was carried out under GIS environment.

## RESULTS AND DISCUSSION

Environmental sanitation means the control of all those factors in man's surroundings, which cause adverse effects on health. There exists marked variation in environmental sanitation in Ladakh that is depicted by the (Table -1) which reveals about half (28.50 percent) of the households surveyed are having poor hygienic conditions. Bad housing conditions also reveal regional contrasts. Poor hygienic conditions in more than 50 percent of the households surveyed have been noted in regions of Drass, Zanskar, Nobra and Pan gong while as very poor hygienic conditions in more than 30 percent of sample households have been reported in the regions of Zanskar and Pan gong. All this was noted in the hygienic conditions, location and type of latrine, location of cowsheds; all these indicators of residential environment show a dismal picture as per recommended standards cited above and makes the region more vulnerable to diseases ecology. 74percent of households are having dry toilet facility and 46percent of households have dry toilet facility at a distance of less than 10 ft. The problem is twofold in district Kargil than that of district Leh. In Kargil district majority of households (>60percent) in all the three regions have toilets at a distance of less than 10 ft. While as majority of households in the regions of Leh and Nobra of Leh district have toilets at a distance of more than 10 ft. However, it is alarming in Pan gong region where all the households were having dry toilets (86.66 per cent)outside house at a distance of less than 10 ft. Animal rearing is practiced in Ladakh but location of cattle shed again poses a threat to life as its location is not conducive for health. Near about 14percent of households surveyed are having cattle sheds inside house and 54 percent are having outside house but that too at a distance of less than 10 ft.

## Table 1. Household Sanitation in different regions of Ladakh

| Regions | House holds Surv eyed | Hygienic Conditions | | | Toilet Type | | Dry Latrine Location | | | Cowshed Location | | | Kitchen Location | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Good | Poor | Very Poor | Flush | Dry | Inside House | Outside House <10 ft. | Outside House >10 ft. | Inside House | Out side House <10 ft. | Out side House >10 ft. | Inside House | Outside House <10ft. |
| | | **Recommended Standards *.** | | | | | | | **>25ft.** | | **>25 ft.** | | | |
| **Zanskar** | 35 | 4 (11.43) | 19 (54.28) | 12 (34.29) | 3 (8.57) | 32 (91.43) | 9 (25.71) | 21 (60.10) | 5 (14.19) | 11 (31.42) | 22 (62.85) | 2 (5.73) | 29 82.86 | 6 17.14 |
| **Kargil** | 45 | 13 (28.89) | 20 (44.44) | 12 (26.67) | 11 (24.44) | 34 (75.56) | 11 (24.45) | 32 (71.10) | 2 (4.45) | 6 (13.33) | 29 (64.45) | 10 (22.22) | 33 73.33 | 12 26.67 |
| **Drass** | 20 | 3 (15.00) | 12 (60.00) | 5 (25.00) | 4 (20.00) | 16 (80.00) | 5 (25.00) | 10 (50.00) | 5 (25.00) | 4 (20.00) | 14 (70.00) | 2 (10.00) | 16 80.00 | 4 20.00 |
| **Average For Kargil** | **100** | **20 (20.00)** | **51 (51.00)** | **29 (29.00)** | **18 (18.00)** | **82 (82.00)** | **25 (25.00)** | **63 (63.00)** | **12 (12.00)** | **21 (21.00)** | **65 (65.00)** | **14 (14.00)** | **78.00** | **22.00** |
| **Leh** | 45 | 18 (40.00) | 15 (33.33) | 12 (26.67) | 14 (31.11) | 31 (68.89) | 10 (22.22) | 7 (15.55) | 28 (62.22) | 2 (4.44) | 9 (20.00) | 17 (37.77) | 37 82.22 | 8 17.78 |
| **Nobra** | 40 | 8 (20.00) | 21 (52.50) | 11 (27.50) | 18 (45.00) | 22 (55.00) | 14 (35.00) | 10 (25.00) | 16 (40.00) | 4 (10.00) | 22 (55.00) | 14 (35.00) | 29 **72.5** | 11 **27.5** |
| **Pan gong** | 15 | 1 (6.67) | 9 (60.00) | 5 (33.33) | 2 (4.44) | 13 (86.66) | 2 (4.44) | 13 (86.66) | - | 4 (26.67) | 11 (73.33) | - | 12 **80** | 3 **20** |
| **Average for Leh** | **100** | **27 (27.00)** | **45 (45.00)** | **28 (28.00)** | **34 (34.00)** | **66 (66.00)** | **26 (26.00)** | **30 (30.00)** | **44 (44.00)** | **10 (10.00)** | **42 (42.00)** | **31 (31.00)** | **78 78.00** | **22 22.00** |
| **Avg. for Ladakh** | **200** | **47 (23.50)** | **96 (48.00)** | **57 (28.50)** | **52 (26.00)** | **148 (74.00)** | **51 (25.50)** | **93 (46.50)** | **56 (28.00)** | **31 (15.50)** | **107 (53.50)** | **45 (22.50)** | **156 78.00** | **44 22.00** |

Source: Based on data obtained from field work (2009)

*Environmental Hygiene Committee, Ministry of Health, Government of India, Oct.1949.

**Ventilation in Ladakh**

Harsh climatic conditions play an important role in the housing structure of Ladakh. Near about 40% of households surveyed were having single storey and 60% were having double storey house however there is a quite regional variation in the same. Double storey houses abundantly were found in regions of Leh, Kargil and Nobra accounting 70% of households while more than 86% single storey houses were housed in Pan gong and 60% in Drass and Zanskar.

It is evident from the (Table 2) that the utilization of rooms for personal use had resulted in floor space less than the recommended standard . It has been revealed from the survey that 70% of the population are having less than 3 rooms for personal use, leading to low Floor space per person. Large regional contrasts are evident from the (Table- 2), and the main reason behind this low floor space per person is the mal adjustment of the available space because of traditional life style practices.

Overcrowding index for Ladakh as a whole is around 3. The number of persons/room is 3 in Kargil as compared to only 2 in Leh but more than the recommended standard of Indian Council of Medical Research in both the districts. The regions of Zanskar, Drass and Pan gong have high crowding index of 4, 3 and 3 respectively while as regions of Leh, Kargil and Nobra have a crowding index of 2 each. This can be attributed to the fact of majority of households in high crowding areas have single storey house.

**Table 2. Household ventilation in different regions of Ladakh**

| Regions | Households surveyed | Single Storey | Double Storey | Rooms for personal use <3p/r | Rooms For personal use >3p/r | Ventilators / Room < 2 | Ventilators / Room > 2 | Size of Ventilator <2 sq.ft. | Size of Ventilator >2 sq.ft. | Floor Space/ Person <100 Sq ft | Floor Space/ Person >100 Sq ft. | Crowding Index. (P/R) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Recommended Standards *** | | **1 room for 2 persons 2 rooms for 3 persons 3 rooms for 5 persons** | | **2 ventilators/room (crosswise)** | | **>3 sq.ft** | | **90 - 100 sq. ft. for 1 person** | | **I per- son/ Room** |
| **Zanskar** | 35 | 21 (60.00) | 14 (40.00) | 26 (74.30) | 9 (25.70) | 18 (51.40) | 17 (48.60) | 19 (54.30) | 16 (45.70) | 23 (65.71) | 12 (34.29) | 4 |
| **Kargil** | 45 | 12 (26.67) | 33 (73.33) | 18 (40.00) | 27 (60.00) | 17 (37.78) | 28 (62.22) | 11 (24.44) | 34 (75.56) | 28 62.22 | 17 (37.78) | 2 |
| **Drass** | 20 | 12 (60.00) | 8 (40.00) | 15 (75.00) | 5 (25.00) | 15 (75.00) | 5 (25.00) | 13 (65.00) | 7 (35.00) | 14 (70.00) | 6 (30.00) | 3 |
| **Avg. for Kargil** | **100** | **45 (45.00)** | **55 (55.00)** | **59 (59.00)** | **41 (41.00)** | **50 (50.00)** | **50 (50.00)** | **43 (43.00)** | **57 (57.00)** | **65 (65.00)** | **35 (35.00)** | **3** |
| **Leh** | 45 | 10 (22.22) | 35 (77.78) | 11 (24.45) | 34 (75.55) | 19 (42.22) | 26 (57.78) | 15 (33.33) | 30 (66.67) | 21 (46.67) | 24 (53.33) | 2 |
| **Nobra** | 40 | 11 (27.50) | 29 (72.50) | 8 (20.00) | 32 (80.00) | 13 (32.50) | 27 (67.50) | 16 (40.00) | 24 (60.00) | 22 (55.00) | 18 ( 45.00) | 2 |
| **Pan gong** | 15 | 13 (86.67) | 2 (13.33) | 11 (73.34) | 4 (26.66) | 9 (60.00) | 6 (40.00) | 11 (73.34) | 4 (26.66) | 11 (73.33) | 4 (26.67) | 3 |
| **Avg. for Leh** | **100** | **34 (34.00)** | **66 (66.00)** | **30 (30.00)** | **70 (70.00)** | **41 (41.00)** | **59 (59.00)** | **42 (42.00)** | **58 (58.00)** | **54 (54.00)** | **46 (46.00)** | **2** |
| **Avg. for Ladakh** | **200** | **79 (39.50)** | **121 (60.50)** | **89 (44.50)** | **111 (55.50)** | **91 (45.50)** | **109 (54.50)** | **85 (42.50)** | **115 (57.5)** | **119 (59.5)** | **81 (40.5)** | **2.7 3** |

Source: - Based on data obtained from fieldwork (2009).

