Comparative Limnology of Some Fresh Water Springs of District Kulgam (Kashmir) with Special Reference to Macroinvertebrate Diversity

Dissertation submitted to in partial fulfillment of the
requirements for the award of the Degree of

Master of Philosophy (M.Phil.)
In
Environmental Science

By
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Under the Supervision of
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November 2012

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Dated: ____________

CERTIFICATE

This is certify that the M.Phil. Dissertation entitled "***Comparative Limnology of Some Fresh water Springs of District Kulgam (Kashmir) with Special Reference to Macroinvertebrate Diversity***" is the original research work of **Mr. Gulzar Ahmad Sheikh** for partial fulfillment of the requirements for the award of the degree of Master of Philosophy (M.Phil.) in Environmental Science.This study has been carried out under my supervision for the period required under statutes and the same has not been submitted elsewhere for the degree.

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ACKNOWLEDEGEMENTS

At the outset, I offer my reverences to the "Almighty God" for bestowing me with wisdom, knowledge, courage and patience to complete my degree successfully.

I have great privilege to express my deep sense of gratitude and indebtedness to my supervisor Prof. Ashok K. Pandit for his keen interest, constant guidance and supervision, concrete suggestions, thoughtful criticism and polite dealing during the pursuance of this study.

I am extremely grateful to Prof. Azra N. Kamili, Head, P.G. Department of Environmental Science, University of Kashmir for her moral support and guidance during my research tenure and also for providing laboratory facilities.

I would like to express my sincere gratitude to Prof. A.R. Yousuf and Prof. G.A Bhat for their constant encouragement during the course of my research work.

Indeed the words at my command are not adequate to convey my heartful thanks to Dr. Sami Ullah Bhat, Assistant Professor P.G Department of Environmental Science, University of Kashmir for his encouragement, ever helping attitude and constructive suggestions.

I wish to extend my sincere thanks to my lab mates for their painstaking efforts in assisting me both in the field and laboratory. I am particularly thankful to Mr. Salim Aijaz, Mr. Naseer Ahmad Dar, Mr. Sayar Yaseen, Mr. Javid Ahmad Shah, Mr. Aadil Hamid, Mr. Showkat Ahmad Lone, Mohd. Sikander Bhat, Ms. Dilafroza Jan, Ms. Nuzhat Shafi. Ms. Aalia Ismat, Ms. Saima Jan, Ms. Afeefa Qayoom and Ms. Rafia Rasheed.

The sincere help and cooperation extended by the aquatic laboratory staff especially Dr. Bilal Ahmad Wani and Ms. Irfana Nabi is thankfully acknowledged.

I get immense pleasure to express my thanks to the galaxy of my friends Mr. Mehrajud Din Dar, Mr. Saleem Wagay, Mr. Iftikar Hussian Gani

and Mr. Zaheer Abass Wani for their constant encouragement and ever available help during this work.

No words can suffice my feeling of gratitude to my revered parents, whose blessings, immense patience and encouragement were the constant source of inspiration during entire period of my study. The adorence and affection of my brothers and sisters has been an asset and source of immense strength to me that goes beyond my expression.

GULZAR AHMAD SHEIKH

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Chapter- 1

INTRODUCTION

Freshwater ecosystems are threatened globally because of pollution, flow regulation, intensified land use, and overexploitation. While the degradation of surface waters has received wide attention in the world, the state and conservation value of ground water-dependent ecosystems particularly springs are still poorly understood. A spring is a well defined area where a natural discharge of groundwater returns to the surface (White, 2005). Springs are formed when the water table intersects with the earth's surface, or groundwater rises to the surface through rock faults, fractures or depressions (Death *et al.*, 2004). Springs are immensely important aquatic resources because they afford a reliable source of high quality ground water at a relatively constant temperature and flow. As the public need for water escalates, springs represent a dependable and increasingly valuable supply of water, particularly during drought conditions. Springs are being tapped for domestic, commercial, agriculture, livestock, industrial and recreational purposes. Springs often provide the only flow (base flow) to rivers and streams during periods of extreme drought.

Spring water resources are tied to climate, groundwater discharge and water quality. Impact of these parameters as well as their natural variability will have a corresponding effect on spring ecosystems. Impacts to water quality may occur through ground water pollution by way of percolation of sewage, fertilizers, pesticides, herbicides or toxic chemicals (Sads *et al.*, 2001) and surface runoff from contaminated uplands into spring sites or decrease in water quality (e.g., drainage, diversion, drought) resulting in wider swings in ionic concentrations (Grootjans *et al.*, 1988).

Springs are supposed to be potential ecological refuges for both plant and animal communities due to their environmental stability (Sabater and Roca, 1992). Although springs have long been valued as a dependable source of water for domestic use, agriculture and livestock, they have only recently been recognized for the uniqueness of their native fauna and what they contribute to local and regional biodiversity (Sada *et al*., 1995). Spring fauna provides unique information on endemism and zoogeographical patterns. Springs are habitats where relict species of former times have got endured, protected from large oscillations in climate (Hynes, 1970). Thus, invertebrate community composition will be highly influenced by spring type and proximity to the source. Springs are often called "hotspots" for aquatic biodiversity (Scarsbrook *et al*., 2007). Springs have a mosaic structure with a high degree of individuality and a zonal character, due to the peculiar physicochemical stability. Springs, besides being obviously important as resources for good quality water, are also relevant habitats with peculiar characteristics (Cantonati *et al*., 2006). They often harbour highly diverse communities of animals and plants, and in some cases the biota shows a high degree of endemism (Di Sabatino *et al.,* 2003; Cantonati *et al*., 2006). Springs provide a habitat for specialised organisms that are adapted to the relatively constant environment (Ellenberg, 1996). Hence, the species composition of springs clearly differs from the adjacent ecosystems in which short-term and seasonal variability in the environment is more pronounced.

Fresh water springs have historically been neglected by ecologists despite the high species richness and diversity recorded within them (Ferrington *et al*., 1995; Hoffsten and Malmqvist, 2000). They must be preserved and protected for the benefit of the ecology, environment, economic well being and quality of life. The spring habitats in Kashmir valley have a tremendous potential for trout culture, providing drinking water to the rising populations and irrigating the fields. However, valley is losing many of these fresh water resources due to contamination through natural as well as human interferences (Mahajan, 1989). Moreover, our knowledge of spring ecosystems in Kashmir valley is very little and only few preliminary reports on spring ecology are available (Qadri and Yousuf, 1979; Rashid, 1982; Yousuf *et al*., 1983; Bhat and Yousuf, 2002; Latief *et al*., 2003; Pandit *et al*., 2001, 2002, 2005a&b, 2007). In spite of such a tremendous importance,springs in Kashmir valley are frequently modified for consumptive or recreational purposes with concomitant impacts on aquatic organisms. The nutrient enrichment in these biotopes result in greater algal growth, increased turbidity, physico-chemical and biological changes that are detrimental to native species. However, no such detailed study exists till now except

Bhat and Pandit (2010) on the discharge potential, chemicalcomposition, distribution, and ecology of facultative and spring dependent flora and fauna. It is in this backdrop an attempt has been made to investigate limnochemistry and biotic diversity of somefresh water spring ecosystems of Kulgam district, Kashmir valley with the following objectives:

- To assess faunistic composition and diversity of macroinvertebrates of the springs,
- To assess the seasonal variation in various physico-chemical parameters of springs vis- a- vis to the potability of water,
- To assess how macroinvertebrates respond to changing water quality and temperature regimes, and
- To study the anthropogenic pressures on the diversity of benthic community and water quality.

Chapter- 2

REVIEW OF LITERATURE

Springs are an important research systems for basic and applied ecology (Glazier, 1998; Williams and Williams, 1998). Springs provide relatively stable abiotic conditions for the aquatic fauna (van der Kamp, 1995) and are inhabited by species adapted to this environment (Di Sabatino *et al.*, 2003). However, hydrological disturbances also occur in springs. Drought periods especially in intermittent springs and in karst springs, as well as heavy rainfalls alter the discharge of springs rapidly which may influence the aquatic macroinvertebrates (Meyer *et al.*, 2003). Such effects are also dependent on the geology and the origin of the groundwater. Past investigations found evidence that discharge is the most important factor influencing the composition of macroinvertebrate assemblages (Mori and Brancelj, 2006; Von Fumetti *et al.*, 2006).

Many ecologists have attempted to classify spring habitats using spring physical and chemical attributes (Glazier, 1991; Hoffsten and Malmqvist, 2000), spring invertebrate communities (Meyer *et al.*, 2003; Ilmonen and Paasivirta, 2005) or both (Zollhöfer *et al.*, 2000). The classification most often used in zoological studies includes three categories of spring types according to the groundwater flow rate and topography of the groundwater source area: helocrene, rheocrene and limnocrene springs (Smith, 1991). In helocrenes groundwater percolates through a layer of detritus or vegetation into a marshy holding area, whereas in rheocrenes emergent groundwater flows rapidly over a gravel or sand substrate, and in limnocrenes a stenothermic groundwater pool is formed at the point of discharge. It was observed that springs often form heterogenous habitat complexes comprising of a mosaic of lentic and lotic habitats and madicolous seepage areas (di Sabatino *et al*., 2003; Cantonati *et al*., 2006).

Some significantstudies have been carried out in the fieldof spring ecology that provide an extensive understanding of the structural and functional significance of springs ecology (Williams *et al.*, 1990; Botosaneanu, 1998) and the importance of some key factors controlling the composition and structure of their communities especially the benthic invertebrate assemblages.

Due to their environmental stability, springs are supposed to be potential ecological refuges for both plant and animal communities (Sabater and Roca, 1992). This is because springs exhibit thermal constancy, and relative hydrological stability (Van Der Kamp, 1995). Various chemical factors have been identified to influence the specific spring fauna (Orendt, 2000; Hahn, 2000). And also substrate composition has been regarded as important (Ilmonen and Paasivirta, 2005). Besides these factors governing the specific spring fauna, discharge has been identified to influence macrozoobenthic spring assemblages, especially with regard to its temporal variation (Smith, 2002; Meyer *et al*., 2003).

According to Hynes (1970) springs are habitats where relict species of these former times have endured, protected from large oscillations in climate. Thus, invertebrate community composition will be highly influenced by spring type and proximity to the source. Springshave a mosaic structure, a high degree of individuality and a zonal character, due to the peculiar physicochemical stability. They often harbour highly diverse communities of animals and plants and in some cases the biota shows a high degree of endemism (Di Sabatino *et al.*, 2003; Cantonati *et al.*, 2006).

Studies reveal that springs provide a habitat for specialised organisms that are adapted to the relatively constant environment (Ellenberg 1996). Most crenobiontic and crenophilous species are stenoecious (Zollhöfer *et al.*, 2000; Cantonati *et al.*, 2006). Hence, the species composition of springs clearly differs from the adjacent ecosystems in which the short-term and seasonal variability in theenvironment is more pronounced.It has been observed that at temperate latitudes, thermal stabilityis one of the main characteristics of springs and the reason for the presence of cold-stenothermic animals (Erman and Erman 1995).

Several studies have shown how geographical factors (Williams and Williams, 1998), permanent flow (Bhat and Pandit, 2010), flow variability (Meyer *et al.*, 2003), organic matter (Smith *et al.*, 2003), water chemistry (Orendt, 2000), water velocity (Ilmonen and Paasivirta, 2005; Ilmonen *et al.*, 2009), substratum composition (Bhat and Pandit, 2010), altitude (Barquín and Death, 2006; Bhat and Pandit, 2010) and local habitat features (Ilmonen and Paasivirta, 2005) have a substantial effect on the spring faunal assemblages. Many workers have reported that within spring habitat heterogeneity has been of particular importance in determining crenic macroinvertebrate community composition (Lindegaard *et al.* 1998; Hahn, 2000).

Springs sustain high levels of biodiversity. Illies (1978) reported the presence of about 1500 species in European springs, of which about 31% are crenobiotic or crenophilic. Springs represent the interface between two distinct ecosystems (groundwater and surface water), and can be considered as "hotspots"of aquatic biodiversity (Cantonati *et al.*, 2006; Scarsbrook *et al.*, 2007), due to their distinct "mosaic" and multiple ecotonal structure which results in high number of microhabitats (Di Sabatino *et al.*, 2003).

Studies have shown that springs host specialized and often endemic or rare taxawhich can be locally threatened (Ilmonen *et al.*, 2009). Several studies on the biotic assemblages of mountain springs have been carried out over recent years in Italy, mainly in the north-eastern Alpine and pre-Alpine area, and in the central and southern Apennines (Bottazzi *et al.*, 2008).

Sada *et al.* (2005) reported that decreases in specialists and increases in generalist species often occur when variability in environmental conditions increases. A decrease in spring-related biodiversity could be indicated by a corresponding increase in upland or introduced aquatic and riparian species. While water quality and aquatic macroinvertebrates respond to acute environmental changes, soil chemistry and spring vegetation composition appear to respond to sustained environmental changes (Bernaldez and Rey Benayas, 1992).

Erman (2002) observed that macroinvertebrate diversity decreases are associated with increase in discharge variability. Macroinvertebrate communities are sensitive to water quality. Their responses to declining flows is partiallydue to associated water quality changes and partially due to desiccation.

Cantonati *et al.* (2006) worked out that the mosaic of microhabitats supported by environmental factors at a spring site accounting for much of the biodiversity and endemism found in spring ecosystems. Thorup and Lindegaard (1977) studied that besides water flow *per se*, substrate characteristics related to water flow are also important factors influencing the fauna of a given microhabitat, providing a mosaic of variable food supply, shelter and light intensity within a spring. Many ecologist reported that aquatic macroinvertebrates make up a substantial proportion of spring biodiversity and aquatic species in spring ecosystems display species-specific responses to spring environments due to a high degree of endemism (Cantonati *et al.*, 2006; Heino *et al.*, 2003; Sada *et al.*, 2005).

Several studies soconductedrevealed that the occurrence of a species may be regulated by thermal regime (Nolte and Hoffman 1992), availability of optimal food resources (Wotton, 1979), or specific microhabitat demands (Lindegaard *et al.*, 1975). Species' occurrences are also affected by interspecific interactions (Hemphill, 1988, Suutari *et al.*, 2004) and their colonisation ability in habitats prone to disturbances (Downes and Lake, 1991; Hoffsten, 2003a, 2004). Hawkins *et al.* (2000) reported that benthic macroinvertebrates are a diverse component of freshwater biodiversity, often used in freshwater bioassessment and classification studies.

Several workers observed that the occurrence of different spring habitat types and the associated high habitat heterogeneity within springs are usually the most importantfactors influencing the composition of macroinvertebrate assemblages (*Glazier* and Gooch, 1987; Lindegaard *et al.*, 1998; Di Sabatino *et al.*, 2003). Substrate type (Von Fumetti *et al.,* 2006), discharge (Hoffsten and Malmqvist, 2000; Von Fumetti *et al.,* 2006), hydrogeological setting (Hoffsten and Malmqvist, 2000), flow permanence (Erman and Erman, 1995; Smith *et al.,* 2003), water pH (Hahn, 2000) and riparian shading (Scarsbrook *et al.,* 2007) have also been identified as key factors regulating spring macroinvertebrate diversity.

Williamsand Williams (1998) reported that insect dominance over amphipods in the northern latitude springs of North America has been suggested to be related to glacial history, where more vagile insects were dominant in more recently glaciated areas. Lower species diversity of macroinvertebrates has been repeatedly detected in springs than in runoff-fed headwater streams in the northern hemisphere (McCabe 1998; Barquín and Death, 2004).

Springs are indicators of the groundwater environment in that springs may be fed by local and regional aquifers in which water residence time could range from a few months to hundredsof years. Residence time determines the temporal scale at which impacts to groundwater quality evoke a spring water quality response (Sada *et al.,* 2004). Climate (short and long-term) is a major control of spring flow parameters. Recharge rates, natural disturbance intensity, and solar radiation are ultimately driven by regional climate patterns (Stevens and Springer, 2004).

Spring water resources are tied to climate, groundwater discharge, and water quality.Impacts to these parameters as well as their natural variability will have a corresponding effect on spring ecosystems. Long-term drought, groundwater withdrawal at local and regional levels, and local diversions at or near the orifice are common impacts on water quantity at spring sites throughout the Western United States. Impacts to water quality may occur through groundwater pollution (percolation of sewage, fertilizers, pesticides, herbicides, or toxic chemicals) (Mitsch and Gosselink 1993; Sada *et al*., 2001), surface runoff from contaminated uplands into spring sites (Basnyat *et al.*, 1999; Tufford *et al*., 1998), or decrease in water quantity (e.g. drainage, diversion, drought) resulting in wider swings in ionic concentrations (Grootjans *et al*., 1988).

According to Cantonati *et al*. (2006) groundwater temperatures tend to be stable, and springs commonly have narrow temperature ranges throughout the year. Erman (2002) opined that the stability in water temperature in the spring environment supports endemic species not found downstream where water temperatures fluctuate.

Groundwater pollution will also influence water chemistry in various ways depending on the pollutants. Springs with recharge areas that include developments and agricultural activities are susceptible to pollution from herbicide, fertilizer, and pesticide usage, septic leach fields, and chemical spills from machinery (Mitsch and Gosselink 2000; Sada *et al.,* 2001). Long-term exposure to a particular set of stable aquatic chemical conditions results in specialized, often endemic, macroinvertebrate and plant communities (Hershler and Sada, 2002; Sada *et al*., 2005).

Manga (2001) used spring water temperature as part of a suite of parameters to estimate mean residence time of groundwater and aquifer characteristics. Cantonati *et al*. (2006) worked out that water temperature indicates depth and velocity of groundwater flux. Stevens and Springer (2004) reported that non-geothermal springs with temperatures above 30°C tend to have low biodiversity. Kadri (2000) reported a temperature difference of 10-11°C between two Nigerian springs but no thermal variations between seasons was recorded.

The pH of spring water is influenced by geology, air pollutants, human impacts, and biological activity (Cantonati *et al.*, 2006).

Dissolved oxygen (DO) is required by biota in spring environments and affects many chemical and biological reactions. Sources of DO include dissolution of atmospheric oxygen and photosynthesis of aquatic or submerged autotrophs. The solubility of oxygen in water varies with temperature. Conditions leading to low DO include warm water temperatures, stagnation, high respiration rates and eutrophication (Penoyer 2003).

Malard and Hervant (1999) found that oxygen levels are dependent on variability and sediment composition and structure, ground water flow velocity, organic matter content and the abundance and activity of microorganisms.

The hardness of waters varies considerably from place to place. In general surface waters are softer than ground waters. The hardness of water reflects the nature of the geological formations with which it has been in contact. The principal hardness causing cations are calcium, magnesium, strontium, ferrous iron, and manganous ions. Meenakumari and Hosmani (2003), Jeelani (2004), Pandit *et al.* (2005b) have worked on this parameter.

Freeze and Cherry (1979) reported thatthe chemistry of spring water is determined primarily by the residence time of water in the aquifer, the reactivity of aquifer materials and the chemical status of influent surface water.

Anderson (1993) reported that spring water nutrient status is influenced by impacts in the recharge zone, groundwater depth and upland inputs of erosion, surface runoff, and animal waste. He observed that nutrient status tends to decrease with groundwater depth.

Sharpe (2002) investigated that chemical composition in addition to concentration influenced mollusk species (e.g. clams, snails, slugs) distribution. Erman (2002) found that temporal variability of spring physical and chemical properties such as discharge, alkalinity, calcium, and temperature directly correlated with insect and mollusk diversity in Sierra Nevada cold springs.

Jones *et al.* (1994) have reported that nutrient enrichment of Florida springs, specifically by nitrate and phosphorus, is a major issue due to the concerns over “Blue baby” syndrome and potential eutrophication. Kumar *et al.* (1997) conducted a field study to assess variations in physico-chemical characteristics of water of the springs located within the boundary of a central Himalayan town where the spring water is used for drinking purposes. Monitoring of 12 springs was carried out for three seasons (winter, summer and monsoon). The results indicate direct influence of unplanned sewage disposal on the spring water quality as reflected by significant regional variations in the concentrations of nitrates, chlorides, sulfates, sulfides and electrical conductivity. Population density varies within the town from 3,110-14,137 persons/km^2 and has direct relationship with the water quality. Springs located in the densely populated area had higher concentrations of all these compounds. Concentrations of nitrates upto 60 ppm were observed in some springs, making water unsuitable for consumption. No significant changes were observed in spring water quality during different seasons.

Bhat and Yousuf (2002) made studies on ecology of periphytic community of seven springs of Kashmir. The water of the spring was alkaline, moderate to typical hard water with low dissolved oxygen and high free carbon dioxide content. The study revealed 50 algal taxa with Bacillariophyceae dominating qualitatively and quantitatively in most of the springs.