* Environmental Hygiene Committee, Ministry of Health, Government of India, Oct.1949

 **ISSN 0973-7502**

## Spatial pattern of residential environment related diseases in Ladakh

There exists marked regional variation in the incidence of bad housing related diseases in Ladakh because of variation of ventilation and sanitation. Of the 300 populations from 200 households, were found suffering from different diseases. Near about 106 patients, comprising 35 percent of total were reported to be suffering from various diseases related to bad housing conditions. The most prevalent respiratory disease reported was cough and cold with an incidence of 24.53 percent to total cases. The incidence of bronchitis was also very high with an incidence of 20.76 per cent. Near about 17 per cent were suffering from asthma.

Among the infectious diseases, diarrhea (18.87 percent), dysentery (10.37 percent) and skin disease (8.49 percent) were prevalent. Incidence of Cough and Cold and Bronchitis was very high in the regions of Zanskar and Drass and Pan gong and low in the regions of Nobra, Leh and Kargil. This can be explained because of high crowding index. Incidence of diarrhea and dysentery was very high in the regions of Zanskar, Pan gong and Drass because of bad environmental sanitation and poor hygienic conditions prevailing in the areas. (Table3).

**Table 3. Incidence of Residential Environmental Disease**

| Regions | No. of reported Cases | Cough cold (%) | Bronchitis (%) | Asthma ( %) | Diarrhea ( % ) | Dysentery ( % ) | Skin Disease (%) |
|---|---|---|---|---|---|---|---|
| **Zanskar** | 23 | 7 (30.44) | 6 (26.08) | 2 (8.69) | 4 (17.41) | 2 (8.69) | 2 (8.69) |
| **Kargil** | 14 | 3 (21.42) | 2 (14.29) | 3 (21.43) | 3 (21.43) | 2 (14.290 | 1 (7.14) |
| **Dras** | 21 | 5 (23.81) | 4 (19.05) | 4 (19.05) | 4 (19.05) | 4 (19.05) | 2 (9.52) |
| **Avg. for Kargil** | **58** | **15 (25.86)** | **12 (20.69)** | **9 (15.52)** | **11 (18.96)** | **6 (10.35)** | **5 (8.62)** |
| **Leh** | 13 | 2 (15.38) | 2 (15.38) | 3 (23.08) | 3 (23.08) | 2 (15.38) | 1 (7.70) |
| **Nobra** | 11 | 2 (18.18) | 2 (18.18) | 3 (27.28) | 2 (18.18) | 1 (9.09) | 1 (9.09) |
| **Pangong** | 24 | 7 (29.17) | 6 (25.00) | 3 (12.50) | 4 (16.67) | 2 (8.33) | 2 (8.33) |
| **Avg. for Leh** | **48** | **11 (22.92)** | **10 (20.84)** | **9 (18.75)** | **9 (18.75)** | **5 (10.41)** | **4 (8.33)** |
| **Total for Ladakh** | **106** | **26 (24.53)** | **22 (20.76)** | **18 (16.98)** | **20 (18.87)** | **11 (10.37)** | **9 (8.49)** |

Source: Based on data obtained from field work-2009

**Table 4. Incidence of diseases by rank**

| | R1 | R2 | R3 | R4 | R5 | R6 | sum ranks | Composite Value |
|---|---|---|---|---|---|---|---|---|
| Zanskar | **1.5** | **1.5** | **6** | **2.5** | **3** | **2** | **16.5** | 2.75 |
| Kargil | **4** | **6** | **3.5** | **2.5** | **3** | **5** | **24** | 4 |
| Drass | **3** | **3** | **1** | **2.5** | **3** | **2** | **14.5** | **2.41** |
| Leh | **5.5** | **4.5** | **3.5** | **5** | **3** | **5** | **26.5** | ***4.41*** |
| Nobra | **5.5** | **4.5** | **3.5** | **6** | **6** | **5** | **30.5** | ***5.08*** |
| Pan gong | **1.5** | **1.5** | **3.5** | **2.5** | **3** | **2** | **14** | **2.33** |

Source: Computed from (Table 3) by the authors

Based on the Ranking, at first, each region is allotted individual ranks based on different percentages of diseases along with overall ranking for each sector as well and secondly mean rank of all the geographical regions is calculated based on their individual ranks in different residential diseases. The minimum mean rank regarded as the most vulnerable for residential environment diseases.

Pan gong and Drass are ranked as most vulnerable because it has influence of climate which prevents both the regions from developing modern infrastructure as temperature reaches to -40$^{o}$C during winters and poverty while as Leh and Nobra respectively are least vulnerable because both the districts are economically sound.

| | Diseases Combination | Index |
|---|---|---|
| Zanskar | **C, B, A, D, Dy.** | **Five Disease** |
| Kargil | **C, B, A, D, Dy.** | **Five Disease** |
| Drass | **C, B, A, D, Dy.** | **Five Disease** |
| Leh | **C, B, A, D, Dy.** | **Five Disease** |
| Nobra | **C, B, A, D, Dy.** | **Five Disease** |
| Pan gong | **C, B, A, D.** | **Four Disease** |

C: Cough & Cold. B: Bronchitis, A: Asthama. D: Diarrhea Dy: Desentry

The diseases combination calculated by weaver's index reveals that in most of the regions five diseases combinations is dominant. The calculated value for Zaskar, Kargil Drass Leh are 52.5, 71.31, 17.25, 29.40 respectively, followed by nobra the reason being very less variation in regional contrast. The only region Pan gong shows the four diseases combination, which is attributed to geophysical constraints and socio-economic backwardness, hence more vulnerable region of ladakh. Therefore, the prevalent diseases found were Cough and cold, bronchitis, asthma, diarrhea, and dysentery and in Pangong region, first four diseases were found dominant.

**Relationship between housing and health**

Regression models representing relationship between housing and health in Ladakh shows considerable regional variation that can be attributed to fact of variation in housing environment. It is evident from the Table (5) that the average rate of change in the incidence of respiratory diseases for a unit change in overcrowding denoted by slope of regression line varies from region to region. The value of coefficient of determination ($r^2$) also reveals significant regional contrasts.

No doubt there are some other factors but near about 58 percent of incidence of respiratory diseases are attributed to only to overcrowding in the region of Zanskar and 62 percent in Pan gong region. The value is less in other regions but not less than 35 percent.