Sada and Vinyard (2002) identified ten anthropogenic factors associated with water developments, physical impacts, and biological invasions that affect distributions and abundance of aquatic invertebrate species in Great Basin springs. The synergy among factors appeared to have a greater affect than any one factor. Sada and Nachlinger (1996) found a negative correlation between spring biodiversity and physical disturbance. Hershler and Sada (2002) reported that non-native species can decrease or eliminate native plant and animal populations through predation, competition, and hybridization. Invasion by upland non native species into desiccated spring areas is a potential threat associated with impacts to spring water resources.

Jeelani (2004) while working on the hydrochemistry of springs of Anantnag district have found calcium ions highest in Karst springs (39.6 mg/L) and lowest in Karewa springs (8.0 mg/L), magnesium ions highest in Karst springs (19.5mg/L) and lowest in alluvial springs 8.4 mg ⁄L, sodium highest in warm springs (53.6mg/L) while potassium was found low in all springs (0.2-3mg/L). The study further revealed that among anions HCO_3^- was found highest in warm springs (160mg/L) and lowest in Karewa springs (38mg⁄L), concentration of chloride being highest in Karewa springs (73mg/L) and lowest in alluvial springs while sulphate was found highest in warm springs (62.5mg/L) and lowest in alluvial springs.

Pandit *et al.* (2005a) investigated the ground water quality of Kashmir valley to determine the portability of the water. For the portability the obtained data was compared with the standards of WHO (1984), BIS (1991) and GWS IS: 10500 (1991) and most of the samples crossed the desirable limits but were within the permissible ranges except iron. L. Toran and White (2005) studied variation in nitrate and calcium as indicators of recharge pathways in Norte springs. This study revealed that nitrate concentrations increased at the end of the growing season, showing the importance of soil zone in the recharge pathway.

Bhat and Pandit (2010) and Bhat *et al.* (2010) while investigating limnochemistry of three freshwater springs of Kashmir Himalaya found that these springs were hard water type with slightly lower values of dissolved oxygen (DO) (1.2-6.4mg/L). The ionic composition of the spring waters revealed the predominance of bicarbonate and calcium over the other ions with usual ionic progression as HCO_3^- >Ca++ >Mg++ >Na+ >K+. None of the parameters studied floated the standards set by WHO for drinking water quality. However, relatively higher values of NO_3-N (2500-3900µg/L), but well within the permissible limits of WHO, were observed. The dissolved silica did not show any temporal variation between different months but exhibited slight spatial variations (17.8-21mg/L).

Odeyemi *et al.* (2010) while carrying outthe bacteriological, physicochemical and mineral studies on Awedele spring water and soil samples in Ado Ekiti, Nigeria concluded that the assessed water and soil samples were generally of poor quality and considered unfit for drinking.

Chapter- 3

STUDY AREA AND STUDY SITES

The valley of Kashmir also referred to be a "Paradise on earth" has been known for its scenic beauty. The high-altitude valley of Kashmir is of tectonic origin, lying between 33^{o} 25′to 34^{o} 50′N and 74^{o} to 75^{o}E. The valley, with varied terrains and dense drainage network, has a unique distinction of having varied resources of natural waters, lentic as well as lotic types, perennial as well as seasonal. Among these habitats the lentic habitats are represented by lakes, ponds, wetlands and similar other small aquatic systems. The lotic habitats are represented by River Jehlum, numerous snow-fed hill streams and coldwater springs which directly or indirectly join the former throughout its course in the valley. Kashmir is exceedingly rich in springs, locally called Nag. The vast array of springs play an important role in maintaining the hydrological regimes of the entire valley. They appear both in the plain areas and at the high altitudes. The water, in most of the spring is cold in summer and warm in winter and as such are regarded as sacrosanct. These springs provide water used for drinking, domestic and irrigation purposes.

Study Sites

The study sites, falling in district Kulgam, are situated at 74° 35′ to 75^{0}11′E longitude and 33° 39′ to 33^{0} 65′ N latitude and lie towards the South West of Kashmir valley, being bound by Pirpanchal range. Kulgam is situated at a distance of 70 km away from the capital city of Srinagar and about 17 kms from Anantnag. The geographical area of the district is 1067km^{2}, including 325 km^{2} of forest land. The total population of the district is 389,015 as per census 2011. The word Kulgam denotes “Kul” meaning thereby the “Whole” and the “Gam” in Arabic to “teach righteousness”. It is named as Kulgam by Syed Hussain Simnani(RA) when beholden with the myriad number of springs and streams flowing through the villages. It is the birth place of famous kashmiri saint Sheikh Noor-Ud- din Noorani(RA). The district hosts a large number of beautiful springs that bring life to many rivers, rivulets, nallahs and streams and provide drinking water facility to all over the district. Five famous springs of district Kulgam were selected for the purpose in the present study. The selected study sites are Qoimoh spring, Parigam spring, Katrooso spring, Khee spring and Kulgam spring. The catchments of these springs, outside the human settlements are agriculture and horticulture lands.

Qoimoh spring: It lies in Qoimoh about 10 km away from the main Kulgam town at an elevation of 1,618m (a.m.s.l). It lies within geo-coordinates 33°43´N and 75° 04´E. There is a famous shrine of female saint, Sadreh Mauj, the mother of known saint Sheikh Noor-Ud-din Noorani(RA), near the spring. This gives a divine touch to the spring. The people of district Kulgam especially Qoimoh attach great religious significance to the spring. The water of this spring is used for drinking purposes and is believed to have healing powers.

Parigam spring: The spring is situated at Parigam about 20 km away from the main Kulgam Bazar on the main road leading from Qoimoh to Shopian. This spring is located at an elevation of 1,722m (a.m.s.l) and within geo-coordinates 33° 41´N and 75°00´E. This spring is present in residential area and its water is used for drinking, washing, and irrigation purposes by the local residents. The catchment outside the residential area is comprised of agriculture and horticulture land. The spring was thronged by thousands of people few years back when a mysterious flower plant namely (*Heegond*) appeared in the spring.

Katrooso spring: The spring is situated in village Katrooso about 12 km away from the main Kulgam town. This spring lies at an elevation of 1,734m (a.m.s.l) and within geoss-coordinates 33° 41´N and 74° 59´E. This spring is fenced by concrete wall. The spring harbours some fishes within it. The local residents have made bathrooms for bathing purposes on its second compartment. This spring is present in highly residential area and its water is used for drinking, washing, and other domestic purposes by the locals.

Khee Jogipora spring: The famous spring is situated in village Khee Joghee pora about 15km awayfrom the main Kulgam town. The spring lies at an elevation of 1,758 m (a.m.s.l) and within geo-coordinates 33°41´N and 75°00´E. The spring is highly decorated and fenced by concrete wall and roofed over the top. The water comes out from the spring through a pipe. It is the birth place of famous Saint Sheikh Noor-Ud-din Noorani$^{(RA)}$ which gives a divine touch to the spring. This spring is present in the residential area and its water is used for drinking and bathing purposes by the local inhabitants. The water of the spring is believed to have skin cure properties.

Kulgam spring: The spring is situated in Kulgam town. The spring lies at an elevation of 1,752m (a.m.s.l) and within geo-coordinates 33° 41´N and 75° 00´E. This spring is fenced by solid concrete wall. It is located to some extent away from residential area and the immediate catchment of the spring is agriculture and horticulture land. Water of this spring is used for drinking, bathing, washing and irrigation purposes.

Site 1: Qoimoh spring

Site 2: Parigam spring

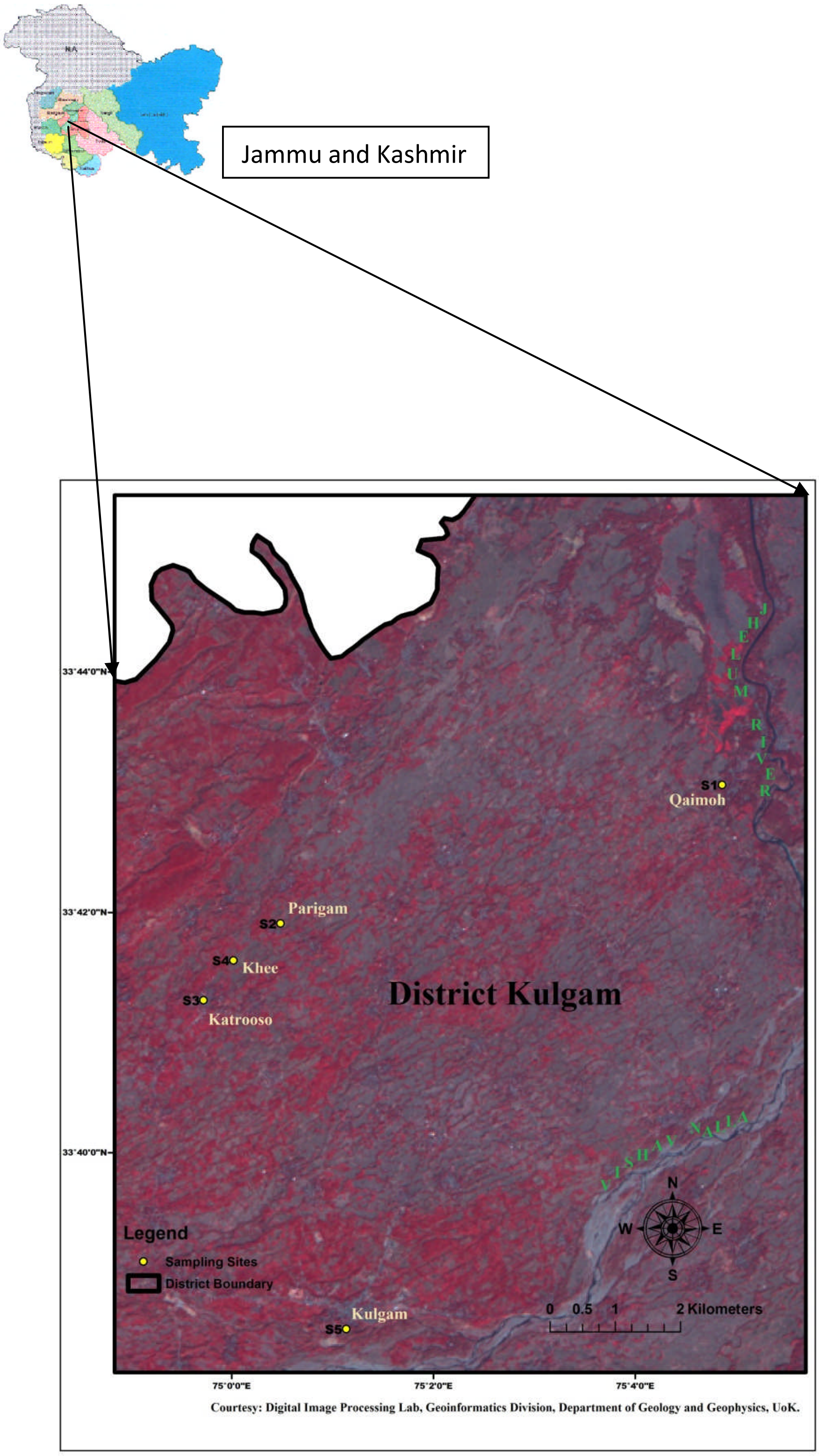
Site 3: Katrooso spring

Site 4: Khee Jogipora spring

Site 5: Kulgam spring

Table 1: General characteristics of springs of Kulgam

Study sites	Altitude (m.a.s.l)	Lat. and Long.	Average Depth (cm)	Average Annual Discharge L/s	Permenence	Substrate Composition	Spring type	Catchment characteristics pattern	Sources of pollution
Qoimoh spring	1618	33° 43´ N and 75° 04 ´ E	66	0.82	Perennial	Pebble, sand and mud	Limnocrene	Residential	Domestic
Parigam spring	1722	33° 41´ N and 75° 00 ´ E	38	0.37	Perennial	pebble, mud and organic matter	Limnocrene	Residential and agricultural	Domestic and agricultural
Katrooso spring	1734	33° 41´ N and 74° 59 ´ E	46	1.55	Perennial	Pebble, gravel, mud and sand	Limnocrene	Residential	Domestic
Khee spring	1758	33° 41´ N and 75° 00 ´ E	163	2.1	Perennial	Pebble and gravel	Limnocrene	Agricultural	Agricultural
Kulgam spring	1752	33° 01´ N and 75° 01 ´ E	50	1.9	Perennial	Gravel, pebble, sand and mud	Limnocrene	Agricultural	Agricultural



Courtesy: Digital Image Processing Lab, Geoinformatics Division, Department of Geology and Geophysics, UoK.

Fig. 1: Study area with study sites

GLIMPSES OF STUDY SITES

Site 1: Qoimoh spring

Site 2: Parigam spring

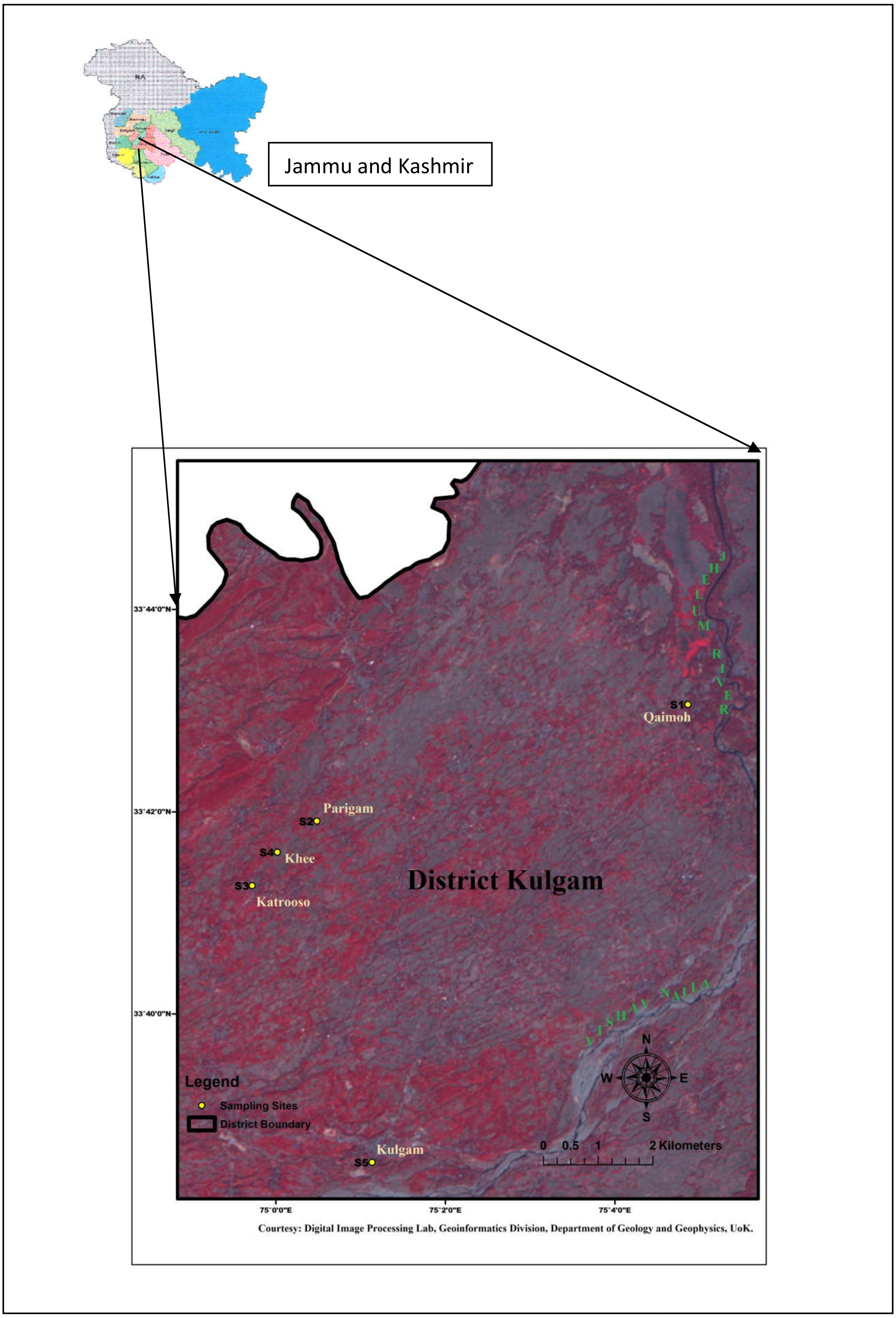
Site 3: Katrooso spring

Site 4: KheeJogipora spring

Site 5: Kulgam spring

Table 1:General characteristics of springsof Kulgam

Study sites	**Altitude (m.a.s.l)**	**Lat. and Long.**	**Average Depth (cm)**	**Average Annual Discharge L/s**	**Permenence**	**Substrate Composition**	**Spring type**	**Catchment characteristics pattern**	**Sourcesof pollution**
Qoimoh spring	1618	33° 43´ N and 75° 04 ´ E	66	0.82	Perennial	Pebble, sand and mud	Limnocrene	Residential	Domestic
Parigam spring	1722	33° 41´ N and 75° 00 ´ E	38	0.37	Perennial	pebble,mud and organic matter	Limnocrene	Residential and agricultural	Domestic and agricultural
Katrooso spring	1734	33° 41´ N and 74° 59 ´ E	46	1.55	Perennial	Pebble, gravel, mud and sand	Limnocrene	Residential	Domestic
Khee spring	1758	33° 41´ N and 75° 00 ´ E	163	2.1	Perennial	Pebble,sand and gravel	Limnocrene	Agricultural	Agricultural
Kulgam spring	1752	33° 01´ N and 75° 01 ´ E	50	1.9	Perennial	Gravel, pebble, sand and mud	Limnocrene	Agricultural	Agricultural



Courtesy: Digital Image Processing Lab, Geoinformatics Division, Department of Geology and Geophysics, UoK.

Figure 1. Study area with study sites

Chapter- 4

MATERIAL AND METHODS

4.1. Physico-chemical Characteristics of Water

The physico-chemical characteristics of spring water were monitored on monthly basis from March 2011 to February 2012. The surface water samples were collected from all the sampling sites in one litre polyethylene bottles for the laboratory investigation. Variables like depth, transparency and temperature were determined on spot, while as other variables were determined in the laboratory within 24 hours of sampling. The analysis was done as per standard methods given by Davis (1938), Golterman and Clymo (1969), CSIR (1974), APHA (1998) and Wetzel and Likens (2000).

4.1.1. Water temperature

The temperature of surface water was recorded by using graduated Celsius thermometer. The bulb of the thermometer was dipped in water for at least two minutes for obtaining the water temperature. The results were expressed in °C.

4.1.2. Hydrogen-ion concentration

The pH of water samples was determined by means of a digital pH meter. Before measuring the pH of water samples, the pH meter was standardized with known buffer solutions of pH 4.7, 7.0 and 9.2.

4.1.3 Conductivity

The conductivity of water samples was measured with the help of a digital conductivity meter. The conductivity meter was calibrated before use with standard potassium chloride solution (0.01M). The results were expressed in μScm^{-1} at 25°C.

4.1.4.Dissolved oxygen

The dissolved oxygen content was determined byWinkler’s method. The initial fixation of the dissolved oxygen was done on spot by collecting the water sample in 300 mL dissolved oxygen bottles to which 1 ml each of manganous sulphate and alkali iodide-azide was added. The bottle was tightly stopped and inverted for few times to mix the reagents thoroughly. The precipitate formed was dissolved by addition of 1ml of concentrated sulphuric acid. 50 mL of the sample was then taken and titrated against 0.025N sodium thiosulphate using starch as indicator.

The D.O. concentration was calculated from the given formula and the results were expressed in mg L^{-1}.

$$\text{Dissolved oxygen}(\qquad) = \frac{\times \quad \times \quad \times 1000}{}$$

V$_1$ = Volume of sodium thiosulphate used

V$_2$ = Volume of the sample taken for titration

N=Normality of sodium thiosulphate

e=Equivalent weight of oxygen

4.1. 5.Free CO_2

To 50 mL of water sample, two drops of phenolpthailin indicator were added and titrated against 0.02 N NaOH. The results obtained were expressed as mg/L.

$$/ \; = \frac{(\qquad\qquad (\quad) \times 1000)}{\text{Volume of sample}}$$

4.1.6.Total alkalinity

100 ml of water sample was titrated against 0.02N H_2SO_4 using methyl orange as indicator. The results were expressed in mg L^{-1} after using the following formula:

$$\text{Total alkalinity as} \qquad (\text{mg L} \quad) = \frac{- \quad \times \quad \times 1000 \times 50}{}$$

V$_1$ =Volume of titrant used for the sample

V$_2$= Volume of titrant used for the blank (mL)

V$_3$= Volume of the sample taken for titration (mL)

N=Normality of H_2SO_4

4.1.7.Total hardness

To 50 mL of water sample, 1-2 mL of buffer solution (NH_4- NH_4OH) and a pinch of EBT indicator was added and then titrated against 0.01M EDTA till wine red colour changes to blue. The concentration (mgL^{-1}) was determined by using the following formula:

$$\text{Total hardness as} \qquad (\text{mg L} \quad) = \frac{- \quad \times 1000}{}$$

V_1 = Volume of EDTA used for the sample (mL)

V_2= Volume of EDTA used for the blank (mL)

V_3= Volume of the sample taken for titration (mL)

4.1.8.Calcium

To 25 mL of water sample 2 mL of 1N sodium hydroxide and a pinch of murexide indicator was added and then titrated against 0.01N EDTA till purple colour appeared. The concentration (mgL^{-1}) was determined by using the following formula:

$$\text{Calcium } (\text{mg L} \quad) = \frac{- \quad \times 400 \times 1.05}{}$$

V_1= Volume of EDTA used for the sample (mL)

V_2= Volume of EDTA used for the blank (mL)

V_3= Volume of the sample taken for stitration (mL)

4.1.9.Magnesium

Magnesium content was obtained from the total hardness and calcium hardness by using the following formula:

$$\begin{aligned} &\text{Magnesium } (\text{mg L} \quad) \\ &\qquad = \text{Total hardness as CaCO } (\qquad) \\ &\qquad - \qquad h \qquad \text{CaCO } (\qquad) \times 0.243 \end{aligned}$$

4.1.10.Chloride

100 mL of sample was titrated against 0.0141N silver nitrate solution using potassium chromate as indicator till brick red colour end point was attained. Concentration in ‘mg L^{-1}’ was determined by using the following formula:

$$\text{Chloride (mg L}\quad) = \frac{\ - \quad \times \quad \times \quad \times 1000}{\quad}$$

V_1 = Volume of silver nitrate used for sample (mL)

V_2 = Volume of silver nitrate used for blank (mL)

V_3 = Volume of the sample taken for titration (mL)

N =Normality of silver nitrate solution.

e = Equivalent weight of chlorine

4.1.11.Sulphate

To 50 mL of aliquot, 10 mL of NaCl-HCl solution followed by 10 mL of glycerol-alcohol solution were added. An amount of 0.15g of barium chloride was mixed with sample by constant stirring. The absorbance was measured against the blank at 400 nm, and the results were expressed in mg/L.

4.1.12.Nitrate - nitrogen

To 100 mL of water sample, 1 mL of sodium salicylate was added and evaporated to dryness on water bath. The residue was treated with 1 mL of concentrated sulphuric acid and after 5-10 minutes 6 mL of distilled water and 7 mL of 30% NaOH solution were added. After development of yellow colour, the intensity was measured at 410nm and the results were expressed in μgL^{-1}.

4.1.13.Ammonical- nitrogen

To 25 mL of water sample, I mL phenol, I mL sodium nitropruside solution and 2.5 mL of oxidizing solution were added and kept at room temperature for about onehour till the colour develops fully. The intensity of colour developed was measured at 640nm. Ammonium chloride was used for making various standards. The results were expressed in μgL^{-1}.

4.1.14. Nitrite- nitrogen

To 45 mL of sample, 1 mL of sulphanilamide reagent was added and was well mixed. After 5 minutes, 1 mL of N-1-napthylethylenediamine dihydrochloride (NEDA) was added and well shaked. After 10 minutes, the intensity of the colour developed was measured at 543nm. The results were expressed in μgL^{-1}. Standard was prepared from sodium nitrite.

4.1.15.Ortho-phosphate phosphorus

The orthophosphate phosphorus concentration was estimated by molybdenum blue method. To 50 mL of water sample 4 mL of ammonium molybdate and 0.5 mL of stannous chloride was added. The intensity of blue colour developed was measured after 10 but before 20 minutes at 690 nm spectrophotometrically (Systronics-116). Potassium dihydrogen phosphate was used for making various standards. The results were expressed in $\mu g\ L^{-1}$.

4.1.16.Biochemical oxygen demand

Biochemical oxygenwasdetermined by modified Winkler's method. Initially the sample was aerated then one ml each of phosphate buffer, magnesium sulphate, calcium chloride and ferric chloride solutions are added to it. The sample was then incubated for five days at temperature25°C and fixation of the dissolved oxygen was done on spot by collecting the water sample in 300 mLafter that 1 ml each of manganous sulphate and alkali iodide-azide was added. The bottle was tightly stopped and inverted for few times to mix the reagents thoroughly. The precipitate formed was dissolved by addition of 1ml of concentrated sulphuric acid. 50 mL of the sample was then taken and titrated against 0.025N sodium thiosulphate using starch as indicator. The BODwas calculated from the given formula and the results were expressed in mgL^{-1}.

$$\text{BOD mg/l} = (D_0 - D_1) - (C_0 - C_1)\ \text{mg} \times \text{decimal fraction of sample used}$$

Where

D_0=DO in the sample bottleon 0^{th} day

D_1=DO in the sample bottleon 5^{th} day

C_0 = DO in the blank bottleon 0th day

C_1 = DO in the blank bottleon 5th day

4.2. Macroinvertebrate Analysis

4.2.1. Collection and preservation

The benthic macroinvertebrates were obtained with the help of D-net having 0.2mm mesh size. The organisms were collected while disturbing the substratum by kicking or forcing ahead the net (Hoffsten and Malmqvist, 2002). The samples were also taken by sweeping the top substrate of half a square meter once or twice ahead of D-net (Ilmonen and Pasivirta, 2005). The organisms were sorted out and the material was passed through a sieve (mesh size 500µm) and preserved in 4% formalin and 70% alcohol depending on the type of organisms to be preserved. The soft- bodied organisms were preserved in 70% alcohol while the shelled organisms like mollusks in 4% formalin (Borror *et al.*, 1976).

4.2.2. Identification

The identification of specimens was done under stereo-microscope with the help of standard taxonomical works (Edmondson, 1959; Borror *et al.*, 1976; Pennak, 1978; McCafferty, 1981; Ward, 1992; Engblom and lingdell, 1999; Yildiz and Balik, 2005).

4.2.3. Counting

The organisms so collected were countedand density was documented as follows:

Density (ind./m^2) = No of individuals collected/Area disturbed(m^2)

4.3. Diversity Indices

4.3.1. Shannon-Weiner diversity index($H^/$)

Species diversity was determined after Shannon-Weiner (1949) as:

$$H^{/} = -\sum_{i=1}^{i=s}\left(\frac{ni}{N}\right)\log e\left(\frac{ni}{N}\right)$$

$H^{/}$= Index of species diversity

n_i = Density of one species

N = Density of all the species

e = Base of natural logarithm $-$ = 2.303 10 $-$

$-\sum$ $-$ $-$ Addition of the expression for values of *i* from *i* = 1 to *i* = S

4.3.2.Sorensen's similarity index

The community coefficient was calculated using Sorensen's similarity Index (Sorensen, 1948) as: S= 2C/A+B

Where

C= Number of common species

A= Number of species in A

B= Number of species in B

4.3.3. Margalef's index

This index was given by Margalf in 1969.It is an attempt to estimate species richness independently of the sample size.The index is given as:

$I_{Margalef} = (S - 1) / \ln(N)$

OR

$I_{\mathrm{Margalef}} = (S-1)2.303X\log_{10}N$

Where,

S=No. of species

N=Total No. of individuals of all species

Chapter- 5

RESULTS

5.1. Physico-chemical Characteristics of Water

5.1.1. pH

During the study period all the investigated springs depicted alkaline pH with values remaining always more than seven (7). The monthly variation of pH values ranged from a minimum of 7.02 at Khee in March, 2011 to a maximum of 7.48 at Katrooso in January, 2012.The mean seasonal variation in the pH values showed constant increasing trend from spring to winter for all the selected sites. It varied from 7.1±0.08 at Khee (spring) to 7.4± 0.1 at Katroso (winter). The annual mean values for pH fluctuated from a minimum of 7.17 ±0.1 at Khee to a maximum of 7.22 ± 0.1 at Katrooso. The other springs occupied intermediate positions between the two extremes (Table 5.1.1 and Fig.5.1.1).

5.1.2. Conductivity

Conductivity represents the total dissolved solids in water column. It ranged from a minimum of 164 μScm^{-1} at Qoimoh in April, 2011 to a maximum of 304 μScm^{-1} at parigam in December, 2011. The data revealed that there was a definite seasonal trend with warmer months recording lower values and colder months recording higher values for conductivity. Seasonally it fluctuated between the lowest mean value (174±10μScm^{-1}) at Qoimoh in spring and the highest (284.3±20.5μScm^{-1}) at Parigam in winter. However, the annual mean values of conductivity varied from a minimum of 207.3±26.02 μScm^{-1} at Khee to a maximum of 245.17±37.85 μScm^{-1} at Parigam. The other springs occupied intermediate positions between the two extremes (Table 5.1.2 and Fig. 5.1.2).

5.1.3. Water temperature

The water temperature did not fluctuate much and remained low through out the study period. In general, the monthly variation of water temperature ranged from a minimum of 6.5°C at Kulgam in January, 2012 to a maximum of 11°C at Parigam in August, 2011. Seasonally temperature fluctuated between the lowest mean value 7.1 ±0.43°C at Qoimoh in winter and the highest 10.4±0.72°C at Parigam in summer. On the basis of annual mean values of water temperature the maximum value was recorded at Parigam (8.79±1.3°C), followed by Kulgam (8.69±1.24°C), Khee

(8.65±1.18°C), Katrooso (8.55±1.16°C) and decreasing to a minimum of (8.55±1.16°C) at Qoimoh (Table 5.1.3 and Fig. 5.1.3.).

5.1.4. Free carbon dioxide

The free carbon dioxide varied from a minimum of 4.2 mg/L at Qoimoh in July, 2011 to a maximum of 8.6 mg/L at Parigam in March, 2011. However, on the basis of seasonal mean values, free carbon dioxide was highest (8.26±0.41 mg/L) in spring at Parigam and lowest (4.4 ±0.17 mg/L) in autumn at Qoimoh. The annual mean values fluctuated from a minimum of (5.53±1.26 mg/L) at Qoimoh to a maximum of (6.86±1.07 mg/L) at Parigam. The other springs occupied the intermediate positions between two extremes. (Table 5.1.4 and Fig. 5.1.4).

5.1.5. Alkalinity

Alkalinity of water was represented by carbonates and bicarbonates. In general, alkalinity varied from a minimum of 76 mg/L at Khee in September, 2011 to a maximum of 148 mg/L at Parigam in January, 2012. However, the lowest (86±11.13 mg/L) and highest (142±5.29 mg/L) seasonal mean values were recorded in autumn (Khee) and winter (Parigam) respectively. A comparison of springs on the basis of annual mean values revealed Parigam (125.17±18.13 mg/L), ranked first, followed by Katrooso (116.42±18.13mg/L), Qoimoh (113.17±17.13mg/L), Kulgam (112.75±18.56 mg/L), and Khee (112.67± 19.19 mg/L) in a decending order (Table 5.1.5 and Fig. 5.1.5).

5.1.6. Total hardness

Total hardness varied from a minimum of 122 mg/L at Khee in July, 2011 to a maximum of 288 mg/L at Parigam in January, 2012. However, the seasonal mean values fluctuated between the lowest mean value (127.33±6.11 mg/L) at Khee in summer and the highest (258.67±27.68 mg/L) at Parigam in winter. On the other hand, the annual mean value of hardness was recorded to be maximum for Parigam (219.58±31.79 mg/L) followed by Qoimoh (199.42±25.69 mg/L), Kulgam (199.08±22.30 mg/L), Katrooso (192.5±34.69 mg/L) and decreasing to a minimum at Khee (166.58±40.58 mg/L) (Table 5.1.6 and Fig. 5.1.6).

5.1.7. Calcium hardness

Calcium hardness varied from the lowest 82 mg/L at Khee in July, 2011 to the highest 208 mg/L at parigam in January, 2012. However, the lowest (89.66±6.8 mg/L) and the highest (189.33±20.13 mg/L) seasonal mean values were recorded in summer (Khee) and winter (Parigam) respectively. A significant spatial variations were observed for calcium hardness on the basis of annual mean values. The maximum value was observed at Parigam (162.08±28.45 mg/L), followed by Qoimoh (140.83±22.20 mg/L), Kulgam (138.58±16.16 mg/L), Katrooso (136.75±29.76 mg/L) and Khee (109.75±23.43 mg/L) in a decreasing order (Table 5.1.7 and Fig.5.1.7).

5.1.8. Magnesium hardness

The monthly variation of magnesium hardness ranged from a minimum of 32 mg/L at Khee in April, 2011 to a maximum of 99 mg/L at Qoimoh in January, 2012. However, on the basis of seasonal maean values, magnesium hardness was the highest (73.66 ±22.74mg/L) in winter at Qoimoh and the lowest (45±16.82 mg/L) in spring at Khee. A comparison of the springs on the basis of annual mean values of magnesium hardness, Qoimoh (60±13.49 mg/L) ranked first, followed by Kulgam (59.58±8.64 mg/L), Parigam (57.5±10.65mg/L), Katrooso (55.75±8.82mg/L) and Khee (54.92±16.52 mg/L) in a decreasing order (Table 5.1.8 and Fig. 5.1.8).

5.1.9. Chloride

Spring waters are enriched by chloride mainly of anthropogenic activity and underlying rocks as salts of sodium, potassium and calcium. Chloride content fluctuated between a minimum of 14 mg/L at Qoimoh in December, 2011 and a maximum of 44 mg/L at Parigam in June, 2011. Seasonal mean values of chloride showed highest concentration (35±9mg/L) at Parigam in summer as against the lowest concentration of (16.66±2.51mg/L) at Qoimoh in winter. However, a comparison of the springs on the basis of annual mean values. Parigam (27.08 ±7.92 mg/L) ranked first followed by Kulgam (23.75±4 mg/L), Katrooso (23.58±3.96 mg/L), Khee (22±2.21 mg/L) and Qoimoh (20.5± 3.89 mg/L) in decreasing order (Table 5.1.9 and Fig. 5.1.9.).

5.1.10. Dissolved oxygen

Dissolved oxygen content of the investigated spring waters remained low throughout the study period, due to the lack of interaction with surface. It ranged from a minimum of 2,8 mg/L at Khee in October,2011 to maximum of 7 mg/L at Kulgam in January, 2012. Seasonally, it fluctuated between the lowest mean value of (3.4±0.52 mg/L) at Khee in Autumn and the highest (6.46±0.61 mg/L) at Kulgam in winter. However, the highest annual mean value for dissolved oxygen (5.65±0.8 mg/L) was recorded for Kulgam, followed by Parigam (5±0.68 mg/L), Qoimoh (4.72±1.05 mg/L), Katrooso (4.45±0.67 mg/L) and decreasing to a minimum (4.1±5.3 mg/L) at Khee. (Table 5.1.10 and Fig. 5.1.10).

5.1.11. Biochemical oxygen demand

The monthly variation in BOD during the study period varied from a minimum of 0.1 mg/L at Khee in January 2012 to a maximum of 1.6 mg/L at Parigam in July, 2011. However, the seasonal mean values ranged from a minimum of (0.2±0.1 mg/L) at khee in winter as against the maximum of (1.5±0.1 mg/L) at parigam in summer. The annual mean values fluctuated from a minimum of (0.45±0.24 mg/L) at Khee to a maximum of (1.06±0.4 mg/L) at parigam. Other springs occupied the intermediate positions between the two extremes. (Table 5.1.11 and Fig. 5.1.11).

5.1.12. Ammonical nitrogen

During the study period, the minimum value of ammonical nitrogen was recorded to be 33µg/L at Qoimoh in March, 2011, against a maximum value of 112µg/L at Parigam in August, 2011. The seasonal mean values fluctuated between a maximum of 38.66±5.13µg/L at Qoimoh in spring and amaximum of 98.66±5.03µtg/L at parigam in winter. However, the annual mean data revealed that the maximum value was found at Parigam (79.25 ±24.61 µg/L) followed by Katrooso (70.91±18.06 µg/L), Qoimoh (66±20.56 µg/L), Khee (64.5±17.16 µg/L) and Kulgam (64.25±14.64 µg/L) in a decreasing order (Table 5.1.12 and Fig.5.1.12).

5.1.13. Nitrate nitrogen (–)

Nitrate nitrogen is the most available form of nitrogen to the aquatic plants as it can be readily utilized by them. On monthly basis nitrate-nitrogen showed a variation from a minimum of 470 µg/L at Kulgam in April, 2011 to a maximum of 2180 µg/L at Parigam in December, 2011. The seasonal mean values fluctuated between the lowest 811.67±75.88 µg/L (Kulgam) in autumn and the highest 1918.3±310.8 µg/L (Parigam) in winter. A significant spatial variations were observed for nitrate nitrogen on the basis of annual mean values. The maximum value was observed at Parigam (1544.6±309.07 µg/L), followed by Khee (1090.7±209.13 µg/L), Kulgam (1066.6±281.25 µg/L), Katrooso (1053.8±271.432 µg/L) and Qoimoh (1037.9±175.27 µg/L) in a decreasing order (Table 5.1.13 and Fig. 5.1.13.).

5.1.14. Nitrite nitrogen (–)

Nitrite nitrogen varied from a minimum of 3.4 µg/L at Khee in January, 2012 to a maximum of 12.5 µg/L at parigam in July, 2012.The seasonal mean values ranged from a minimum of 4.96±0.58 µg/L (Khee) in autumn to a maximum of 11.9±0.65 µg/L (Parigam) in summer. However, comparing the springs on the basis of annual mean values, the highest value of nitrite nitrogen was observed at Parigam (10.11±1.30 µg/L) as against the lowest recorded at Khee (5.46±1.02 µg/L).The other springs occupied the positions between the two extrems. (Table 5.1.14 and Fig. 5.1.14).

5.1.15. Ortho-phosphate phosphorus (OPP)

During the study period, ortho-phosphate phosphorus varied from a minimum of 24µg/L (Khee) in the month of September, 2011 to a maximum of 196µg/L (Parigam) in the month of January, 2012. However, minimum seasonal mean value for ortho-phosphate phosphorus was recorded in autumn (50±27.05µg/L) at Khee against the maximum value of (189.6±11.93µg/L) at Parigam in winter. A comparison of the springs on the basis of annual mean values, revealed Parigam (164.67± 18.54µg/L) ranked first, followed by Kulgam (128± 18.62µg/L), Qoimoh (112.25± 16.97µg/L), Katrooso (87.16 ± 29.24µg/L) and Khee (67.33 ± 27.83µg/L) in a decreasing order (Table 5.1.15 and Fig. 5.1.15)

5.1.16. Sulphate

During the study period, the minimum value of sulphate was recorded to be 1.1 mgL (Qoimoh) in July, 2011 against a maximum value of 3.4 mg/L (Parigam) in January, 2012. The seasonal mean values fluctuated between a minimum of 1.26±0.2mg/L at Qoimoh in summer and a maximum of 3.76± 0.55 mg/L at Parigam in winter. However, the annual mean data revealed that maximum value was recorded at Parigam (2.46± 0.56 mg/L), followed by Kulgam (2.07± 0.24 mg/L), Qoimoh (1.79± 0.44 mg/L), Katrooso (1.77± 0.29mg/L) and Khee (1.48± 0.25 mg/L) in a decreasing order (Table 5.1.16 and Fig. 5.1.16).

5.1.17. Heavy metals

The concentration of five heavy metals namely chromium (Cr) nickel (Ni), lead (Pb), zinc (Zn) and iron (Fe) were also recorded in spring water samples. The concentration of lead (Pb) ranged from a minimum of 0.001 ppm (Qoimoh and Khee) to a maximum of 0.015 ppm (Parigam), zinc (Zn) concentration ranged from a minimum of 0.0003 ppm (Katrooso) to a maximum of 0.007 ppm (Parigam), iron(Fe) concentration ranged from a minimum of 0.0001 ppm (Katrooso) to a maximum of 0.003 (Parigam), nickel(Ni) concentration ranged from a minimum of 0.00068 ppm (Khee) to a maximum of 0.0026 ppm (Parigam) and chromium(Cr) concentration ranged from a minimum of 0.0019 ppm (Qoimoh) to a maximum of 0.0027 ppm (Katrooso, Khee and Kulgam). However, the concentration of all the investigated heavy metals were found to be well within WHO permissible limits (Table 5.1.17 and Fig. 5.1.17).