**Table 4. Region-wise Regression Models.**

| Regions | Coefficient of Correlation (r) | Coefficient of Determination ($r^2$) | Regression Equation ( y=a + bx ) |
|---|---|---|---|
| **Kargil** | **+0.623** | **0.385** | **Y=1.641+0.0149x** |
| **Drass** | **+0.692** | **0.479** | **Y= 1.992+0.0053x** |
| **Zanskar** | **+0.764** | **0.583** | **Y= 2.374+0.0036x** |
| **Leh** | **+0.593** | **0.352** | **Y=1.501+0.0230x** |
| **Nobra** | **+0.682** | **0.465** | **Y=1.892+0.0041x** |
| **Pan gong** | **+0.792** | **0.627** | **Y=2.463+0.0021x** |

**Source:** Based on data obtained from fieldwork (2009)

## CONCLUSIONS AND SUGGESTIONS

Geophysical constraints, socio-economic backwardness and traditional living styles in the region of ladakh paves way to poor hygienic conditions, poor ventilation, bad environmental sanitation followed by overcrowding which have resulted as health hazardous as all of them ways out the favourable factors for diseases ecology, thus, leading to number of residential environmental diseases. From the study, it was found that bad housing conditions reveal regional contrasts. Poor hygienic conditions in more than 50 percent of the households surveyed in regions of Drass, Zanskar, Nobra and Pan gong while as very poor hygienic conditions in more than 30 percent of sample in the regions of Zanskar and Pangong. The hygienic standards of location and type of latrine, location of cowsheds; shows a dismal picture as per recommended standards, 46percent of households have dry toilet facility at a distance of less than 10 ft in ladakh. The problem is twofold in district Kargil than that of district Leh. In Kargil district majority of households (>60 percent) in all the three regions have toilets at a distance of less than 10 ft. Large regional contrasts were found from the field in terms of floor space per person. 70 percent of the population are having less than 3 rooms for personal use, leading to low Floor space per person i.e. less than 100 sq feet and the main reason behind this low floor space per person is the mal adjustment of the available space because of traditional life style practices, leading to not only a marked regional variation but also a very high overall incidence of all bad housing related diseases namely cough and cold (24.53 percent), bronchitis (20.76percent), asthma (16.98percent), diarrhea (18.87 percent), dysentery (10.37 percent) and skin diseases (8.49 percent). Following suggestions are made for future planning;

- Low cost sanitation schemes/ loans needs to be implement-ted/ given in all the regions at priority basis by Rural Development Department and animal husband-dry. That will not only reduce the bad sanitation problem but also help in the sustainable health management in the area.

- Public enlightment campaign is very essential so that residents will know the importance of good housing conditions to their health. Health Department should come forward for better health programmes for the people. Social awareness camps needs to be organized in the area.

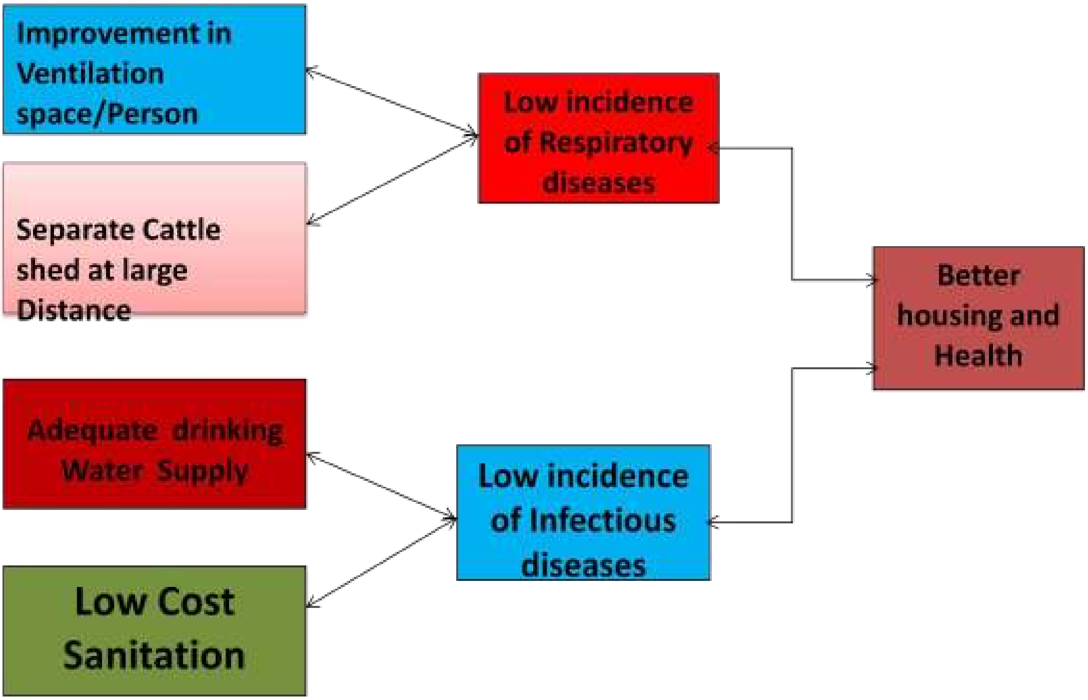


**Fig. 2 Planning Strategy Model**

## ACKNOWLEDGEMENTS

The authors are highly grateful to world renounced medical geographer, Professor Rais Akhtar, (Professor Emeritus) Ex. HOD, Department of Geography and Regional Development, University of Kashmir for suggestions in conducting this research work.

## REFERENCES

Akhtar, R. 1991. *Environmental Pollution and Health Problems*, APH. New Delhi, pp 1-3.

Akhtar, R. 1998. *Urban Crowding and Health*, Atti Del Sesto Seminario International di Geografia medica, RUX, Perugia, p. 470.

Aldrich, B.C and Sandhu, R.S. 1990. *Housing in Asia- Problems and Perspectives*, Rawat Publishers, pp. 10-11.

Aragones, J.I. 2001. *Residential Environments:Choice, Satisfaction and Behavior*, ABC-clio, Sweden. p.95.

Broun, M. J. 2011. *Poverty, Inadequate Housing and Health*, U.S. Centre for Env. Studies. pp.51-90

Cairneros, S. 1990. *Housing and Health in Third World*, Earth scan, London.

Dever, 1972. Leukemia and Housing in N.D McGlashan (Ed.) Medical Geography: *Techniques and Field Studies*, London, 233-245p.

Gilg, A. 1985. *An Introduction to Rural Geography*, Edward Arnold Publishers, p.61

Griffiths, M. 1971. *A Geographical Study of Mortality in an Urban Area*, Urban Studies, **8**:112.

Husain , M. 1998. *Geography of Jammu and Kashmir*, Rajesh Publications, New Delhi, 12p.

Jacobi, P.R. 1994. Household and environment in the city of Sao Paulo Brazil. *Environment and Urbanization*, **6**(2): 87-110.

Martin, L.K. and Singh, 1992. Housing in Third World – Analysis and Solutions, Concept Publishing Company, New Delhi, 211-214 p.

Martin, A.E. 1967. Environment, Housing and Health, Urban Studies, **4**: 1-3.

McGranahan, G. 1991. Environmental Problems and the Urban Households in Third World Countries, Stockholm Environmental Institute, Stockholm. 42 p.

Misra, P.D. 2000. Health and Disease- Dynamics and Dimensions, APH Pub., 230p.

Park, K. 2010. Preventive and Social Medicine, 558-560 p.

Raza, M. 1978. *The Valley of Kashmir*: A Geographical Interpretation, vol.1: the Land, Vikas Publishing House, New Delhi.

Rahman, A. 1998. Household Environment and Health B.R. Pub. New Delhi, 119 p.

Sagwal, S.S. 1991. *Ladakh-Ecology and Environment*, Ashish Publishing House, New Delhi , 9-10p.

Singh and Rahman, 1997. Indoor air quality and respiratory diseases in Aligarh City, *Geographer*, **44**:20-32

Srivastava, S and Srivastava, M.N. 1991. Housing and Disease, In Sociology of Health in India, (Ed) T.M.Dak, Rawat Publications, Jaipur, pp. 314.

United Nations Habitat Report 1989. Report of the Commission on Human Settlement on the work of its 12th Session (44 Session Supplement No 8 (a/44/8), New York: United Nations General Assembly.

WHO 1961. Technical Report Series, No.225

WHO 1965. Technical Report Series, No.297

WHO 1997. The World Health Report, World Health Organization, Geneva, p.12

WHO 2005. Technical Report Series, No. 1465

WHO 2006. Residential Environment Report, p.37

WHO 2010. Promoting Health in the Human Environment, Technical Report

# SOCIO ECONOMIC STUDIES OF GULMARG WILDLIFE SANCTUARY-A PRELIMINARY SURVEY

**Sumira Tyub**, Aashik H Mir*, Azra N. Kamili and Mohd Mansoor Bhat**

Centre of Research for Development, University of Kashmir, Srinagar-190006
*P.G. Department of Environmental Science, University of Kashmir, Srinagar-190006
** Corresponding author email: sumira9@in.com

**ABSTRACT**

Socio economic study is a construct that reflects one`s access to collectively desired resources, they may be in terms of material goods, money, power, healthcare or educational facilities. So, socioeconomic assessment is a way to learn about the social, cultural, economic and political conditions of stakeholders including individuals, groups, communities and organizations. Socio economic studies of Gulmarg Wildlife Sanctuary was undertaken to assess the economic and social benefits from Gulmarg , to ascertain economic status of the households in terms of household income, expenditure, health and security aspects and to find the mindset of people for the conservation of natural resources. It was evident from the present study that the socio economic status of these villages is low, which will lead to an increased pressure on natural resources. People mostly are uneducated and are not aware about their concerns towards environment. People with low socio economic status shift to forest areas (which are ecologically very rich in terms of flora and fauna) thereby damaging them. Tourist activities also damage the natural resources. All these activities lead to degradation of environment of Gulmarg.

***Key words:*** Socio economic, Gulmarg, natural resources

## INTRODUCTION

Socio economic environment refers to a wide range of interrelated and diverse aspects and variables relating to or involving a combination of social and economic factors. These aspects and variables could, in general, be categorized into several categories including, economic, demographic, public services and social services (Sharma *et al.,* 2011). Socio-economic conditions are usually hard to identify and assess, as they are related to the human beings and their characteristics, which usually differ widely within the same community and from one community to another. Furthermore, as socio-economic assessment deals with dynamic variables, no comprehensive list of areas of concern could be developed to fit socioe-conomic assessment in all cases. However, there ae a number of broad sets of socio economic impacts that could be developed including economic impacts, demography, employment, health, and community resources including political, social, economic and cultural conditions (Murdock *et al.,* 1986). The socio-economic study is intended to assess the prevailing socio-economic conditions in the study site. This includes provision of a baseline study and characterizing the existing state of the study site. This will assist in identifying the main areas of concern. Analyze the impacts of the prevailing environmental conditions on the socioeconomic structure of the study sites and develop a set of guidelines for establishing viable communities.

Kashmir is a beautiful Himalayan valley with breathtaking mountain scenery, clear lakes, lush vegetation and magnificent forests. The valley is home to a rich biodiversity including large number of bird species many of which are unique to Kashmir. The tourism industry has greatly benefited the state economy. Among the major tourist attractions in the state are Gulmarg, Pahalgam, Sonmarg, Mughal Gardens, Yusmarg, and Ladakh. Gulmarg commonly called "Meadow of Flowers" is 52km away from Srinagar. It is located at an average altitude of 2,680m from above mean sea level. Gulmarg is among the most famous tourist destination in India; however, there is a need for some strict regulations to save the environment of the area from over tourism. The region mainly has great tourist potential whereas other economic areas including industrial and agricultural sectors potential is limited to some villages only. The local population of Gulmarg is primarily migratory (Gujjars) whereas the population in the surrounding sub-regions lives in villages.

So, keeping in view the importance of socio-economic studies and scanty literature available for Gulmarg Wildlife Sanctuary, it was worthwhile to undertake the present study of socio economic survey of Gulmarg.

## MATERIAL AND METHODS

Study was carried out by surveying different villages around Gulmarg Wildlife Sanctuary. A total of 10% household at random were selected and visited from each area. Two methods were used for the survey which included questionnaire and interview method. A questionnaire soliciting the information pertaining to social and economic status that may have influenced changes on the people was used. The questionnaires were designed to obtain profiles of the household and family members indicating number of family members, age, sex, occupation, income, education, living standard and family land holding. The questionnaire consisted of 17 questions, with most questions requiring a restricted response, although there was the opportunity for open answers. To reduce the possibility of non response because some of the respondents were farmers and uneducated, the questionnaire was concise as possible. The questions were connected with awareness, non-awareness of local residents for their views on protection, tourism, services, socio-economic conditions, state provisions etc.

To know and assess the exact nature of socio-economic dimensions, the interview method was adopted which proved sociologically relevant and methodologically suitable. Because majority of the respondents did not fill the questionnaire and wanted to be interviewed as this was relatively easy and comfortable for them. The interview schedule consists of four components viz. income status, health status, type of family and recreational facilities to know the exact socio-economic dimensions with main stress on the type of family, health status, income status and treatment of family members.

In addition to primary data, secondary data was also obtained from various departments (Department of GIS and Remote sensing, Gulmarg Development Authority, Books and Journals). The figures and tabulation of data collected led to socio economic explanation and interpretation of response given by respondents.

## RESULTS

The preliminary survey of these study sites revealed the following results:

### Demographic Status

On survey in the demo-graphic status of the study area it was depicted that the total population of the three villages of Gulmarg was 2,914 consisting of 1,617 males and 1,297 females (Table 1). The highest number of households 140 was recorded at Ferozpora followed by Drang (114) and Gulmarg (54). The highest number of males was found at Drang (579) and that of females at Ferozpora (500). Out of this majority (67.0%) of people live in nuclear family while as least percentage (16.7%) live in single family followed by joint family (16.1%). As far as the location of toilets in these houses was concerned it was observed that about 93% of toilets were located outside house at Gulmarg, followed by Drang 40% and Ferozpora 22%. Whereas at Ferozpora 78% of households have toilets inside house, followed by Drang 60%. At Gulmarg 7% of households use open places for defecation.

**Table 1. Demographic status**

| S. No | Villages | Population | | | No. of Households |
|---|---|---|---|---|---|
| | | Total Population | Males | Females | |
| 1. | Gulmarg | 878 | 475 | 403 | 54 |
| 2. | Drang | 973 | 579 | 394 | 114 |
| 3. | Ferozpora | 1063 | 563 | 500 | 140 |
| 4. | Total | 2914 | 1617 | 1297 | 308 |

*Source; Population Census Report, 2011*

**Educational status and educational facilities**

On studying the gender wise educational status of the three villages it was found that the highest percentage of educated people was found at Ferozpora (56.9) followed by Drang (52.4) and Gulmarg (33.8) (Fig 1). Highest percentage of educated males was recorded at Ferozpora (63.9) followed by Drang (59.5) and Gulmarg (41.0). Likewise, the highest number of educated females were found at Ferozpora (49.0) followed by Drang (41.8) and Gulmarg (25.3). There were a total of 4 primary schools, 2 middle schools, 2 high schools and 3 anganwari centers. Two anganwari centers were found at Ferozpora and one was found at Gulmarg.

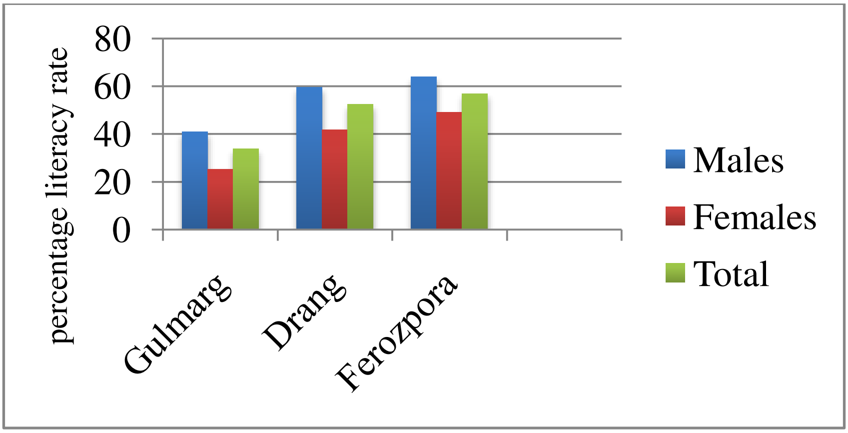


**Fig 1. Genderwise educational status at three sites**

## Building structure

Building structures were represented by Pucca houses and Kaccha houses (Fig 2). The highest percentage (88.8) of Pucca houses was recorded at Ferozpora and highest percentage (100) of Kaccha houses was recorded at Gulmarg. The highest percentage single storey buildings was recorded at Gulmarg (100) and lowest at Ferozpora (53.7) and double storey buildings were recorded at Ferozpora (46.2) only.

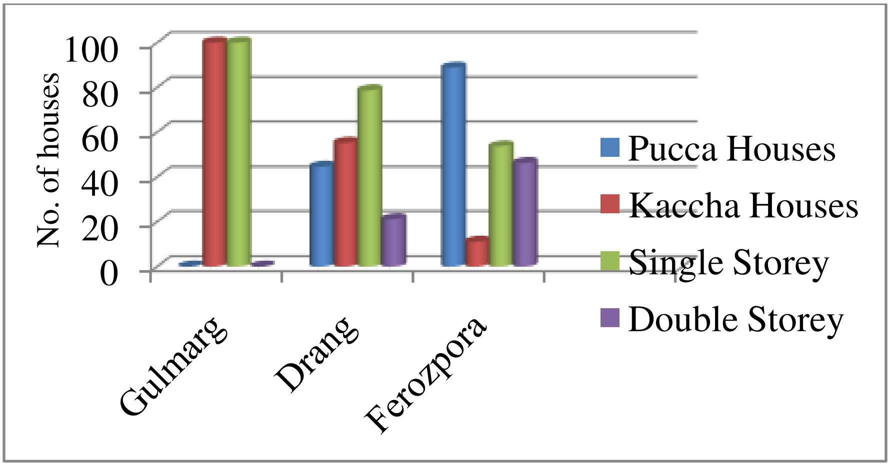

**Fig.2. Percentage proportion of building structures of Gulmarg villages**

## Health status

The health status of the people of the three villages indicates that majority of the people were suffering from persistent Cough (7.5%) followed by asthma (5.9%), fever and headache (5.7%) and at last by Polio (2.5%). No case of depression was found in the three villages.