Table 5.1.1: Monthly, seasonal and annual mean variations in pH of springs during March 2011- Feb. 2012

	Spring					Summer				
Sites	**March**	**April**	**May**	**Mean**	**SD**	**June**	**July**	**Aug**	**Mean**	**SD**
Qoimoh	7.17	7.10	7.18	**7.15**	**0.04.**	7.08	7.03	7.15	**7.08**	**0.06**
Parigam	7.08	7.13	7.16	**7.12**	**0.04**	7.03	7.11	7.10	**7.08**	**0.04**
Katroso	7.24	7.08	7.14	**7.15**	**0.08**	7.09	7.11	7.22	**7.14**	**0.07**
Khee	702	7.18	7.11	**7.10**	**0.08**	7.04	7.02	7.17	**7.07**	**0.08**
Kulgam	7.11	7.14	7.08	**7.11**	**0.03**	7.02	7.12	7.21	**7.11**	**0.09**

	Autumn					Winter					AM	SD
	Sept.	**Oct.**	**No.**	**Mean**	**SD**	**Dec.**	**Jan.**	**Feb.**	**Mean**	**SD**		
Qoimoh	7.23	7.26	7.30	**7.26**	**0.03**	7.45	7.28	7.20	**7.31**	**0.12**	**7.20**	**0.11**
Parigam	7.17	7.23	7.38	**7.26**	**0.10**	7.36	7.33	7.11	**7.26**	**0.13**	**7.18**	**0.11**
Katroso	7.32	7.22	7.21	**7.25**	**0.06**	7.28	7.48	7.32	**7.36**	**0.10**	**7.22**	**0.11**
Khee	7.24	7.33	7.28	**7.28**	**0.04**	7.34	7.24	7.14	**7.24**	**0.10**	**7.17**	**0.11**
Kulgam	7.27	7.25	7.32	**7.28**	**0.03**	7.35	7.42	7.22	**7.33**	**0.10**	**7.20**	**0.12**

AM = Annual Mean

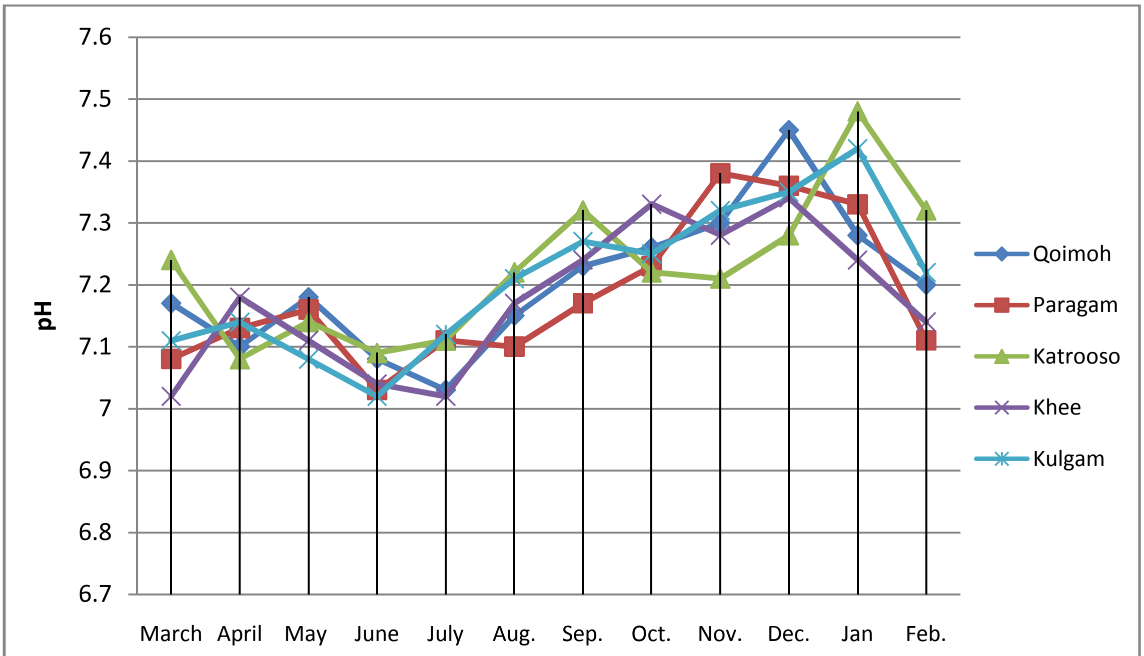


Fig. 5.1.1: Monthly variations of pH in five selected springs during the study period.

Table 5.1.2: Monthly, seasonal and annual mean variations in conductivity (µS/cm) of springs during March 2011- Feb. 2012

	Spring					Summer				
Sites	**March**	**April**	**May**	**Mean**	**SD**	**June**	**July**	**Aug**	**Mean**	**SD**
Qoimoh	186	164	174	**174.6**	**11.0**	194	208	200	**200.6**	**7.0**
Parigam	215	194	182	**197.0**	**16.7**	233	242	286	**253.6**	**28.3**
Katroso	176	182	166	**174.6**	**8.0**	188	212	228	**209.3**	**20.1**
Khee	188	166	178	**177.3**	**11.0**	208	238	224	**223.3**	**15.0**
Kulgam	210	182	174	**188.6**	**18.9**	205	234	252	**230.3**	**23.7**

	Autumn					Winter					AM	SD
Sites	**Sept.**	**Oct.**	**Nov.**	**Mean**	**SD**	**Dec.**	**Jan.**	**Feb.**	**Mean**	**SD**		
Qoimoh	214	194	222	**210.0**	**14.4**	244	264	228	**245.3**	**18.3**	**207.6**	**28.7**
Parigam	245	224	268	**245.6**	**22.0**	304	286	263	**284.3**	**20.5**	**245.1**	**37.8**
Katroso	218	196	211	**208.3**	**11.2**	242	248	221	**237.0**	**14.1**	**207.3**	**26.0**
Khee	234	200	234	**222.6**	**19.6**	254	245	217	**238.6**	**19.2**	**215.5**	**27.8**
Kulgam	238	206	234	**226.0**	**17.4**	284	254	238	**258.6**	**23.3**	**225.9**	**31.6**

AM = Annual Means

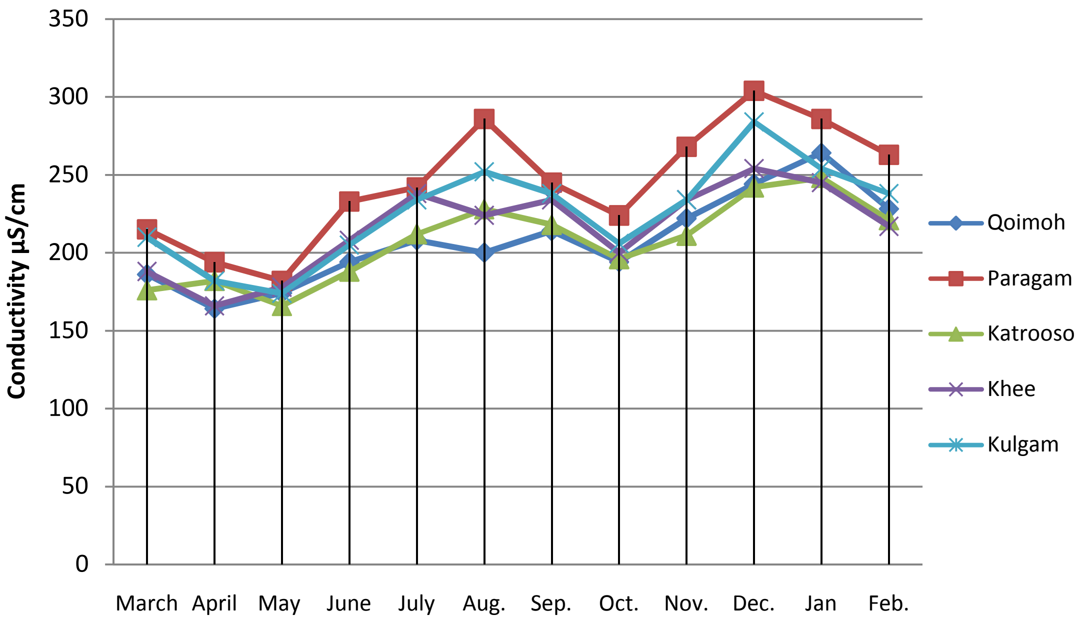


Fig. 5.1.2: Monthly variations in conductivity µS/cm of five selected springs during the study period.

Table 5.1.3: Monthly seasonal and annual mean variations in water temperature (^{0}C) of springs March 2011-Feb. 2012

	Spring					Summer				
Sites	**March**	**April**	**May**	**Mean**	**SD**	**June**	**July**	**Aug**	**Mean**	**SD**
Qoimoh	7.6	8.3	8.6	**8.1**	**0.4**	9.3	9.8	10.4	**9.8**	**0.5**
Parigam	7.8	8.4	8.6	**8.2**	**0.5**	9.6	9.9	10.6	**10.0**	**0.5**
Katroso	7.5	8.5	8.8	**8.2**	**0.6**	9.6	9.8	10.6	**10.0**	**0.5**
Khee	7.7	8.4	8.7	**8.2**	**0.5**	9.4	9.7	10.8	**9.9**	**0.7**
Kulgam	7.6	8.6	8.8	**8.3**	**0.6**	9.5	9.9	10.8	**10.0**	**0.6**

	Autumn					Winter					AM	SD
Sites	**Sept.**	**Oct.**	**Nov.**	**Mean**	**SD**	**Dec.**	**Jan.**	**Feb.**	**Mean**	**SD**		
Qoimoh	9.7	9.2	8.5	**9.1**	**0.6**	7.4	6.6	7.3	**7.1**	**0.4**	**8.5**	**1.1**
Parigam	9.8	9.3	8.6	**9.2**	**0.6**	7.6	6.8	7.4	**7.2**	**0.4**	**8.7**	**1.1**
Katroso	9.4	9.1	8.5	**9.0**	**0.4**	7.6	6.8	7.4	**7.2**	**0.4**	**8.6**	**1.1**
Khee	9.7	9.3	8.6	**9.2**	**0.5**	7.4	6.7	7.5	**7.2**	**0.4**	**8.6**	**1.2**
Kulgam	9.8	9.2	8.6	**9.2**	**0.6**	7.4	6.5	7.6	**7.1**	**0.5**	**8.6**	**1.2**

AM = Annual Mean

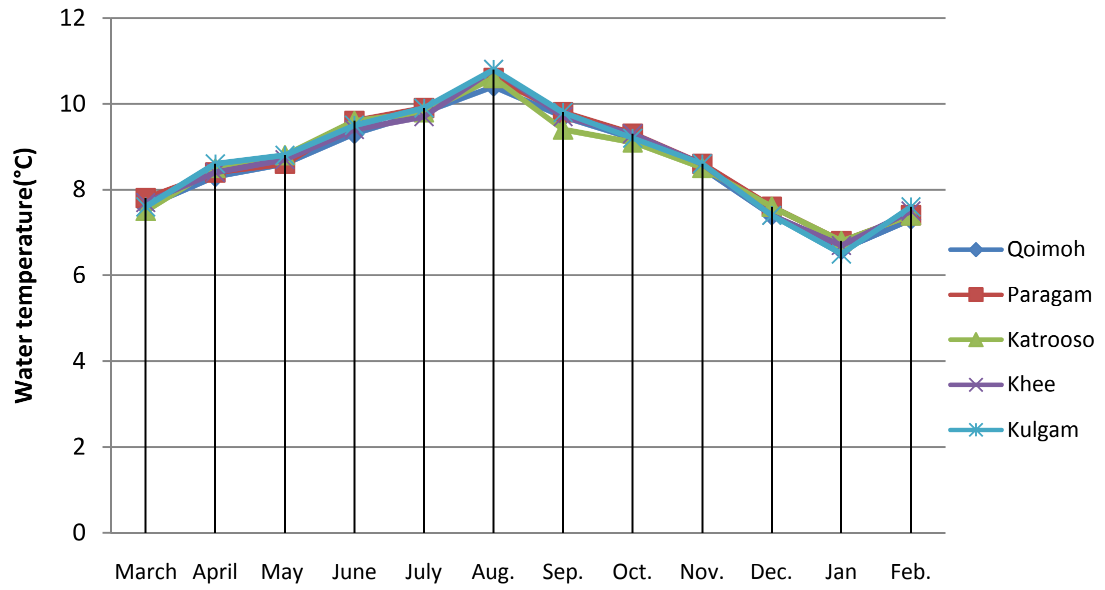


Fig. 5.1.3: Monthly variations in water temerature(°C) of five selected springs during the study period.

Table 5.1.4: Monthly, seasonal and annual mean variations in free carbon dioxide (mg/L) of springs during March 2011- Feb. 2012

	Spring					**Summer**				
Sites	**March**	**April**	**May**	**Mean**	**SD**	**June**	**July**	**Aug**	**Mean**	**SD**
Qoimoh	7.4	7.8	5.6	**6.9**	**1.1**	5.1	4.2	4.6	**4.6**	**0.4**
Parigam	8.6	8.4	7.8	**8.2**	**0.4**	7.2	6.3	5.6	**6.36**	**0.8**
Katroso	7.2	6.3	6.7	**6.7**	**0.4**	5.7	5.4	5.2	**5.43**	**0.2**
Khee	7.3	6.6	6.4	**6.7**	**0.4**	5.8	5.5	5.6	**5.63**	**0.1**
Kulgam	8.2	7.5	7.8	**7.8**	**0.3**	6.2	5.8	5.4	**5.80**	**0.4**

	Autumn					**Winter**					**AM**	**SD**
Sites	**Sept.**	**Oct.**	**Nov.**	**Mean**	**SD**	**Dec.**	**Jan.**	**Feb.**	**Mean**	**SD**		
Qoimoh	4.2	4.3	4.6	**4.3**	**0.2**	5.4	6.4	6.7	**6.1**	**0.6**	**5.5**	**1.2**
Parigam	5.4	5.7	6.2	**5.7**	**0.4**	6.6	7.4	7.2	**7.0**	**0.4**	**6.8**	**1.0**
Katroso	5.2	4.8	5.3	**5.1**	**0.2**	6.1	6.6	6.8	**6.5**	**0.3**	**5.9**	**0.7**
Khee	5.3	4.7	4.3	**4.7**	**0.5**	5.2	6.4	6.5	**6.0**	**0.7**	**5.8**	**0.8**
Kulgam	4.8	5.3	5.8	**5.3**	**0.5**	6.3	6.7	7.4	**6.8**	**0.5**	**6.4**	**1.0**

AM = Annual Mean

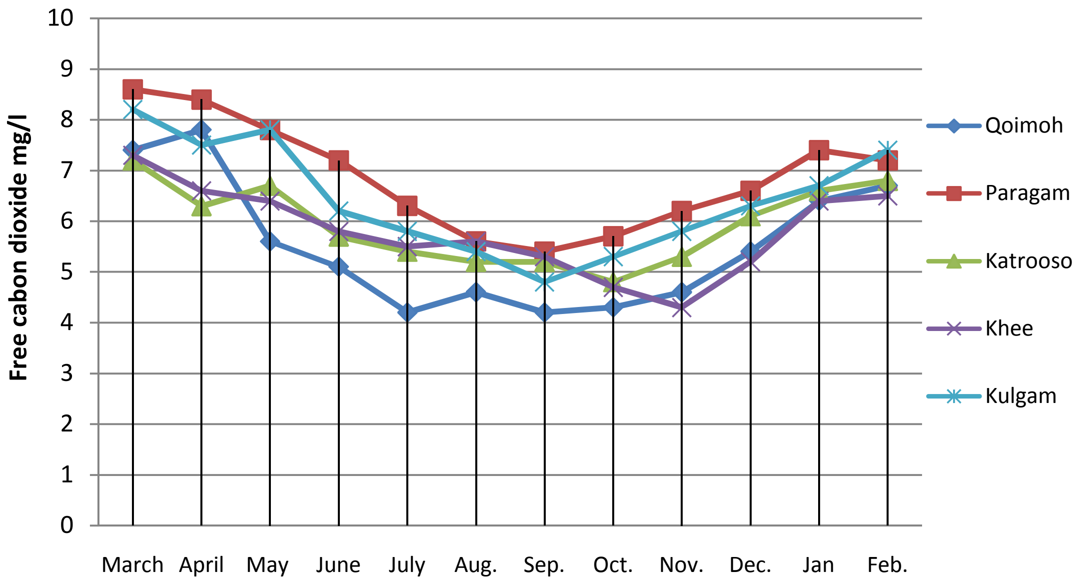


Fig. 5.1.4: Monthly variatbons in free carbon dioxide mg/L of five selected springs during the study period.

Table 5.1.5: Monthly, seasonal and annual mean variations in alkalinity (mg/L) of springs during March 2011-Feb. 2012

	Spring					Summer				
Sites	**March**	**April**	**May**	**Mean**	**SD**	**June**	**July**	**Aug**	**Mean**	**SD**
Qoimoh	124	129	118	**123.6**	**5.50**	112	103	96	**103.6**	**8.0**
Parigam	138	140	136	**138.0**	**2.0**	128	112	99	**113.0**	**14.5**
Katroso	130	133	123	**128.6**	**5.1**	108	100	88	**98.6**	**10.0**
Khee	117	126	108	**116.0**	**9.1**	100	82	78	**86.6**	**11.7**
Kulgam	128	133	122	**127.6**	**5.5**	116	103	88	**102.3**	**14.0**

	Autumn					Winter					AM	SD
Sites	**Sept.**	**Oct.**	**Nov.**	**Mean**	**SD**	**Dec.**	**Jan.**	**Feb.**	**Mean**	**SD**		
Qoimoh	84	92	106	**94.0**	**11.1**	124	138	132	**131.3**	**7.0**	**113.1**	**17.13**
Parigam	96	103	124	**107.6**	**14.5**	138	148	140	**142.0**	**5.2**	**125.1**	**18.13**
Katroso	92	100	118	**103.3**	**13.3**	129	140	136	**135.0**	**5.5**	**116.4**	**18.13**
Khee	76	84	98	**86.0**	**11.1**	114	128	124	**122.0**	**7.2**	**102.6**	**19.19**
Kulgam	82	89	108	**93.0**	**13.4**	121	136	127	**128.0**	**7.5**	**112.7**	**18.56**

AM = Annual Mean

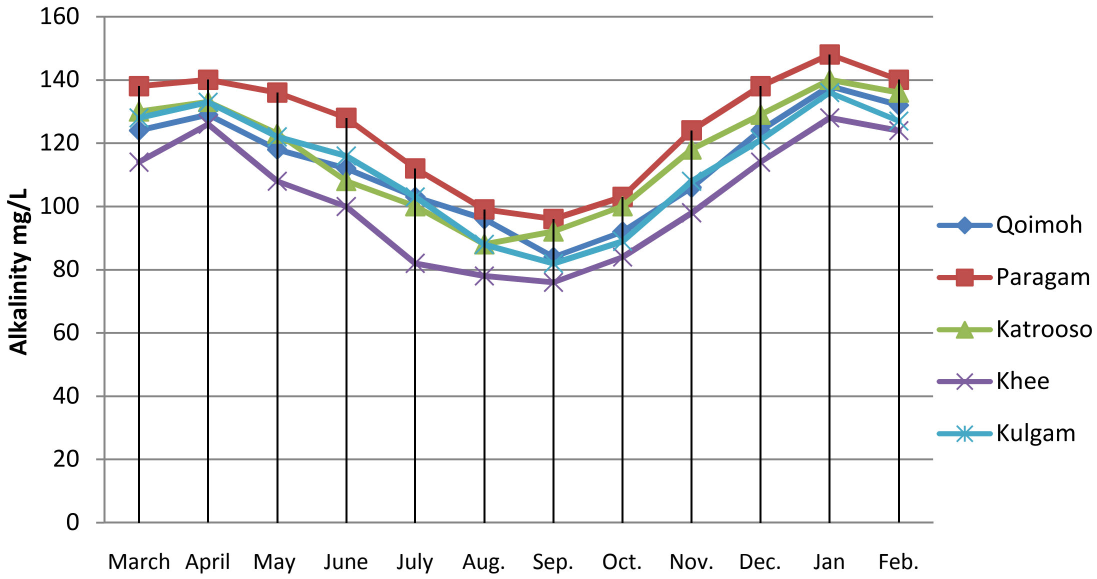


Fig. 5.1.5: Monthly variations in alkalinity mg/L of five selected springs during the study period.