## Economic status

Economic status showed that majority (59.3%) of families fall in BPL (Below Poverty Line) category and about (40.6%) of families fall in APL (Above Poverty Line) category (Fig 3). Almost (90.7%) families of Gulmarg fall in BPL category followed by Drang (46.8%).Likewise (61.1%) families of Ferozpora were recorded to fall in APL category followed by Drang (53.1%) and least at Gulmarg (9.2%).

In terms of property ownership (Land) the total percentage of cultivated land was 70.2% and that of uncultivated land was 19.3%. Data shows the highest percentage of cultivated land in Ferozpora (77.7%) followed by Drang (61.7%). The highest percentage of uncultivated land was recorded at Drang (38.2%) followed by Ferozpora (22.2%). The Gulmarg site had no property ownership land. As far as property ownership in terms of livestock was concerned the study revealed that 66.4% of families had cattle only and 16.7% of families had poultry only, while as 9.0% of families had both (Cattle and poultry) and 7.7% of families had none. The sources of annual income in three sites showed that major source of income for the population was tourism (41.7%) followed by income generated from livestock (22.8%) which was in turn followed by employment (12.6%) and the rest (22.7%) was generated from the others sources.

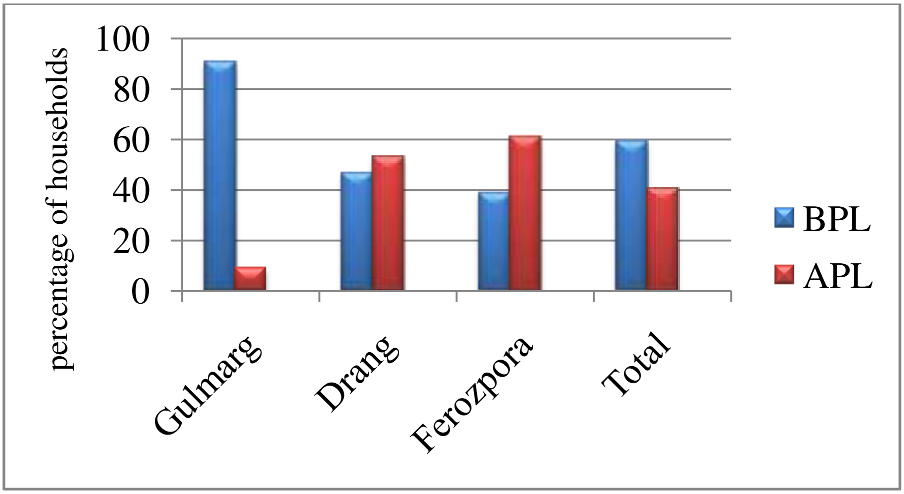


**Fig.3. Percentage proportion of economic status of families**

### Livestock population

The livestock population in 3 villages was recorded as 1530 consisting of 1530 cattle and 312 poultry birds. The highest number of livestock was recorded at Gulmarg (648) followed by Drang (538) and Ferozpora (344).

### Religious and developmental places

As far as the different religious and other developmental places at 3 sites were concerned it was found that neither any bank nor any Computer center was found at any of the site. A total of 3 industrial and manufacturing units and two primary health centers were found at three sites. In addition 4 mosques were also found at the three sites.

### Pollution and conservational status of natural resources

Majority of the people (65.6%) were of the opinion that the pollution of Gulmarg is due to tourism and about (34.3%) were of the opinion that tourism does not contribute to pollution of Gulmarg. The majority (85.3%) of respondents were in favour of conservation of natural resources whereas as only a few (14.6%) respondents were against it. 98% respondents from Gulmarg were in favour of conserving natural resources followed by 80% in Drang and 78% in Ferozpora. However, 22% in Ferozpora, 20% in Drang and 2% in Gulmarg were against it. The study about the firewood collection revealed that the 100% of households of Gulmarg collect fuel wood from nearby forests, followed by Drang 77% and Ferozpora 20%. Whereas about 71% of households of Ferozpora purchase the fuel wood, followed by Drang 16%.

## DISCUSSION

Soomwanshi *et al*. (2006) revealed that a more stable income means better nutrition and education opportunities for the children and an overall improvement in the daily life of the entire family. At the same time Richard (2006) contented that economic growth will be more pronounced in countries were professional field colleges and universities are prevalent. From the recorded data it was observed that both social and economic status of the people of these villages is low. The overall percentage below poverty line (BPL) families is 59%, showing their low socio economic status. The population of villages under study is not very high, but they lack the educational facilities at high and higher secondary schools levels which is the main cause for low literacy rate in Gulmarg. People of Gulmarg were politically very active as is evident from the voter list. They participate in elections for their well being but no attention is being paid towards them. Their role in democracy is thus being neglected. Being unemployed are consistently found to have a large negative effect on individual well being (Clark and Oswald, 1994). Because of lack of educational facilities and attention by the Govt. authorities most of the people there are unemployed. Both aggregate unemployment and inflation have significant adverse effects on individual happiness (Di Tella *et al*., 2001), where per captia national income is strongly positively related to life satisfaction (Deaton, 2008; Stevenson and Wolfers, 2008). Since income is positively and significantly related to well being across individuals and across countries, although the effect is relatively small and diminishing (Clark *et al*., 2008) so the living status of villages under study is not very high.

Disparities in the health are observable across the socio economic spectrum, the difference is intensified among individuals living in poverty (Fiscella and Williams, 2004). Most of the people here are suffering from respiratory problems followed by Asthma because of high concentration of smoke from Chulas in these houses and because of their traditional way of keeping their cattle along with them in their houses as families using kerosene, wood, and coal as fuel for cooking are more likely to have illness (Mishra, 2003). The dampness and the presence of moulds within living environments have also been linked to respiratory illness (Spengler *et al*., 2004). Some workers have also revealed the negative impact of poor housing conditions on the mental health of the people (Bonnefoy, 2003, Harphan & Habib, 2009) which is evident from the condition of the people living in Gulamrg as almost all the families live in kutcha houses and due to indoor air pollution result in acute respiratory illness from biomass combustion.

## CONCLUSIONS

It was evident from the present study that the socio economic status of these villages is low, which will lead to an increased pressure on natural resources. People mostly are uneducated and are not aware about their concerns towards environment. People with low socio economic status shift to forest areas (which are ecologically very rich in terms of flora and fauna) thereby damaging them. Tourist activities also damage the natural resources. All these activities lead to degradation of environment of Gulmarg.

All these problems can be solved in a judicious way only by making people aware about the consequences of degrading the environment and by providing them the information about the services provided by nature. Various facilities such as health and education must be provided by the Govt. and other agencies in order to raise their socio economic status. Various community development projects both at local and regional level should be implemented, so that people can get benefits from various schemes of the Govt.

## REFERENCES

Bonnefoy, X. 2003. Housing and health in Europe Preliminary results of a pan-European study. *American Journal of Public Health,* **93**(9): 1559-1563.

Clark, A., and Oswald, A. 1994. Unhappiness and Unemployment. *Economic Journal,* **104**(424): 648-659.

Clark. A., Etile, F., Vinay, F., Senik, C.and Vander Straeten, K. 2008. Heterogeneity in reported in well being: Evidence from twelve European countries. *Economic Journal,* **115**: 118-132.

Deaton, A. 2008. Income, Health and Well being around the world: Evidence from the gallup poll. *Journal of Economic Perspectives,* **22** (2): 53-72.

Di Tella, R., MacCulloch, R., and Oswald, A. 2001. The macroeconomics of happiness. *The Review of Economics and Statistics,* **85**(4): 809-827.

Fiscella, K. and Williams., D. R. 2004. Health disparities based on socioeconomic inequities: implications for urban health care. *Acad Med,* **79**(12): 1139-47.

Harphan, T.and Habib, H. 2009. Urban health in developing countries: What do we know and where do we go? *Health and Place,* **15**(1): 107-116.

Mishra, V. 2003. Indoor Air Pollution from Biomass combustion and acute respiratory illness in pre-school age children in Zimbabwe. *International Journal of Epidemiology,* **32**(5): 847-549.

Murdock, G. P., Textor, R. H. Barry III, and White, D. R. 1986. Ethnographic Atlas. *World Cultures,***2** (4)-first computer version.