Table 5.1.6: Monthly, seasonal and annual mean variations in total hardness as CaCo$_3$ (mg/L) of springs during March 2011-Feb. 2012

	Spring					Summer				
Sites	**March**	**April**	**May**	**Mean**	**SD**	**June**	**July**	**Aug**	**Mean**	**SD**
Qoimoh	185	166	174	**175.0**	**9.5**	168	180	198	**182.0**	**15.0**
Parigam	194	178	185	**185.6**	**8.0**	192	218	204	**204.6**	**13.0**
Katroso	165	145	138	**149.3**	**14.0**	156	182	193	**177.0**	**19.0**
Khee	168	125	128	**140.3**	**24.0**	126	122	134	**127.3**	**6.1**
Kulgam	183	158	178	**173.0**	**13.2**	192	210	184	**195.3**	**13.3**

	Autumn					Winter					AM	SD
Sites	**Sept.**	**Oct.**	**Nov.**	**Mean**	**SD**	**Dec.**	**Jan.**	**Feb.**	**Mean**	**SD**		
Qoimoh	212	210	227	**216.3**	**9.3**	245	228	200	**224.3**	**22.7**	**199.4**	**25.7**
Parigam	228	222	238	**229.3**	**8.0**	255	288	233	**258.6**	**27.6**	**219.5**	**31.8**
Katroso	208	215	224	**215.6**	**8.0**	221	242	221	**228.0**	**12.1**	**152.5**	**34.6**
Khee	106	168	198	**177.3**	**17.9**	213	233	218	**221.3**	**10.4**	**166.5**	**40.5**
Kulgam	189	205	215	**203.0**	**13.1**	222	238	215	**225.0**	**11.7**	**199.0**	**22.3**

AM = Annual Mean

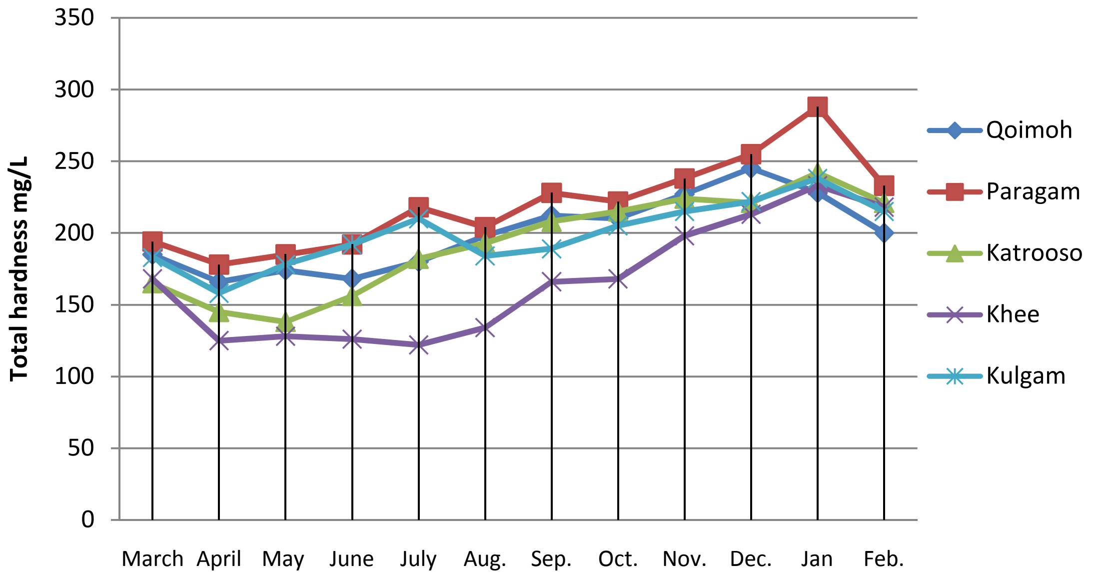


Fig. 5.1.6: Monthly variations in total hardness mg/L of five selected springs during the study period.

Table 5.1.7: Monthly, seasonal and annual mean variations in calcium hardness (mg/L) of springs during March 2011-Feb. 2012

	Spring					**Summer**				
Sites	**March**	**April**	**May**	**Mean**	**SD**	**June**	**July**	**Aug**	**Mean**	**SD**
Qoimoh	122	118	118	**119.3**	**2.3**	110	128	138	**125.3**	**14.2**
Parigam	139	117	124	**126.6**	**11.2**	135	156	166	**152.3**	**15.8**
Katroso	117	98	88	**101.0**	**14.7**	109	122	135	**122.0**	**13.0**
Khee	104	93	89	**95.3**	**7.7**	92	82	95	**89.6**	**6.8**
Kulgam	138	110	122	**123.3**	**14.0**	135	156	124	**138.3**	**16.2**

	Autumn					**Winter**					**AM**	**SD**
Sites	**Sept.**	**Oct.**	**Nov.**	**Mean**	**SD**	**Dec.**	**Jan.**	**Feb.**	**Mean**	**SD**		
Qoimoh	164	155	168	**162.3**	**6.6**	178	146	145	**156.3**	**18.7**	**140.8**	**22.2**
Parigam	178	174	188	**180.0**	**7.2**	192	208	168	**189.3**	**20.1**	**162.0**	**28.4**
Katroso	162	160	155	**159.0**	**3.6**	165	182	148	**165.0**	**17.0**	**136.7**	**29.7**
Khee	101	107	124	**110.0**	**11.9**	136	158	136	**143.3**	**12.7**	**109.7**	**23.4**
Kulgam	128	137	148	**137.6**	**10.0**	155	166	144	**155.0**	**11.0**	**138.6**	**16.2**

AM = Annual Mean

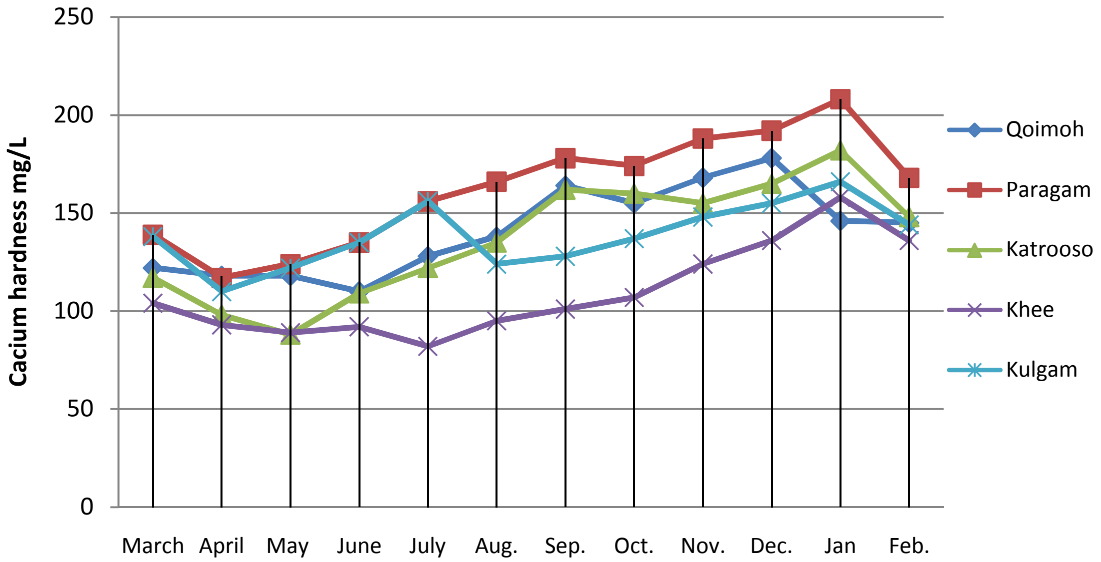


Fig. 5.1.7: Monthly variations in calcium hardness mg/L of five selected springs during the study period.

Table 5.1.8: Monthly, seasonal and annual mean variations in magnesium hardness (mg/L) of springs during March 2011-Feb. 2012

	Spring					Summer				
Sites	**March**	**April**	**May**	**Mean**	**SD**	**June**	**July**	**Aug.**	**Mean**	**SD**
Qoimoh	63	48	56	**55.6**	**7.5**	58	52	60	**56.6**	**4.2**
Parigam	55	61	61	**59.0**	**3.4**	57	62	38	**52.3**	**12.6**
Katroso	48	47	50	**48.3**	**1.5**	47	60	58	**55**	**7.0**
Khee	64	32	39	**45.0**	**16.8**	34	40	39	**37.6**	**3.2**
Kulgam	45	48	56	**49.6**	**5.6**	57	54	60	**57**	**3.0**

	Autumn					Winter					AM	SD
Sites	**Sept.**	**Oct.**	**Nov.**	**Mean**	**SD**	**Dec.**	**Jan.**	**Feb.**	**Mean**	**SD**		
Qoimoh	48	55	59	**54.0**	**5.5**	67	99	55	**73.6**	**22.7**	**60.0**	**13.5**
Parigam	50	48	50	**49.3**	**1.1**	63	80	65	**69.3**	**9.3**	**57.5**	**10.5**
Katroso	46	55	69	**56.6**	**11.5**	56	60	73	**63.0**	**8.8**	**55.7**	**8.8**
Khee	65	61	74	**66.6**	**6.6**	77	75	82	**78.0**	**3.6**	**56.8**	**8.8**
Kulgam	61	68	67	**65.3**	**3.7**	56	72	71	**66.3**	**8.9**	**59.6**	**8.6**

AM = Annual Mean

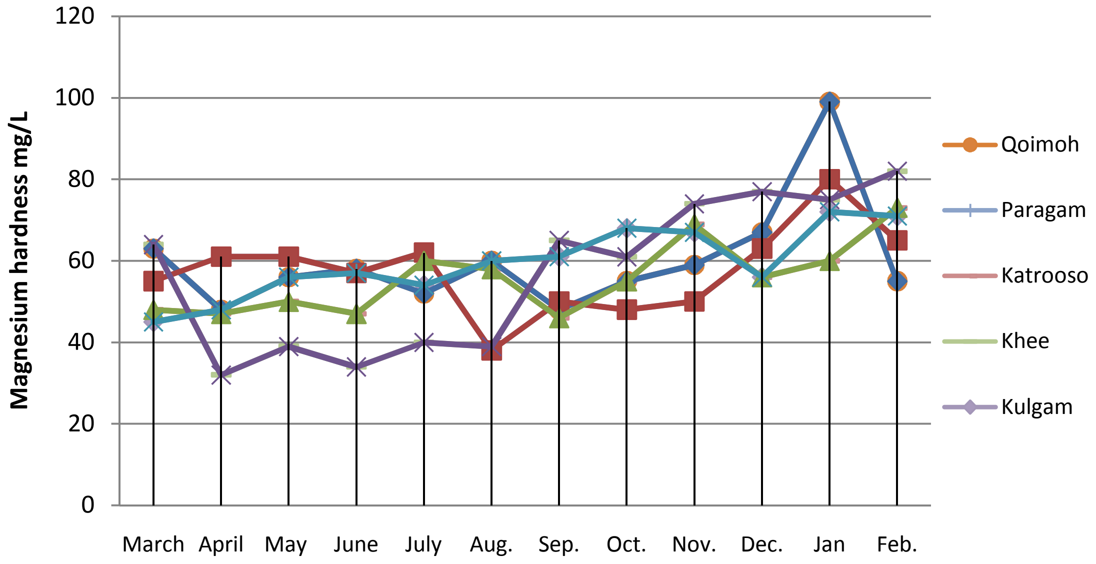


Fig. 5.1.8: Monthly variations in magnesium hardness mg/L of five selected springs of during study period.

Table 5.1.9: Monthly, seasonal and annual mean variations in chloride content (mg/L) of springs during March 2011-Feb 2012

	Spring					Summer				
Sites	**March**	**April**	**May**	**Mean**	**SD**	**June**	**July**	**Aug**	**Mean**	**SD**
Qoimoh	22	21	24	**22.3**	**1.5**	27	26	21	**24.6**	**3.2**
Parigam	28	32	34	**31.3**	**3.0**	44	35	26	**35**	**9.0**
Katroso	24	27	23	**24.6**	**2.0**	28	31	26	**28.3**	**2.5**
Khee	18	22	23	**21.0**	**2.6**	26	25	26	**24.3**	**2.0**
Kulgam	26	24	27	**25.6**	**1.5**	31	28	22	**27**	**4.5**

	Autumn					Winter					AM	SD
Sites	**Sept.**	**Oct.**	**Nov.**	**Mean**	**SD**	**Dec.**	**Jan.**	**Feb.**	**Mean**	**SD**		
Qoimoh	19	20	16	**18.3**	**14**	14	17	19	**16.6**	**2.5**	**20.5**	**3.8**
Parigam	22	21	17	**20.0**	**18**	18	23	25	**22.0**	**3.6**	**27.0**	**7.9**
Katroso	21	16	21	**19.3**	**22**	22	23	21	**22.0**	**1.0**	**23.5**	**3.9**
Khee	19	21	22	**20.6**	**23**	23	21	22	**22.0**	**1.0**	**22.0**	**2.2**
Kulgam	21	19	16	**18.6**	**22**	22	25	24	**23.6**	**1.5**	**23.7**	**4.0**

AM = Annual Mean

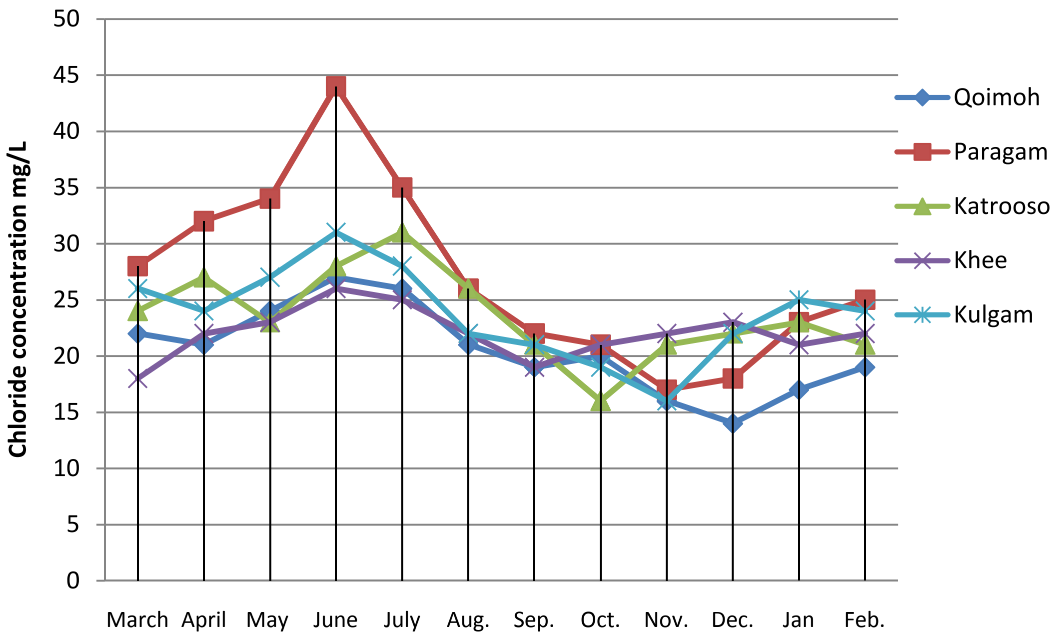


Fig. 5.1.9. Monthly variations in chloride concentration (mg/L) of five selected springs during the study peroiod.

Table 5.1.10: Monthly, seasonal and annual mean variations in dissolved oxygen (mg/L) of springs during March 2011-Feb. 2012

	Spring					Summer				
Sites	**March**	**April**	**May**	**Mean**	**SD**	**June**	**July**	**Aug.**	**Mean**	**SD**
Qoimoh	4.2	4.8	5.4	**4.8**	**0.6**	5.2	5.4	4.6	**5**	**0.4**
Parigam	4.6	4.4	5.8	**4.9**	**0.7**	5.8	6.2	5.4	**5.8**	**0.4**
Katroso	4	4.3	4	**4.1**	**0.2**	4.8	5.3	4.6	**4.9**	**0.3**
Khee	3.4	4.2	4.3	**3.9**	**0.5**	4.4	4	3.6	**4**	**0.4**
Kulgam	4.8	5.2	5.8	**5.2**	**0.5**	6.4	6	5.8	**6**	**0.3**

	Autumn					Winter					AM	SD
Sites	**Sept.**	**Oct.**	**Nov.**	**Mean**	**SD**	**Dec.**	**Jan.**	**Feb.**	**Mean**	**SD**		
Qoimoh	2.9	3.2	4.2	**3.4**	**0.6**	6.5	6	4.3	**5.6**	**1.1**	**4.7**	**1**
Parigam	4.4	4	5.2	**4.5**	**0.6**	4.5	4.8	5.4	**4.9**	**0.4**	**5**	**0.6**
Katroso	3.6	3.3	4.4	**3.7**	**0.5**	5	5.6	4.5	**5**	**0.5**	**4.4**	**0.6**
Khee	3.6	2.8	3.8	**3.4**	**0.5**	4.8	5.3	5.1	**5**	**0.2**	**4.1**	**0.7**
Kulgam	4.6	4	5.9	**4.8**	**0.9**	6.6	7	5.8	**6.4**	**0.6**	**5.6**	**0.8**

AM = Annual Mean

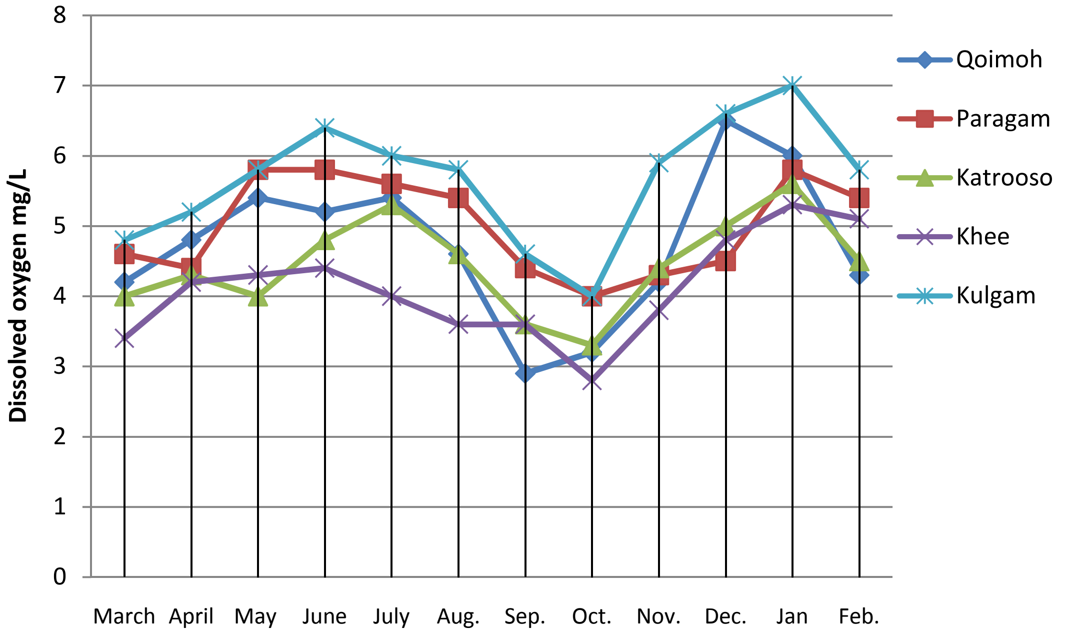


Fig. 5.1.10. Monthly variations in dissolved oxygen Mg/L of five selected springs during study period.