Richard, H.M. 2006. Can higher education foster economic growth? *Chicago Fed Letter*, 229.

Sharma, A. Siciliani, L. and Harris, A. 2011. Human capital composition and growth. *An International and Interdisciplinary Journal for Quality of Life Measurement*, **21**: 513-521.

Somwanshi, S. Dash, P. and Prashant, P. 2006. Socio economic survey of Gudwanwadi Check Dam Project, Centre for Technology Alternatives for Rural Areas Department of Humanities and Social Sciences, Indian Institute of Technology, Bombay.

Spengler, J. D. 2004.Housing characteristics and children's respiratory health in the russian federation. *American Journal of Public Health,* **94**(4): 657-662.

Stevenson, B. and Wolfers, J. 2008. Economic growth and subjective well-being: Reassessing the Easterlin Paradox, Brookings Papers on Economic Activity. pp 1-102.

# PHYTOSOCIOLOLOGY AND BIOMASS OF DOMINANT MACROPHYTES IN HOKERSAR WETLAND OF KASHMIR HIMALAYA

**Sadaf Bashir and A.K.Pandit**
P. G. Department of Environmental Science, University of Kashmir,
Srinagar-190006, Jammu & Kashmir, India

**ABSTRACT**

Phytosociological analysis of Hokersar wetland was carried out during 2008 – 2009. Four study sites were chosen for the collection of macrophytes during spring, summer and autumn seasons. In all, 20 species of macrophytes were identified belonging to different groups. Highest diversity and carbon fixation capacity was recorded for site II (Shikarghat) during summer season and the dominant group was rooted floating-leaf type followed by emergents.

***Key words:*** Hokersar wetland, macrophytes, seasons

## INTRODUCTION

Aquatic macrophytes are key components of aquatic and wetland ecosystems. As primary producers, they are at the base of herbivorous and detritivorous food chains, providing food to invertebrates, fish and birds and organic carbon for bacteria. Their stems, roots and leaves serve as a substrate for periphyton, and a shelter for numerous invertebrates and different stages of fish, amphibians and reptiles (Timms and Moss, 1984; Dvořák, 1996). Biogeochemical processes in the water column and sediments are to a large extent influenced by the presence/absence and type of macrophytes which can also have a profound impact on water movement and sediment dynamics in water bodies. Some macrophytes are of major importance for their direct contributions to human societies by providing food, biomass, and building materials (Costanza *et al.,* 1997, Engelhardt and Ritchie, 2001, Egertson *et al.,* 2004, Bornette and Puijalon, 2011).

In case of a wetland, the community structure consists of macrophytic, microbial, benthos, faunal community etc. All these are interdependent upon one another but the general structure of community is determined by plants and not by other characteristics (Hanson and Churchill, 1961). The response of each species population towards the incoming heat, moisture and light as modified by vegetation itself is the matter of fluctuation (Harold, 1958). The magnitude of these changes is studied through changes in number of plants per unit area. Therefore, the present study entitled “Phytosociology and biomass of dominant macrophytes in Hokersar” was undertaken.

## STUDY AREA

Hokersar, “the Queen wetland” falls in western Himalaya having a temperate climate. The wetland lies from 34°04'to 34° 06'N latitude and 74°40' to 74° 45'E longitude towards west of Srinagar city on the Srinagar – Baramulla National highway. The wetland lies at an altitude of 1584 metres above mean sea level. It is situated at a distance of 10 kilometres from Srinagar.

The wetland has reduced from an area of 13.5sq km in beginning of the twentieth century to only 10 sq km at present. The wetland receives water from a number of streams, Doodhganga which brings water from Doodhganga river enters the marshy habitat of Hokersar near Hajibagh in the east and leaves the wetland through the needle weir gate at Sozieth village in north- western region of the wetland. Sukhnag nalla enters into the wetland in the southwest and directly discharges into the exit gate near Sozieth village. The water table keeps on fluctuating greatly through the seasons of the year in response to the main discharge from the Doodhganga channel. The maximum depth of water is 1.76 metres in the wetland.

Following study sites (Fig. 1) were selected:

**Site I:** This site is located at Hajibagh (Soibugh). It lies at the inlet i.e., Doodhganga. It has muddy water.

**Site II:** This site lies towards the northern side of wetland near shikarghat (entry side), characterised by patches of marshy land.

**Site III:** It lies towards the central area of the wetland. It has a dense macrophytic growth and is not navigable.

**Site IV:**This site is located at Sozieth (Goripora). This site lies at the outlet of Hokersar

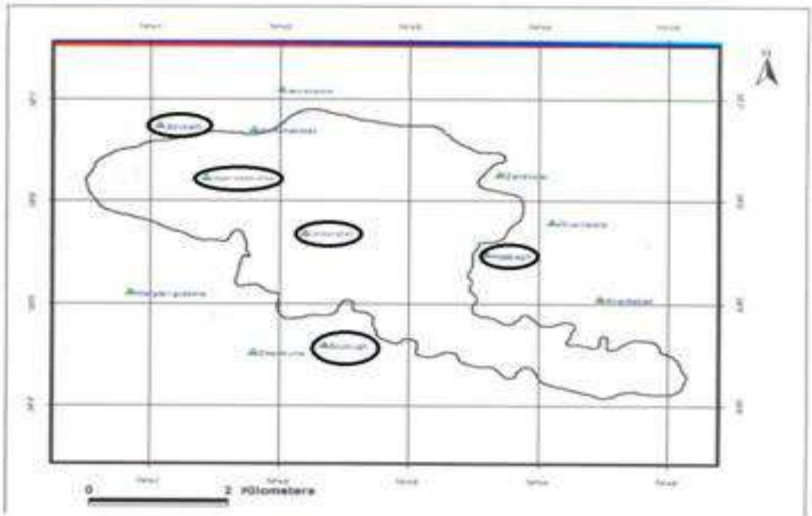

Fig. 1 Map of the study area Hokarsar wetland
Source: Department of Geology and Geophysics (Remote Sensing and GIS), University of Kashmir, Srinagar

## MATERIAL AND METHODS

The phytosociological analyses were conducted by laying quadrats of definite size (50x50 cm) at and around the selected sites (Misra, 1968). The macrophytes falling in each quadrat were sorted and identified up to species level.

The vegetational data was quantitatively analysed for density, frequency and abundance according to Curtis and McIntosh (1950). The relative values of density, frequency and abundance were summed up to get Importance value index (IVI) of individual species in order to express the dominance and ecological success of the species. Species diversity was determined by using Shannon – Wiener information index

Biomass was estimated by Harvest method. The macrophytes falling in randomly laid quadrats were brought to the laboratory in poly bags, washed to render them free of mud, debris and crustaceans etc. Fresh weight of the plants was recorded on a balance. The plants were then wrapped in newspaper and kept in hot air oven at 105°C overnight to record dry weight and then biomass of various macrophytic species was estimated on fresh weight/ dry weight basis.

## RESULTS

Hokersar presented a rich foristic composition. Striking variability was recorded in composition, distribution and extent of colonization of macrophytes from the wetland. The four main communities of macrophytes recorded during the study include:

i. Emergents
ii. Rooted floating-leaf type
iii. Free floating type; and
iv. Submerged

**Emergents:**This group was represented by:

*Typha angustata, Phragmites australis, Hippuris vulgaris, Sparganium ramosum, Myriophyllum verticillatum, Cyperus* sp. and *Menyanthese trifoliata.*

**Rooted floating-leaf type:** This group included:

*Trapa natans, Nymphoides peltatum, Nymphaea alba, Potamogeton natans, Marsilea quadrifolia* and *Hydrocharis dubia.*

**Free floating type:** The macrophytes of this group were:

*Azolla pinnata, Salvinia natans* and *Lemna minor.*

**Submergeds:** This group was represented in the wetland by macrophytes like:

*Ceratophyllum demersum, Potamogeton pectinatus, Potamogeton crispus* and *Potamogeton leucens.*

Emergents like were found along the shoreline and in patches throughout the wetland but mostly they were predominant at site I in all the three seasons (Fig. 2). A belt of plants with floating leaves composed of *Nymphaea alba*, *Nymphoides peltatum* and *Trapa natans* were found in abundance in the open water area of the wetland, that is, at site II and site III (Fig. 3 and 4). Submergents like *Ceratophyllum demersum* occupied the deeper zones of the wetland and were observed in abundance at site IV (Fig.5).

Species diversity was found maximum at site II and minimum at site IV. Highest value of Shannon-Weiner index was found in spring and summer seasons (Fig. 6). Similarly, biomass was recorded highest at site II in summer season followed by site III (Fig. 7).

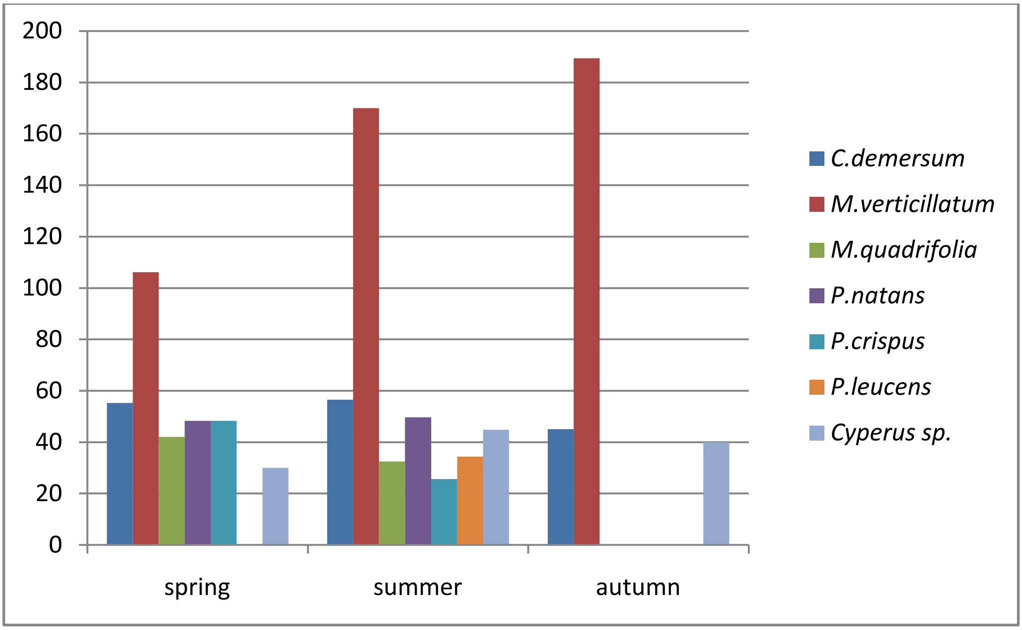


**Fig. 2. IVI of macrophytes at site I in different seasons**

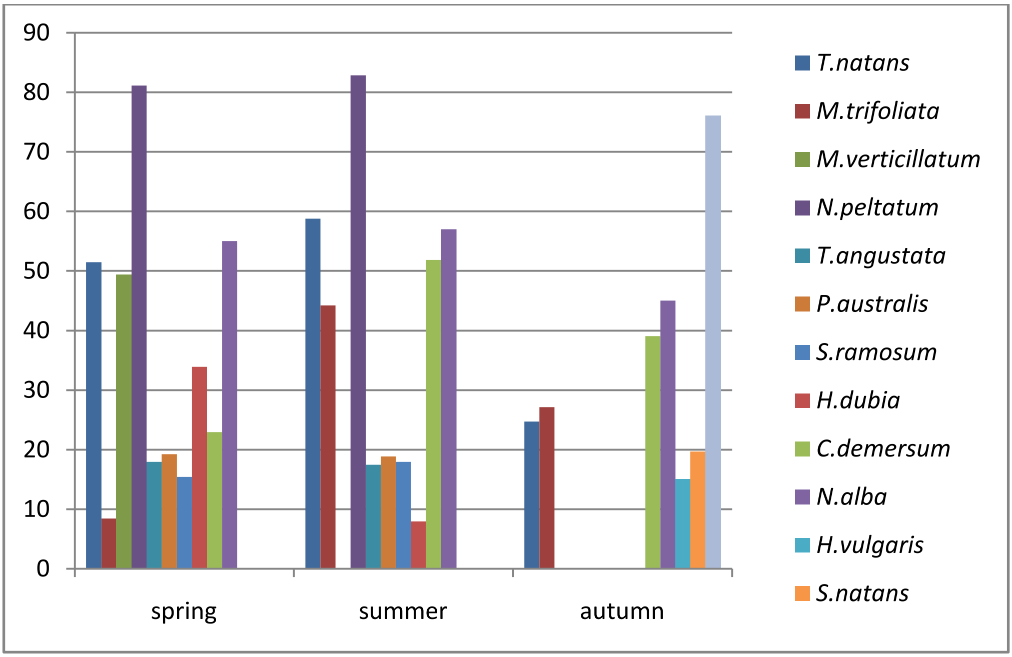


**Fig. 3. IVI of macrophytes at site II in different seasons**

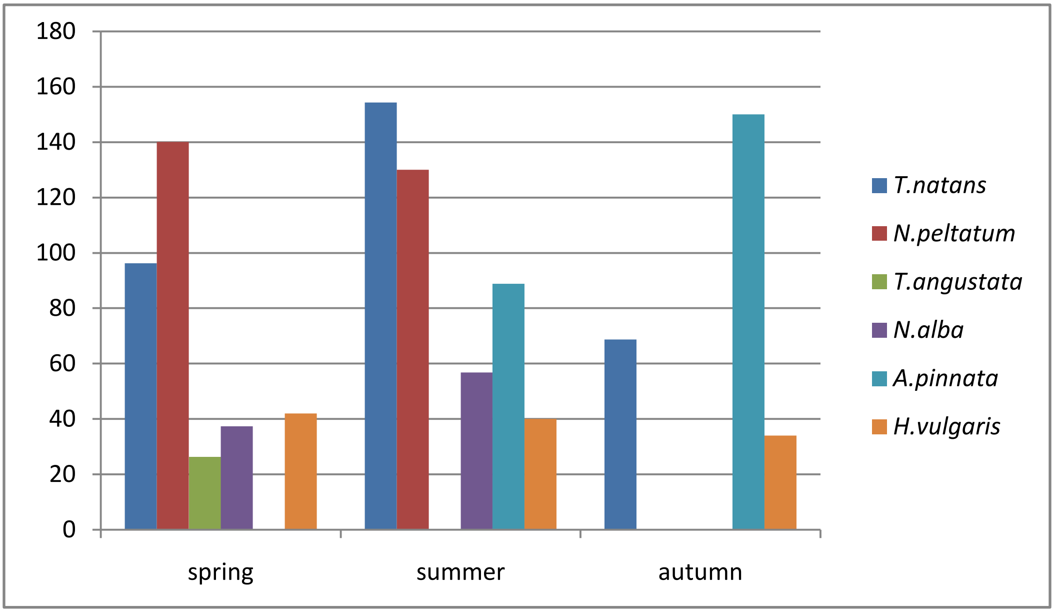


**Fig. 4. IVI of macrophytes at site III in different seasons**

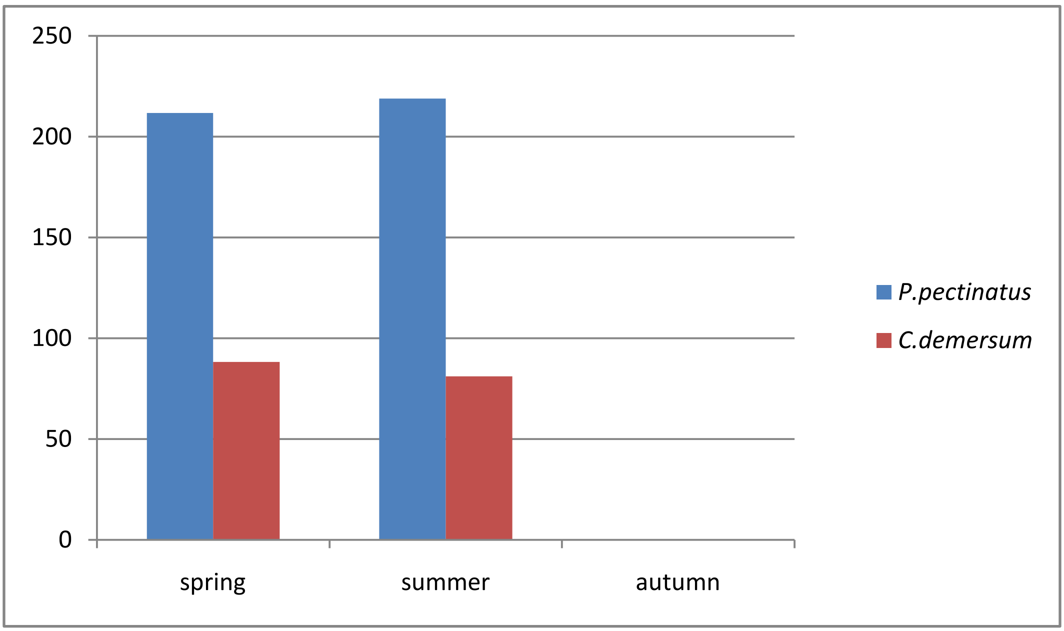


**Fig. 5. IVI of macrophytes at site IV in different seasons**

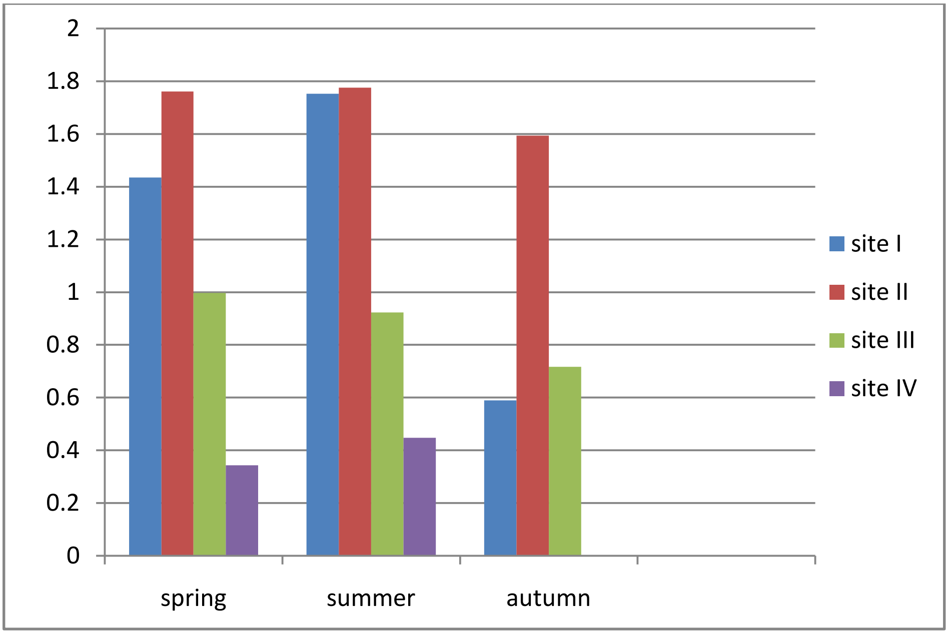


**Fig. 6. Species diversity of four sites in different seasons**

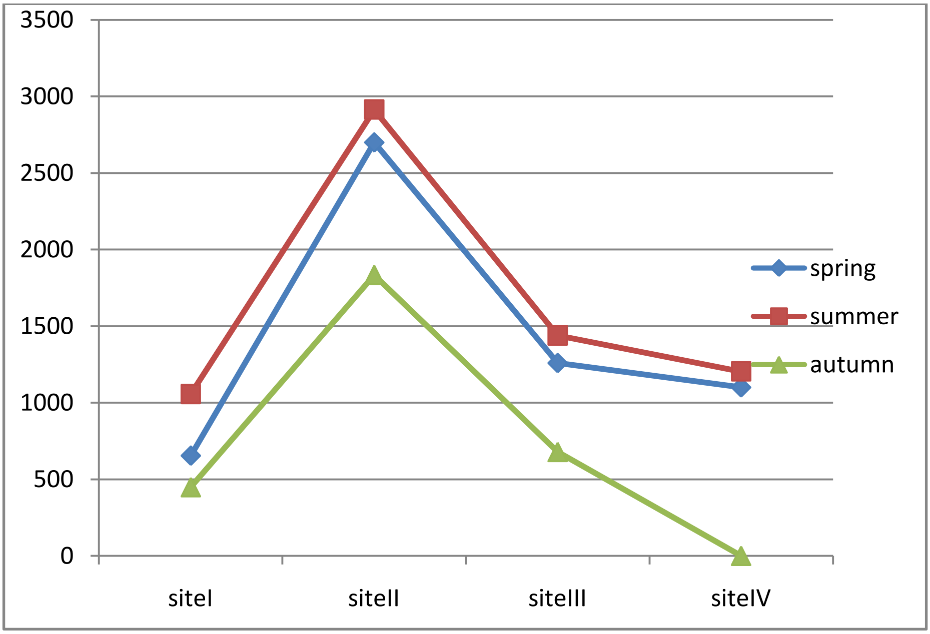


**Fig. 7. Variation in biomass of macrophytes in different seasons at different sites**

## DISCUSSION

The wetland has profuse growth of macrophytes. A marked difference in the distribution of macrophytes in the water body was observed. A total of 20 species were reported during present investigation and this decrease in the number of species from 37 (Kumar *et al*., 2004) can be due to the heavy anthropogenic pressures on the wetland. The reduction in the number of species may be due to the decreased water transparency. According to Best( 1982) water clarity has a direct relationship with the number of macrophytic species that a lake could support. High turbidity results in decreased light penetration in the lake waters, thereby rendering the growth of plants difficult and chances of survival significantly reduced.

Prolific growth of macrophytes was observed during spring and summer seasons and it can be due to nutrients accumulated as a result of decomposition during autumn and winter as well as the entry from catchment area. Besides in Kashmir summer season is characterised by longer photoperiods and higher water temperatures. These two factors may also be responsible for their optimum growth (Kundangar and Zutshi, 1987). In autumn, lakes support low macrophytic density. The majority of the species disappear completely and rest are harvested by locals.

Among emergents, *Myriophyllum veticillatum* and *Typha angustata* were dominant. Prolific growth of these macrophytes is probably due to perenating organs like bulbs, rhizomes etc buried deep under the sediment and their compareative tolerance to changing physical and climatic conditions (Gopal, 1994). Rooted floating-leaf type was most dominant, probably due to broader leaves for reception of solar radiations (Pandit *et al*., 2007). Submerged do not contribute much because of the fact that most of the area of the wetland remains covered by floating-leaf type vegetation, restricting the solar radiations to reach the underwater flora.