Table 5.1.11: Monthly, seasonal and annual mean variations in biochemical oxygen demand (mg/L) of springs during March 2011-Feb. 2012

	Spring					Summer				
Sites	**March**	**April**	**May**	**Mean**	**SD**	**June**	**July**	**Aug**	**Mean**	**SD**
Qoimoh	0.5	0.8	0.6	**0.6**	**0.1**	0.8	1.1	1.2	**1.0**	**0.2**
Parigam	1.1	1.2	1.3	**1.2**	**0.1**	1.5	1.6	1.4	**1.5**	**0.1**
Katroso	0.8	0.8	1.1	**0.9**	**0.1**	1.2	1.2	1.5	**1.3**	**0.1**
Khee	0.5	0.5	0.6	**0.5**	**0.0**	0.8	0.9	0.6	**0.7**	**0.1**
Kulgam	0.6	0.8	0.9	**0.7**	**0.1**	1.2	1.5	1.3	**1.3**	**0.1**

	Autumn					Winter					AM	SD
Sites	**Sept.**	**Oct.**	**Nov.**	**Mean**	**SD**	**Dec.**	**Jan.**	**Feb.**	**Mean**	**SD**		
Qoimoh	1.1	0.7	0.4	**0.7**	**0.3**	0.2	0.2	0.4	**0.2**	**0.1**	**0.6**	**0.3**
Parigam	1.2	1.1	0.9	**1**	**0.1**	0.4	0.3	0.8	**0.5**	**0.2**	**1**	**0.4**
Katroso	1.1	0.9	0.6	**0.8**	**0.2**	0.4	0.2	0.5	**0.3**	**0.1**	**0.8**	**0.3**
Khee	0.4	0.3	0.2	**0.3**	**0.1**	0.2	0.1	0.3	**0.2**	**0.1**	**0.4**	**0.2**
Kulgam	1.1	0.8	0.5	**0.8**	**0.3**	0.6	0.4	0.5	**0.5**	**0.1**	**0.8**	**0.3**

AM = Annual Mean

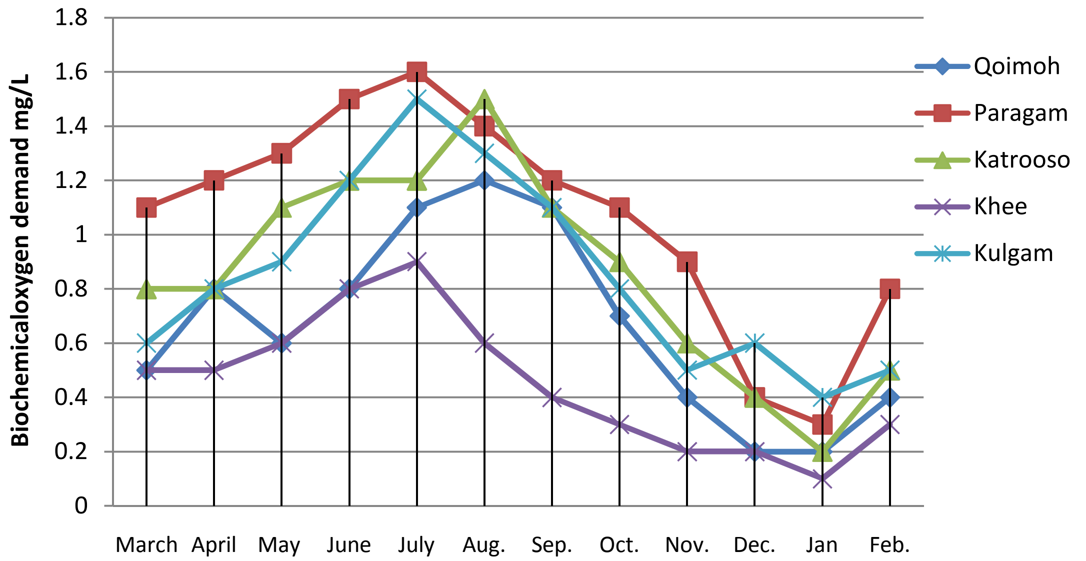


Fig. 5.1.11: Monthly variations in biochemical oxygen demand(mg/L) of five selected springs during the the study period.

Table 5.1.12: Monthly, seasonal and annual mean variations in ammonical-N (µg/L) of springs during March 2011-Feb. 2012

	Spring					Summer				
Sites	**March**	**April**	**May**	**Mean**	**SD**	**June**	**July**	**Aug**	**Mean**	**SD**
Qoimoh	33	43	40	**38.6**	**5.1**	54	78	99	**77.0**	**22.5**
Parigam	38	48	52	**46.0**	**7.2**	68	98	112	**92.6**	**22.4**
Katroso	45	53	65	**54.3**	**10.0**	76	89	88	**84.3**	**7.23**
Khee	42	49	62	**51.0**	**10.1**	68	84	83	**78.3**	**8.9**
Kulgam	45	54	64	**54.3**	**9.5**	69	75	78	**74.0**	**4.5**

	Autumn					Winter					AM	SD
Sites	**Sept.**	**Oct.**	**Nov.**	**Mean**	**SD**	**Dec.**	**Jan.**	**Feb.**	**Mean**	**SD**		
Qoimoh	74	58	68	**66.6**	**8.0**	74	89	82	**81.6**	**7.5**	**66.0**	**20.5**
Parigam	96	64	79	**79.6**	**16.0**	98	104	94	**98.6**	**5.0**	**79.25**	**24.6**
Katroso	84	42	55	**60.3**	**21.5**	77	89	88	**84.6**	**6.6**	**70.9**	**18.0**
Khee	68	38	45	**50.3**	**15.6**	72	85	78	**78.3**	**6.5**	**64.5**	**17.1**
Kulgam	74	34	54	**54.0**	**20.0**	68	83	73	**74.6**	**7.6**	**64.2**	**14.6**

AM = Annual Mean

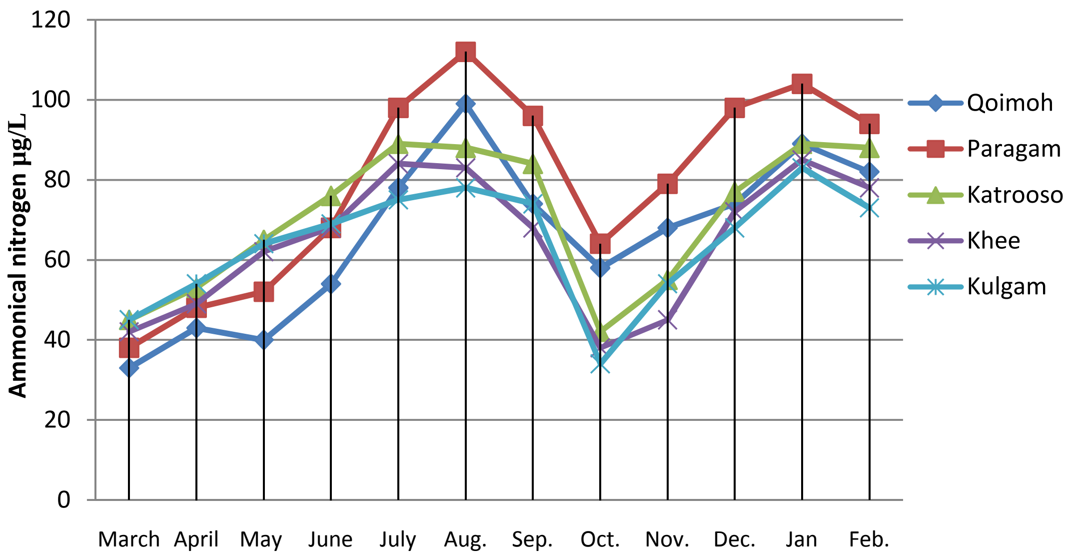


Fig. 5.1.12: Monthly variation in ammonical nitrogen µg/L of five selected springs during the study period.

Table 5.1.13: Monthly, seasonal and annual mean variations in nitrate-N (µg/L) of springs during March 2011-Feb. 2012

	Spring					Summer				
Sites	**March**	**April**	**May**	**Mean**	**SD**	**June**	**July**	**Aug**	**Mean**	**SD**
Qoimoh	1210	970	920	**1033.3**	**155.0**	1100	915	860	**958.3**	**125.7**
Parigam	1400	1170	2200	**1590.0**	**540.6**	1960	1210	1320	**1496.6**	**405.0**
Katroso	1010	870	1770	**1216.7**	**484.3**	1370	950	470	**930.0**	**450.3**
Khee	935	1120	1660	**1238.3**	**376.7**	1445	1180	800	**1141.6**	**324.2**
Kulgam	1090	670	950	**903.3**	**213.9**	1010	1220	780	**1003.3**	**220.0**

	Autumn					Winter					AM	SD
Sites	**Sept.**	**Oct.**	**Nov.**	**Mean**	**SD**	**Dec.**	**Jan.**	**Feb.**	**Mean**	**SD**		
Qoimoh	910	765	1100	**925.0**	**168.0**	1320	1285	1100	**1235.0**	**118.2**	**1037.9**	**175.2**
Parigam	1980	1760	1550	**1763.3**	**215.0**	2080	2115	1560	**1918.3**	**310.8**	**1692.1**	**370.8**
Katroso	810	690	960	**820.0**	**135.2**	1350	1285	1100	**1245.0**	**129.7**	**1052.9**	**349.5**
Khee	1210	760	1120	**1030.0**	**238.1**	1420	1520	908	**1282.7**	**328.3**	**1173.2**	**279.3**
Kulgam	730	880	825	**811.6**	**75.8**	1180	1275	1064	**1173.0**	**105.7**	**972.8**	**190.9**

AM = Annual Mean

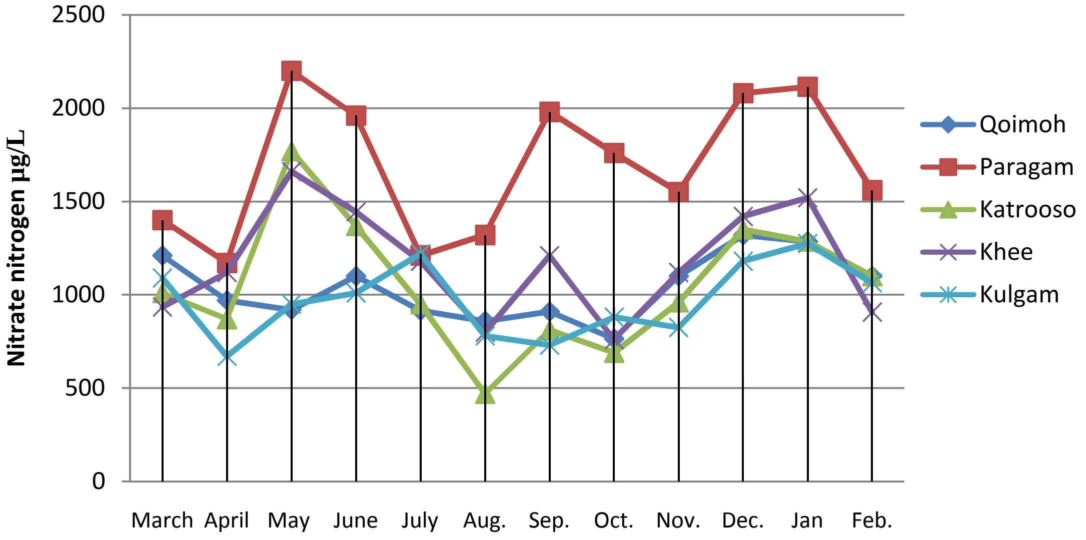


Fig. 5.1.13: Monthly variations in nitrate nitrogen µg/L of five selected springs during the study period.

Table 5.1.14: Monthly, seasonal and annual mean variations in nitrite-N (µg/L) of springs during March 2011-Feb. 2012

	Spring					Summer				
Sites	**March**	**April**	**May**	**Mean**	**SD**	**June**	**July**	**Aug.**	**Mean**	**SD**
Qoimoh	6.18	8	7.4	**7.2**	**0.9**	7.9	8.4	7.6	**7.7**	**0.2**
Parigam	9.32	10	8.8	**9.3**	**0.6**	12	12.5	11.2	**11.9**	**0.6**
Katroso	6.1	7.4	8	**7.2**	**0.9**	9	9.6	7.6	**8.73**	**1**
Khee	4.2	6.2	6.2	**5.5**	**1.1**	6.8	6.4	5.6	**6.2**	**0.6**
Kulgam	8.4	8.8	8.6	**8.6**	**0.2**	10.2	10	9.4	**9.8**	**0.4**

	Autumn					Winter					AM	SD
Sites	**Sept.**	**Oct.**	**Nov.**	**Mean**	**SD**	**Dec.**	**Jan.**	**Feb.**	**Mean**	**SD**		
Qoimoh	5.8	5.5	7.6	**6.3**	**1.1**	7.2	5.4	7.2	**6.6**	**1**	**6.8**	**0.9**
Parigam	8.9	10	10.6	**9.8**	**0.8**	10.3	8.2	9.5	**9.3**	**1**	**10.1**	**1.3**
Katroso	6.2	7.3	8.4	**7.3**	**1.1**	7.2	7.2	7.8	**7.4**	**0.3**	**7.6**	**1.0**
Khee	4.3	5.2	5.4	**4.9**	**0.5**	6.2	3.4	5.6	**5**	**1.4**	**5.4**	**1.0**
Kulgam	7.9	6.8	8.8	**7.8**	**1**	8.2	6.4	8.8	**7.8**	**1.25**	**8.5**	**1.1**

AM = Annual Mean

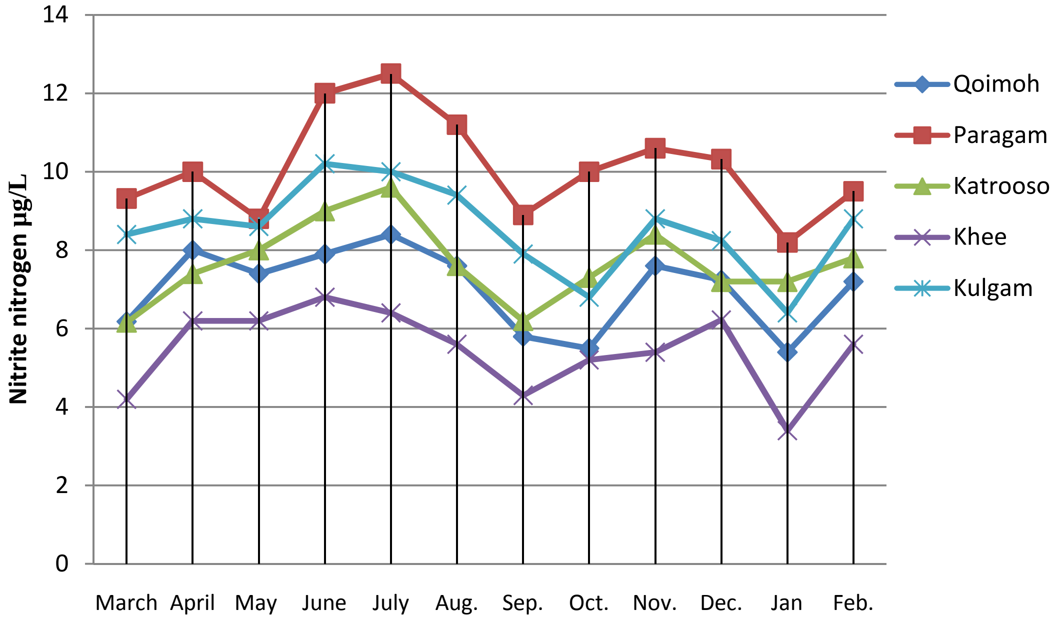


Fig. 5.1.14. Monthly variations in nitrite nitrogen µg/L of five seleccted springs during the study period.

Table 5.1.15: Monthly, seasonal and annual mean variations in ortho-phosphate phosphorus (µg/L) of springs during March 2011-Feb. 2012

	Spring					Summer				
Sites	**March**	**April**	**May**	**Mean**	**SD**	**June**	**July**	**Aug.**	**Mean**	**SD**
Qoimoh	120	111	98	**109.6**	**11.0**	104	116	112	**110.6**	**6.1**
Parigam	154	147	136	**164.6**	**9.0**	145	168	170	**161.0**	**13.8**
Katroso	102	88	77	**89.0**	**12.5**	56	84	48	**62.6**	**18.9**
Khee	78	67	42	**62.3**	**18.4**	38	55	64	**52.3**	**13.2**
Kulgam	118	105	121	**114.6**	**8.5**	132	157	142	**143.6**	**12.5**

	Autumn					Winter					AM	SD
Sites	**Sept.**	**Oct.**	**Nov.**	**Mean**	**SD**	**Dec.**	**Jan.**	**Feb.**	**Mean**	**SD**		
Qoimoh	90	88	104	**94.0**	**8.7**	126	144	134	**134.6**	**9.0**	**112.2**	**16.9**
Parigam	155	160	192	**162.3**	**8.7**	188	196	185	**189.6**	**5.6**	**164.6**	**18.5**
Katroso	38	84	99	**73.6**	**31.7**	122	130	118	**123.3**	**6.1**	**87.1**	**29.2**
Khee	24	48	78	**50.0**	**27.0**	98	116	100	**104.6**	**9.8**	**67.3**	**27.8**
Kulgam	118	98	116	**110.6**	**11.0**	132	155	142	**143**	**11.5**	**128.0**	**18.6**

AM = Annual Mean

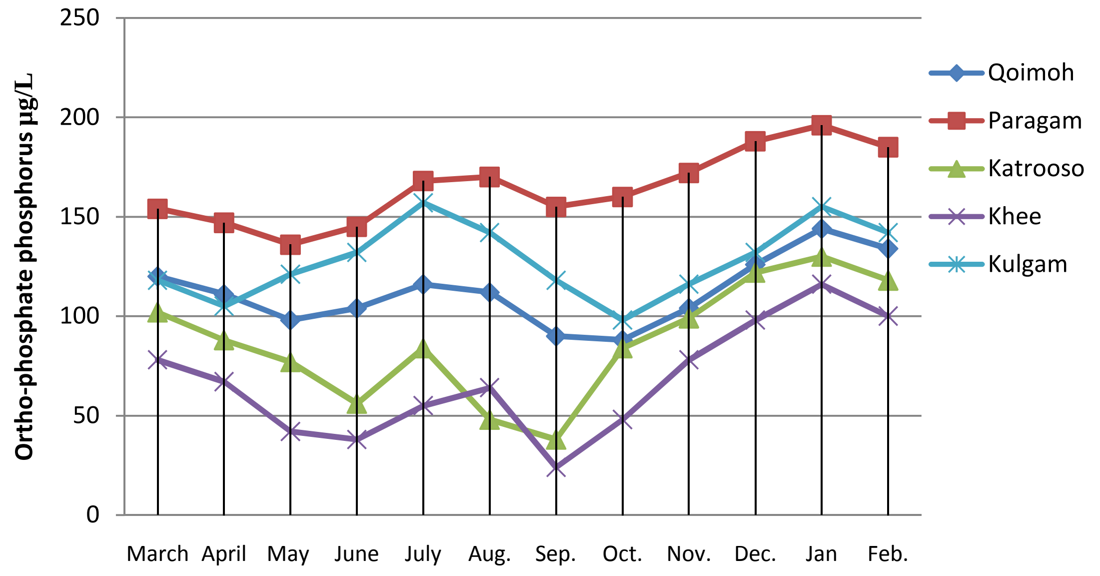


Fig. 5.1.15: Monthly variations in ortho-phosphate phosphorus (µg/L) of five selected springs.

Table 5.1.16: Monthly, seasonal and annual mean variations in sulphate (mg/L) of springs during March 2011-Feb. 2012

	Spring					Summer				
Sites	**March**	**April**	**May**	**Mean**	**SD**	**June**	**July**	**Aug**	**Mean**	**SD**
Qoimoh	1.3	1.7	2.2	**1.7**	**0.4**	1.5	1.1	1.2	**1.2**	**0.2**
Parigam	2.2	2.8	2.8	**2.6**	**0.3**	2.2	2	1.6	**1.9**	**0.3**
Katroso	1.6	1.2	1.8	**1.5**	**0.3**	1.4	1.8	2	**1.7**	**0.3**
Khee	1.1	1.5	1.2	**1.2**	**0.2**	1.1	1.7	1.1	**1.3**	**0.3**
Kulgam	2	1.8	1.6	**1.8**	**0.2**	1.8	2	2.2	**2**	**0.2**

	Autumn					Winter					AM	SD
Sites	**Sept.**	**Oct.**	**Nov.**	**Mean**	**SD**	**Dec.**	**Jan.**	**Feb.**	**Mean**	**SD**		
Qoimoh	1.7	2.2	2.3	**1.7**	**0.3**	2.6	2.3	1.8	**2.2**	**0.4**	**1.7**	**0.4**
Parigam	2	2.6	3.4	**2.4**	**0.7**	3.5	4.4	3.4	**3.7**	**0.5**	**2.4**	**0.5**
Katroso	1.6	2	2.12	**1.7**	**0.2**	2.5	2.2	2.2	**2.3**	**0.1**	**1.7**	**0.3**
Khee	1.8	1.5	1.6	**1.4**	**0.1**	2	1.7	1.4	**1.7**	**0.3**	**1.4**	**0.2**
Kulgam	2.1	2.4	2.2	**2.2**	**0.1**	3.2	3.1	2.8	**3**	**0.2**	**2.0**	**0.2**

AM = Annual Mean

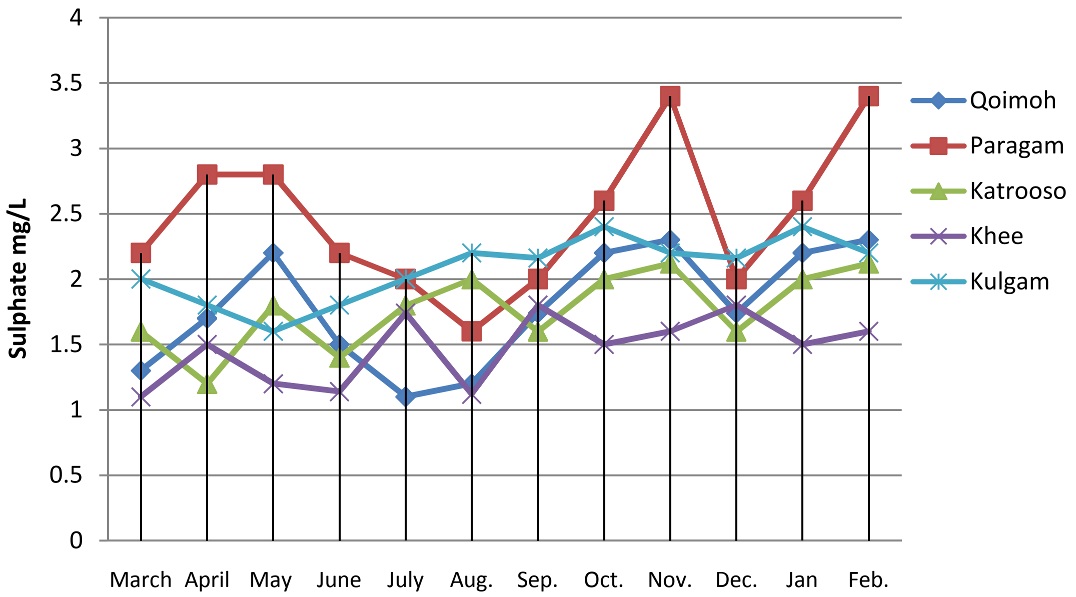


Fig. 5.1.16: Monthly variations in sulphate concentrion mg/L of five selected springs during the study period.

Table 5.1.17: Heavy metal concentration in (ppm) of the spring waters

	Chromium	**Nickel**	**Lead**	**Zinc**	**Iron**
Sites					
Qoimoh	0.0019	0.0017	0.0010	0.003	0.001
Parigam	0.0010	0.0026	0.0150	0.007	0.003
Katroso	0.0027	0.0011	0.0080	0.0003	0.0001
Khee	0.0027	0.0006	0.0010	0.003	0.0005
Kulgam	0.0027	0.0011	0.0037	0.003	0.002

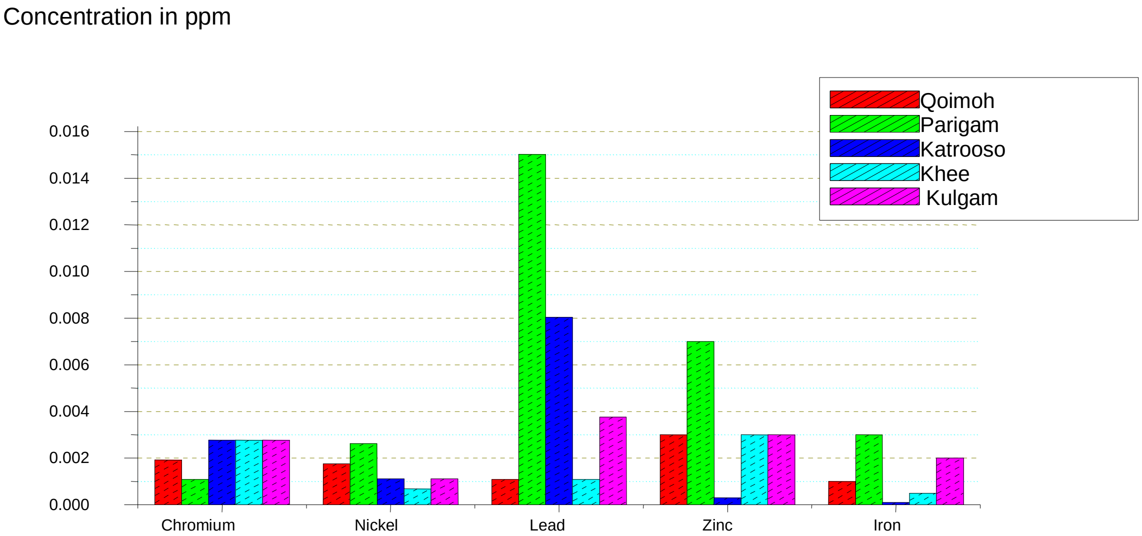


Fig 5.1.17: The heavy metal concentrations of five selected spring waters during the study period

5.2. Correlation Analysis Among Various Physico-chemical Parameters of Water

Correlation analysis is a powerful statistical tool for assessing the relationship between two variables (Gotelli and Ellison, 2004). In the present study on springs the correlation analysisamong various physico-chemical parameters is depicted in Table 4.1.18. A perusal of data revealed that pH showed positive correlation with conductivity (r=0.671), calcium hardness (r=0.642) and magnesium hardness(r= 0.596). However Conductivity maintained positive correlation withfree carbon dioxide (r=0.702), calcium hardness (r=0.891), magnesium hardness (r=0.872) and chloride (r=0.885). Further, water temperature revealed negative correlation with dissolved oxygen (r= -0.585), free carbon dioxide (r= - 0.455) and sulphate (r=-0.729). Free carbon dioxide showed positive correlation with calcium hardness (r=0.928) and magnesium harness (r=0.930) while negatively correlated with water temperature (r=- 0.655). Alkalinity depicted positive correlation with ammonical nitrogen (r=0.998) while showing negative correlation with free carbon dioxide (r=-0.596). Total hardness showed positive correlation with calcium hardness (r=0.998), magnesium hardness (r=0.884) and chloride (r=0.695) while depicting negative correlation with water temperature (r=-0.473). On the other hand chloride showed positive correlation with conductivity (r=0.885), total hardness(r=0.695), and negative correlation with alkalinity (r=-0.619). Dissolved oxygen showed negative correlation with water temperature (r=-0.585), BOD (r=-0.608), ammonical nitrogen (r=-0.581), and nitrite nitrogen (r=-0.638), while showing positive correlation with nitrate (r=0.635) and sulphate (r=0.596). Biochemical oxygen demand showedpositive correlation with water temperature (r=0.689) and free carbon dioxide (r=0.580) while depicting negative correlation with dissolved oxygen (r=-0.608). Ammonical nitrogen maintained positive correlation with alkalinity (r=0.998), BOD (r=0.998), while showing negative correlation with dissolved oxygen (r=-0.581). However nitrate depicted positive correlation with dissolved oxygen (r=0.635) and negative correlation with BOD (r=-0.830) and ammonical nitrogen (r=-0.839). Orthrophosphate phosphorus had positive correlation with conductivity (r=0.618). On the other hand sulphate depicted positive correlation with dissolved oxygen (r=0.596) and negative correlation with water temperature (r=-0.729) and nitrate (r=-0.614).

Table 5.1.18: Correlation analysis among various physico-chemical parameters of water

	pH	Con	WT	CO_2	Alk	TH	Ca	Mg	Cl	DO	BOD	NH_4-N	NO_3-N	NO_2-N	OPP	SO_4
pH	1															
Conductivity µS/cm	0.671*	1														
Water Temperature °C	0.048	0.301	1													
Free Carbon dioxide mg/L	0.567	0.702*	-0.655*	1												
Acid Neutralizing Capacity	0.192	-0.434	-0.128	-0.596*	1											
Total Hardness mg/l	0.402	-0.196	-0.473	0.097	0.571	1										
Calcium Hardness mg/l	0.642*	0.891**	-0.094	0.928**	-0.489	0.998**.	1									
Magnesium Hardness mg/l	0.596*	0.872**	-0.118	0.930**	-0.514	0 .884**	0.995**	1								
Chloride content mg/l	0.536	0.885**	-0.047	0.305	-0.619*	0.695*	0.983**	0.978**	1							
Dissolved Oxygen mg/l	-0.409	-0.223	-0.0585*	0.338	-0.574	-0.291	0.130	0.185	0.201	1						
BOD mg/l	0.235	-0.400	0.0689*	0.580*	0.397	0.230	-0.463	-0.492	-0.594*	-0.308*	1					
Ammonical-N µg/l	0.208	-0.414	-0.115	-0.484	0.998**	0.593*	-0.466	-0.491	-0.596*	-0.581*	0.998**	1				
Nitrate-N µg/l	-0.073	0.253	-0.059	0.491	0.642*	-0.315	0.389	.377	0.520	0.635*.	-0.830**	-0.839**	1			
Nitrite-N µg/l	0.323	-0.104	0.055	-0.384	0.626*	0.480	-0.233	-.278	-0.335	-0.638*	0.835**	0.835**	-0.721**	1		
Orthophosphorus µg/l	-0.379	0.618*	-0.305*	-0.062	0.168	0.206	-0.314	-.260	-0.344	0.124	0.158	-0 .070	-0.245	1		
Sulphate mg/l	-0.111	-0.330	-0.729*	0.326	0.485	0.116	-0.020	.027	-.077	0.596*	-0.301	0.306	0.165	-0.614*	0.323	1

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

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

Where Cond = Conductivity, WT= Water temperature, Alk = Alkalinity, TH = Total hardness, DO = Dissolved oxygen, BOD = Biochemical oxygen demand, OPP = Orthophosphate phosphorus.

5.3. MACROINVERTEBRATES

5.3.1. Species Composition and Population Density

Species composition and abundance of any faunal assemblage reflect the characteristics of the system there in. Macroinvertebrates thus collected during the present investigation from March 2011 to February 2012, belong to three phyla viz. Annelida, Arthropoda and Mollusca. The macroinvertebrate community of the five studied springs did not vary much in species composition. A total of 26 taxa were recorded from all the study sites. However, the number of taxa varied in the five springs. Phylum Annelida (6) was represented by class Oligochaeta (3) and class Hirudinea (3). Phylum Arthropoda was represented by class Crustacea (1), class Insecta (14) and class Archnida (1), while as the phylum Mollusca (4) was comprised of classes Gastropoda and Pelecypoda. Among the Arthopoda, the species rich class Insecta is itself an assemblage of different orders (Trichoptera-4, Odonata-1, Hemiptera -1, Diptera-6, Coleosptera-1 and Ephemeroptera-1). Thus, the phylum Annelida included six species namely *Branchiura sowerbyii*, *Erpobdella octoculata*, *Glossiphonia* sp., *Placobdella* sp., *Limnodrillus* sp. and *Tubifex tubifex*. Similarly phylum Arthropoda included sixteen species namely *Gammarus pulex*, *Dolomedes* sp., *Baetis* sp., *Hydropsychide* sp., *Glossosoma* sp., *Limnephilus* sp., *Anaxjunius* sp., *Chironomus* sp., *Rhyacophila* sp., *Tabanus* sp., *Tipula* sp., *Coraxia* sp., *Simulium* sp., *Hydrobiomorpha* sp. and *Elmidae* sp. However, the phylum Mollusca included only four species (*Lymnaea auricular*, *Lymnaea columella*, *Corbicula* sp. and *Tropicorbis* sp.).

Among the spring macroinvertbrates *Chironomous* sp., *Tubifex tubifex*, *Limnodrillus* sp., *Erpobdella octoculata*, *Branchiura sowerbyii*, *Lymnaea auricularia* and *Gammarus pulex* were the most dominant forms, being present in all the five springs. However, species like *Dolomedes* sp., *Simulium* sp., *Corbicula* sp., *Placobdella* sp., *Rhyacophila* sp. and *Glossosoma* sp., were least present and were sporadiac in their occurrence with only few individuals being encountered here and there. Out of 26 taxa, the highest number of species were recorded at Kulgam (24), followed by Katrooso (20), Qoimoh (18), Khee (17) and decreasing to the lowest of 16 species at Parigam.

5.3.1.1. Annelida

Annelid community was represented by five species (*Glossiphonia* sp., *Erpobdella octoculata, Tubifex tubifex, Limnodrillus* sp., and *Branchiura sowerbyii*) at Qoimoh, Kulgam and Parigam springs while six species (*Glossiphonia* sp., *Placobdella* sp., *Erpobdella octoculata*, *Tubifex tubifex*, *Limnodrillus* sp., and *Branchiuria sowerbyii*) at Katrooso spring and four species (*Erpobdella octoculata*, *Tubifex tubifex, Limnodrillus* sp., and *Branchiura sowerbyii*) at the Khee spring were encountered. The maximum diversity was recorded at Katrooso spring (6) against minimum diversity (4) being reported at Khee spring. Annelida contributed the major proportion to the overall population density of the macroinvertebrates. Considerable seasonal and spatial variations were observed in the population density of the group. During the study period the population density of annelids varied from a minimum of 10 ind/m^2 at Kulgam in January, 2012 to a maximum of 305 ind/m^2 at Parigam in July, 2011 (Tables 5.3.1-5.3.5). The seasonal mean values for population density of annelida fluctuated between the lowest of 48 ind/m^2 at Kulgam in winter and the highest of 802 ind/m^2 at Parigam in summer. However, the annual mean population revealed it to be maximum at Parigam (555±199.25 ind/m^2), followed by Qoimoh (285±103.80 ind/m^2), Katrooso (131.5±49.9 ind/m^2), Kulgam (129±66.48 ind/m^2) and decreasing to the lowest (98±38.96 ind/m^2) at Khee during the entire study period (Tables 5.3.1a-e and Figs. 5.3.1a-e).

5.3.1.2. Mollusca

Phylum Mollusca was represented by four species namely *Lymnaea auricularia*, *Lymnaea columella*, *Corbicula* sp. and *Tropicorbis* sp. However, the shelled animals were represented by 3 species (*Lymnaea auricularia*, *Lymnaea columella* and *Corbicula* sp.) at Qoimoh, 2 species (*Lymnaea auricularia, Lymnaea columella*) at Parigam, Katrooso and Khee springs and 4 species ((*Lymnaea auricularia*, *Lymnaea columella* and *Corbicula* sp., and *Tropicorbis* sp.) at Kulgam spring. Although *Lymnaea auricularia* and *Lymnaea columella* were common in all the springs but *Tropicorbis* sp. was reported only from Kulgam spring. The population density of the group was quiet low, yet definite spatial and temporal variations were observed during the study period. In general, the population density of

Mollusca ranged from a minimum of 1 ind/m^2 at Qoimoh in January to a maximum of 36 ind/m^2 at Kulgam in September (Tables 5.3.1 - 5.3.5). The seasonal density of Mollusca depicted a fluctuation from a minimum of 8 ind/m^2 both at Qoimoh and Khee in winter to a maximum of 91 ind/m^2 at Kulgam in autumn during the entire study period. The peak density of the group was observed in summer throughout the study period across all the springs except at Kulgam (91 ind/ m^2 in autumn).A comparison of the springs on the basis of annual mean values of density revealed that Kulgam (61.25±25.95 ind/m^2) ranked first, followed by Qoimoh (22.75±13.72 ind/m^2), Katrooso (22±7.87 ind/m^2), Parigam (17.5±5) and Khee(15±5.77 ind/m^2) in a decreasing order (Tables 5.3.1a-e and Figs. 5.3.1a-e).

5.3.1.3. Arthropoda

Arthropoda community was represented by 10 species (*Gammarus pulex*, *Dolomedes* sp., *Hydropsychida* sp., *Chironomus* sp., *Rhyacophila* sp., *Simulium* sp., *Baetis* sp., *Tabanas* sp., *Coraxia* sp., and *Elmidae* sp.) at Qoimoh spring, 9 species (*Gammarus pulex*, *Limnephilus* sp., *Chironomus* sp., *Tabanus* sp., *Bezzia* sp., *Simulium* sp., *Tipula* sp. and *Elmidae* sp.) at Parigam spring, 12 species (*Gammarus pulex*, *Hydropsychida* sp., *Glossosoma* sp., *Limnephiles* sp., *Chironomus* sp., *Rhyacophila* sp., *Bezzia sp*., *Tabanus* sp., *Simulium* sp., *Tipula* sp., *Coraxia* sp. and *Elmidae* sp.) at Katrooso spring, 11 species (*Gammarus pulex*, *Hydropsychida* sp, *Glossosoma* sp., *Limnephiles* sp., *Chironomus* sp., *Rhyacophila* sp., *Bezzia* sp., *Tabanus* sp., *Tipula* sp., *Coraxia* sp. and *Elmidae* sp.) at Khee spring and 15 species (*Gammarus pulex*, *Dolmedes* sp., *Baetis* sp., *Hydropsychida* sp, *Glossosoma* sp., *Anax junius* sp., *Chironomus* sp., *Rhyacophila* sp., *Bezzia* sp., *Tabanus* sp., *Simulium* sp., *Coraxia* sp., *Hydrobiomorphia* sp. and *Elmidae* sp.) at Kulgam spring. Among arthropods, the maximum diversity was recorded at Kulgam (14) as against the minimum diversity being reported at Parigam spring (9), After Annelida, Arthropoda contributed the major proportion to overall population density of the collected macroinvertebrates. Monthly population density oscillated between 15 ind/m^2 at Khee in January and 82 ind/m^2 at Parigam in May (Tables 5.3.1 - 5.3.5) and significant seasonal and spatial variations were found in the population density of the group. However on seasonal basis, the population density of Arthropoda ranged from the lowest 65 ind/m^2 at Katrooso in winter to the highest 199 ind/m^2 at Kulgam in summer. The annual mean values depicted the highest density at Parigam (161.75± 34.88 ind/m^2), followed by Qoimoh (135.25±43.62 ind/m^2), Kulgam (134.5± 58.63 ind/m^2), Katrooso (101± 26.94 ind/m^2), and falling to the lowest at Khee (92.5±28.05 ind/m^2) during the entire study period (Tables 5.3.1a-e and Figs. 5.3.1a-e).

5.3.2. Seasonal Succession

Seasonal succession based on relative density showed that in spring season, the macroinvertebrate community was dominated by Arthropoda at Katrooso (R.D=45, 71%), Khee (R.D=45.98%) and Kulgam (R.D=52.35%) while Annelida was dominated at Qoimoh (R.D=63.91%) and Parigam (R.D=72.82%). In summer season, the benthic macroinvertebrate community was dominated by annelids across all the study sites: Qoimoh (R.D=61.68%), Parigam (R.D=79.01%), Katrooso (R.D=57.14%), Khee (R.D=48.60) and Kulgam (R.D=43.03). In autumn almost similar succession trend as that of summer was maintained with Annelida being dominance across all the study sites. Segmented animals made maximum proportions at Qoimoh (R.D=62.95%), Parigam (R.D=79.42%), Katrooso (R.D=53.33%), Khee (R.D=50.64%) and Kulgam (R.D=43.65%). However, in winter the macroinvertebrate community was again dominated by Annelida at Qoimoh (R.D=57%), Parigam (R.D=66.95%), and Katrooso (R.D=47.61%) while Arthropoda was dominated at Khee (R.D=50%) and Kulgam (R.D=45%) (Tables 5.3.1-5 and Figs. 5.3.1-5). Comparatively the contribution of Mollusca was least through out the study period with the relative density values ranging from a minimum of 1.58 at Parigam in spring to a maximum of 26 at Kulgam in autumn. It is interesting to note that though there was a general decrease in the relative density of Annelida across all the study sites in winter yet Arthropoda depicted slight increase in their relative density values during winter. Mollusca at Kulgam and Parigam also showed increasing trend in the relative density during winter. Among Arthropoda the minimum contribution to relative density (R.D=17.98%) was recorded at Parigam in autumn while the maximum contribution towards relative density (R.D=50%) was registered at Kulgam in winter. Overall Annelida registered a relative density fluctuating from a minimum of 43.10% at Kulgam in winter to a maximum of 79.42% at Parigam in autumn.

A comparison of springs revealed that the highest annual mean density of benthic macroinvertebrate community was recorded at Parigam (244.75±74.40 ind/m^2), followed by Qoimoh (138.66±55.32 ind/m^2), Kulgam (112±45.32 ind/m^2), Katrooso (84.83±25.99 ind/m^2) and falling to the lowest at Khee (68.75±24.69 ind/m^2) during the entire study period.