The wetland has experienced reduction in the number of species and peak diversity and biomass were observed during summer

## REFERENCES

Best, E.P.H. 1982. The aquatic macrophytes of lake Vechten. Species composition, spatial distribution and production. *Hydrobiologia*, **95**: 65-77.

Bornette, G and Puijalon, S. 2011. Response of aquatic plants to abiotic factors: A review. *Aquat. Sci.,* **73**: 1-14.

Costanza, R., d'Arge R, de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. and van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature,* **387**: 253-260.

Curtis, J.T. and McIntosh, R.P. 1950. The interrelations of certain analytic and synthetic phyto-sociological characters. *Ecology*, **31**:434-455.

Dvořák, J. 1996. An example of relationships between macrophytes, macroinvertebrates and their food resources in a shallow eutrophic lake. *Hydrobiologia,* **339**: 27-36.

Engelhardt, K.A.M. and Ritchie, M.E. 2001. Effects of macrophyte species richness on wetland ecosystem functioning and services. *Nature,* **411**: 687-689.

Egertson, C.J., Kopaska, J.A. and Downing, J.A. 2004. A century of change in macrophyte abundance and composition in response to agricultural eutrophi-cation. *Hydrobiologia,* **524**: 145-156.

Gopal, B.1994. The role of ecotones in the conservation and management of tropical inland waters. *Mittelungen International a Vereingung Limnologie*, **24**:17-25.

Hanson, H.C. and Churchill, E.D. 1961. *The Plant Community*. Reinhold Publishing Corp., New York.

Harold, F. and Heady 1958. Vegetational changes in the California Annual type. *Ecology,* **39**: 402-416.

Pandit, A.K and Kumar, R. 2006. Comparative studies on ecology of Hokarsar wetland, Kashmir: Present and Past. *J. Himalayan Ecol. Sustain. Dev.*, **1**: 73-81.

Kundangar, M.R.D. and Zutshi, D.P. 1987. Ecology and production of some important macrophyte species in two rural communities of Kashmir. *Journal of Hydrobiology,* **3**(6): 57-62.

Misra,1968. *Ecology Workbook*. Oxford and I.B.H. Publishing Co., New Delhi.

Kumar,R., Rather, G.H. and Pandit.A.K. Primary productivity of dominant macrophytes in Hokersar perennial wetland in Kashmir Himalaya. *Journal of Himalayan Ecol. Sustain. Dev*., **2**: 33-36.

Timms, R.M. and Moss, B. 1984. Prevention of growth of potentially dense phytoplankton populations by zooplankton grazing, in the presence of zooplanktivorous fish, in a shallow wetland ecosystem. *Limnol. Oceanogr.,* **29**: 472-486.