5.3.3. Species Diversity

5.3.3.1. Shannon-Weiner index

The macroinvertebrate community was analysized for species diversity by applying Shannon-Weiner index. The diversity index showed the highest value at Kulgam (2.60), followed by Katrooso (2.44), Khee (2.13), Qoimoh (2.12) and decreasing to the lowest (1.82) at Parigam ((Table 5.3.3 and Fig. 5.3.3).

5.3.3.2. Simpsons diversity index

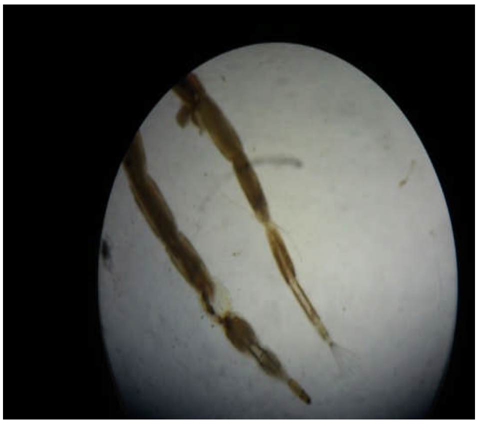
The Simpson's diversity index was employed to the benthic macroinvertebrate community to measure diversity. The diversity index did not show any significant variations among the study sites. However, the diversity index recorded highest value at Kulgam (0.89), followed by Katrooso (0.88), Khee (0.84), Qoimoh (0.83), and falling to the lowest at Parigam (0.78) (Table 5.3.3 and Fig. 5.3.3).

5.3.3.3. Margalef's diversity index

The Margalef's diversity index was also applied to the benthic macroinvertebrate community to measure diversity. The diversity index fluctuated from a minimum of 1.87 at Parigam to a maximum of 3.19 at Kulgam. The other sites occupied the intermediate position between the two extremes (Table 5.3.3 and Fig. 5.3.3).

GLIMPSES OF MACROINVERTEBRATES

Baetis sp.



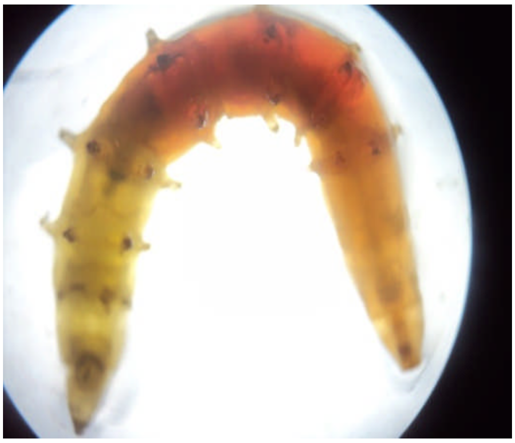
Bezzia sp.

Limnephilus sp.

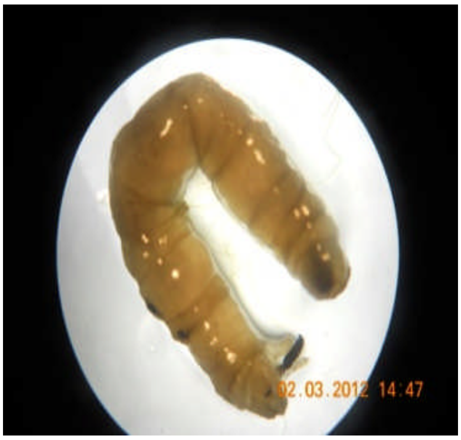
Procladus sp.

Coraxia sp.

Chironomus sp.

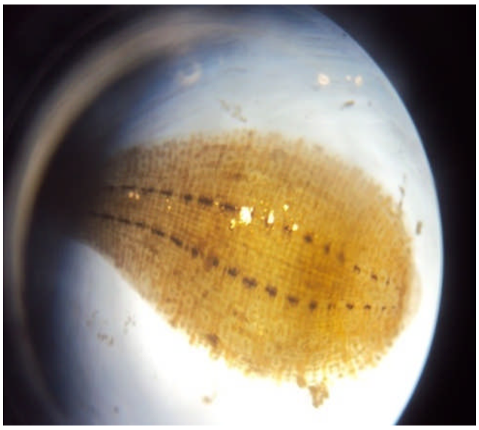


Tabanus sp.



Tipula sp.

Rhyacophila obscura



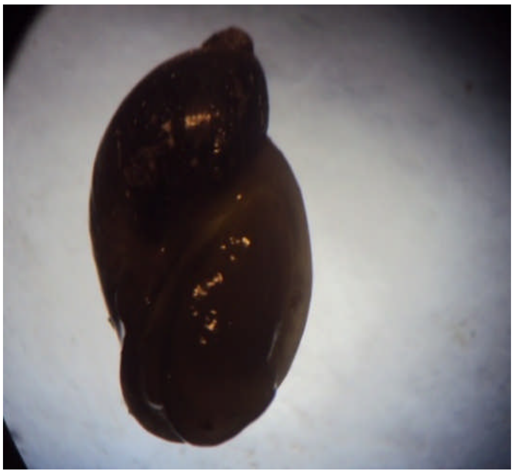
Placobdella sp.

Limnodrillus sp.

Gammarus pulex

Branchiura sowerbyii

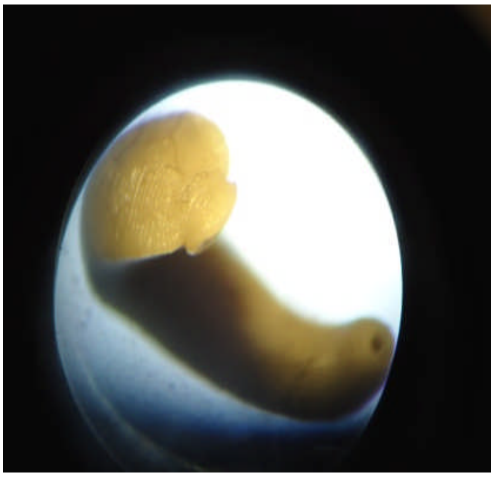
Elimidae sp.



Lymnaea columella

Anisoptera (Dragon flies) nymph

Glossiphonia sp.



Erpobdella octoculata

Table 5.3.1: Monthly and seasonal variations in density (ind/m^2) of macroinvertebrates at Qoimoh spring from March 2011-Feb. 2012.

Seasons	**Spring**			**Summer**			**Autumn**			**Winter**				
Months	**Mar**	**April**	**may**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mean**	**SD**
Taxa/species														
Annelida														
Glossiphonia sp.	0	1	3	2	1	0	1	1	0	0	0	0	**0.75**	**0.96**
Erpobdella octoculata	16	20	23	25	24	18	19	17	14	10	11	15	**17.66**	**4.83**
Tubifex tubifex	34	52	46	55	68	61	62	38	24	13	17	23	**41.08**	**18.93**
Limnodrillus sp.	15	20	20	24	30	28	33	22	15	7	8	8	**19.16**	**8.79**
Branchiura sowerbyii	8	11	18	12	10	9	8	4	2	0	2	4	**7.33**	**5.15**
Total	73	104	110	118	133	116	123	82	55	30	38	50	**86.00**	**36.03**
Mollusca														
Lymnaea auricularia	2	4	7	6	6	9	7	4	2	2	1	3	**4.41**	**2.53**
Lymnaea columella	0	2	4	5	4	6	4	3	1	1	0	1	**2.58**	**2.02**
Corbicula sp.	0	0	0	2	2	1	1	1	0	0	0	0	**0.58**	**0.79**
Total	2	6	11	13	12	16	12	8	3	3	1	4	**7.58**	**5.07**
Arthropoda														
Gammarus pulex	13	14	22	24	20	23	16	21	14	9	12	15	**16.91**	**4.88**
Dolomedes sp.	0	0	2	1	2	0	0	1	1	0	0	0	**0.58**	**0.79**
Hydropsychide sp.	0	2	3	1	0	2	1	1	1	1	0	0	**1.00**	**0.95**
Chironomus sp.	16	22	24	21	32	33	22	16	10	14	6	12	**19.00**	**8.27**
Rhyacophila sp.	0	2	2	1	3	4	5	3	2	0	2	0	**2.00**	**1.59**
Simulium sp.	0	0	1	2	1	2	1	0	1	1	0	0	**0.75**	**0.75378**
Baetis sp.	0	0	0	2	2	2	2	1	0	2	1	2	**1.16**	**0.93744**
Tabanus sp.	2	0	3	1	2	0	0	1	3	0	0	1	**1.08**	**1.1645**
Coraxia sp.	3	5	3	1	0	0	2	2	0	0	0	0	**1.33**	**1.66**
Elmidae sp.	0	2	2	3	1	1	2	1	0	0	1	2	**1.25**	**0.96**
Total	34	47	62	57	63	67	51	47	32	27	22	32	**45.08**	**15.36**
Grand Total	109	157	183	188	208	199	186	137	90	60	61	86	**138.66**	**55.32**

Table 5.3.2: Monthly and season variations in density (ind/m^2) of macroinvertebrates at Parigam spring from March 2011-Feb. 2012.

Seasons	**Spring**			**Summer**			**Autumn**			**Winter**				
Months	**Mar**	**April**	**may**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mean**	**SD**
Taxa/species														
Annelida														
Glossiphonia sp.	0	0	1	2	0	0	1	1	0	0	0	0	**0.416**	**0.66**
Erpobdella octoculata	38	46	42	56	72	58	44	42	38	22	18	26	**41.83**	**15.47**
Tubifex tubifex	85	88	110	115	134	98	84	76	72	56	42	58	**84.83**	**26.58**
Limnodrillus sp.	29	34	38	60	74	58	62	42	40	28	18	24	**42.25**	**17.45**
Branchiura sowerbyii	10	13	18	22	25	28	17	22	11	8	3	11	**15.66**	**7.55**
Total	162	181	209	255	305	242	208	183	161	114	81	119	**185.00**	**63.95**
Mollusca														
Lymnaea auricularia	2	2	4	7	6	5	3	2	3	6	3	3	**3.83**	**1.74**
Lymnaea columella	0	2	2	1	3	2	3	3	4	2	0	2	**2.00**	**1.20**
Total	2	4	6	8	9	7	6	5	7	8	3	5	**5.83**	**2.12**
Arthropoda														
Gammarus pulex	6	8	12	10	8	6	8	4	3	4	2	3	**6.166**	**3.09**
Limnephilus sp.	0	0	0	1	0	2	1	2	0	1	0	1	**0.66**	**0.77**
Chironomus sp.	42	45	55	52	42	36	32	26	33	44	28	45	**40.00**	**9.105**
Procladius sp.	0	0	0	2	2	2	1	1	0	1	0	0	**0.75**	**0.86**
Tabanus sp.	1	0	3	1	2	0	0	0	3	0	0	0	**0.83**	**1.19**
Bezzia sp.	0	2	1	3	5	2	2	1	0	2	1	2	**1.75**	**1.35**
Simulium sp.	0	0	3	2	2	1	1	2	0	0	1	0	**1.00**	**1.04**
Tipula sp.	0	0	0	2	2	0	1	0	1	1	0	0	**0.58**	**0.79**
Elmidae sp.	2	6	8	3	1	0	2	1	0	0	1	2	**2.16**	**2.48**
Total	51	61	82	76	64	49	48	37	40	53	33	53	**53.91**	**14.81**
Grand Total	215	246	297	339	378	298	262	225	208	175	117	177	**244.75**	**74.40**

Table 5.3.3: Monthly and season variations in density (ind/m^2) of macroinvertebrates at Katrooso spring from March 2011-Feb. 2012.

Seasons	**Spring**			**Summer**			**Autumn**			**Winter**				
Months	**Mar**	**April**	**may**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mean**	**SD**
Taxa/species														
Annelida														
Glossiphonia sp.	3	3	6	5	8	6	4	2	1	0	0	2	**3.33**	**2.53**
Placobdella sp.	0	1	2	0	1	3	2	1	0	0	0	0	**0.83**	**1.02**
Erpobdella octoculata	14	21	16	24	26	23	23	21	17	14	13	11	**18.58**	**4.99**
Tubifex tubifex	8	11	8	12	9	6	6	4	0	3	2	3	**6.00**	**3.71**
Limnodrillus sp.	6	11	10	16	22	13	14	15	9	6	3	8	**11.08**	**5.24**
Branchiura sowerbyii	3	2	3	4	8	6	9	5	3	2	1	2	**4.00**	**2.52**
Total	34	49	45	61	74	57	58	48	30	25	19	26	**43.83**	**17.06**
Mollusca														
Lymnaea auricularia	4	6	6	6	6	6	9	7	4	3	2	3	**5.16**	**1.99**
Lymnaea columella	3	2	3	4	6	3	0	0	1	2	0	2	**2.16**	**1.80**
Total	7	8	9	10	12	9	9	7	5	5	2	5	**7.33**	**2.74**
Arthropoda														
Gammarus pulex	14	16	8	10	13	18	21	15	12	8	8	8	**12.58**	**4.37**
Hydropsychide sp.	2	3	5	1	1	2	0	2	1	0	1	1	**1.58**	**1.37**
Glossosoma sp.	1	2	1	1	0	0	1	0	1	2	0	1	**0.83**	**0.71**
Limnephilus sp.	2	1	2	1	0	2	0	0	0	0	0	0	**0.66**	**0.88**
Chironomus sp.	10	14	18	16	11	8	6	8	12	6	9	11	**10.75**	**3.76**
Rhyacophila obscura	1	0	2	1	4	2	0	1	2	0	0	0	**1.08**	**1.24**
Bezzia sp.	3	2	3	0	2	0	2	0	2	1	1	2	**1.50**	**1.08**
Tabanus sp.	0	0	0	1	1	0	2	1	2	0	0	0	**0.58**	**0.79**
Simuluium sp.	0	0	1	4	2	2	1	0	1	0	0	0	**0.91**	**1.24**
Tipula sp.	0	2	2	3	2	0	1	0	3	0	0	0	**1.08**	**1.24**
Coraxia sp.	2	1	2	0	0	0	0	0	0	0	0	2	**0.58**	**0.90**
Elmidae sp.	3	3	2	2	1	2	1	0	0	2	1	1	**1.50**	**1.00**
Total	38	44	46	40	37	36	35	27	36	19	20	26	**33.66**	**8.77**
Grand Total	79	101	100	111	123	102	102	82	71	49	41	57	**84.83**	**25.99**

Table 5.3.4: Monthly and season variations in density (ind/m^2) of macroinvertebrates at Khee spring from March 2011-Feb. 2012

Seasons	**Spring**			**Summer**			**Autumn**			**Winter**				
Months	**Mar**	**April**	**may**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mean**	**SD**
Taxa/species														
Annelida														
Erpobdella octoculata	12	15	16	18	23	26	24	22	16	11	8	11	**16.83**	**5.84**
Tubifex tubifex	3	5	4	6	6	2	2	3	1	0	0	0	**2.66**	**2.22**
Limnodrillus sp.	6	11	13	12	18	21	23	15	8	6	8	6	**12.25**	**5.94**
Branchiura sowerbyii	0	2	1	4	1	2	0	3	1	0	0	0	**1.16**	**1.33**
Total	21	33	34	40	48	51	49	43	26	17	16	17	**32.91**	**13.31**
Mollusca														
Lymnaea auricularia	3	3	5	5	3	5	3	4	3	3	2	1	**3.33**	**1.23**
Lymnaea columella	0	2	3	4	3	2	1	2	1	0	0	2	**1.66**	**1.30**
Total	3	5	8	9	6	7	4	6	4	3	2	3	**5.00**	**2.21**
Arthropoda														
Gammarus pulex	5	8	8	12	13	16	14	15	8	10	3	3	**9.58**	**4.50**
Hydropsychide sp.	0	2	1	1	1	2	1	0	0	0	0	0	**0.66**	**0.77**
Glossosoma sp.	0	0	0	1	2	1	1	0	1	0	0	0	**0.50**	**0.67**
Chironomus sp.	16	14	14	16	21	11	21	18	8	11	9	13	**14.33**	**4.27**
Rhyacophila sp.	0	0	2	1	2	2	1	0	0	1	0	0	**0.75**	**0.86**
Limnephilus sp.	0	1	2	2	0	2	0	1	0	0	0	0	**0.66**	**0.88**
Bezzia sp.	3	2	0	0	2	0	0	0	2	0	3	4	**1.33**	**1.49**
Tabanus sp.	0	0	0	0	2	2	1	2	0	0	0	0	**0.58**	**0.90**
Tipula sp.	0	0	0	1	2	4	0	0	2	0	0	0	**0.75**	**1.28**
Coraxia sp.	2	2	0	0	0	0	0	2	0	0	0	1	**0.58**	**0.90**
Elmidae sp.	0	2	2	3	1	2	3	0	0	0	0	0	**1.08**	**1.24**
Total	26	31	29	37	46	42	42	38	21	22	15	21	**30.83**	**10.08**
Grand Total	50	69	71	86	100	100	95	87	51	42	33	41	**68.75**	**24.69**

Table 5.3.5: Monthly and season variations in density (ind/m^2) of macroinvertebrates at Kulgam spring from March 2011-Feb. 2012.

Seasons	**Spring**			**Summer**			**Autumn**			**Winter**			**Mean**	**SD**
Months	**Mar**	**April**	**may**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**		
Taxa/species														
Annelida														
Glossiphonia sp.	4	3	3	4	7	9	4	2	0	0	1	3	**3.33**	**2.64**
Erpobdella octoculata	14	15	22	24	32	34	25	22	18	13	6	8	**19.41**	**8.73**
Tubifex tubifex	2	5	3	3	6	8	3	5	0	0	1	1	**3.083**	**2.50**
Limnodrillus sp.	8	9	13	14	18	22	16	21	6	4	0	2	**11.08**	**7.36**
Branchiura sowerbyii	4	5	3	6	8	12	12	8	6	3	2	4	**6.08**	**3.34**
Total	32	37	44	51	71	85	60	58	30	20	10	18	**43.00**	**22.75**
Mollusca	0													
Lymnaea auricularia	9	8	11	13	18	21	25	22	16	14	10	8	**14.58**	**5.82**
Lymnaea columella	3	3	2	2	5	8	8	6	5	3	2	2	**4.083**	**2.27**
Corbicula sp.	0	0	1	2	2	1	1	2	3	1	0	0	**1.083**	**0.99**
Tropicorbis sp.	0	0	2	1	2	0	2	1	0	0	0	0	**0.66**	**0.88**
Total	12	11	16	18	27	30	36	31	24	18	12	10	**20.41**	**8.90**
Arthropoda														
Gammarus pulex	11	8	8	14	17	18	14	15	10	6	3	4	**10.66**	**4.99**
Dolomedes sp.	0	0	1	2	1	0	0	0	1	0	0	0	**0.41**	**0.66**
Baetis sp.	3	4	6	4	2	5	0	0	2	1	0	0	**2.25**	**2.13**
Hydropsychide sp.	2	2	1	1	2	2	3	0	1	0	1	0	**1.25**	**0.96**
Glossosoma sp.	1	3	0	3	2	3	1	2	1	0	0	0	**1.33**	**1.23**
Limnephilus sp.	0	1	1	2	0	1	2	0	0	0	0	0	**0.58**	**0.79**
Anaxjunius sp.	2	4	4	3	5	6	8	2	0	0	8	12	**4.50**	**3.55**
Chironomus sp.	21	24	23	23	20	25	24	16	14	8	8	10	**18.00**	**6.52**
Rhyacophila obscura	0	2	3	1	4	3	5	1	0	0	0	0	**1.58**	**1.78**
Tabanus sp.	3	3	5	4	2	2	3	2	1	3	0	2	**2.50**	**1.31**
*Tipula*sp.	0	2	0	1	2	0	0	2	2	0	0	0	**0.75**	**0.96**
Coraxia sp.	1	2	3	0	0	0	0	3	2	1	0	0	**1.00**	**1.20**
Simulium sp.	0	0	1	4	2	2	1	0	1	0	0	0	**0.91**	**1.24**
Hydrobiomorpha sp.	0	0	1	2	0	2	2	1	0	1	1	0	**0.83**	**0.83**
Elmidae sp.	5	4	2	3	2	2	3	0	0	1	2	0	**2.00**	**1.59**
Total	49	59	59	67	61	71	66	44	35	21	23	28	**48.58**	**17.99**
Grand Total	93	107	119	136	159	186	162	133	89	59	45	56	**112.00**	**45.32**

Table 5.3.1a: Seasonal variations in density (ind/m^2) of macroinvertebrates at Qoimoh spring from March 2011-Feb. 2012.

Phylum	Spring	Summer	Autumn	Winter	Mean	SD
Annelida	287	367	260	118	258.00	103.80
Mollusca	19	41	23	8	22.75	13.72
Arthropoda	143	187	130	81	135.25	43.62

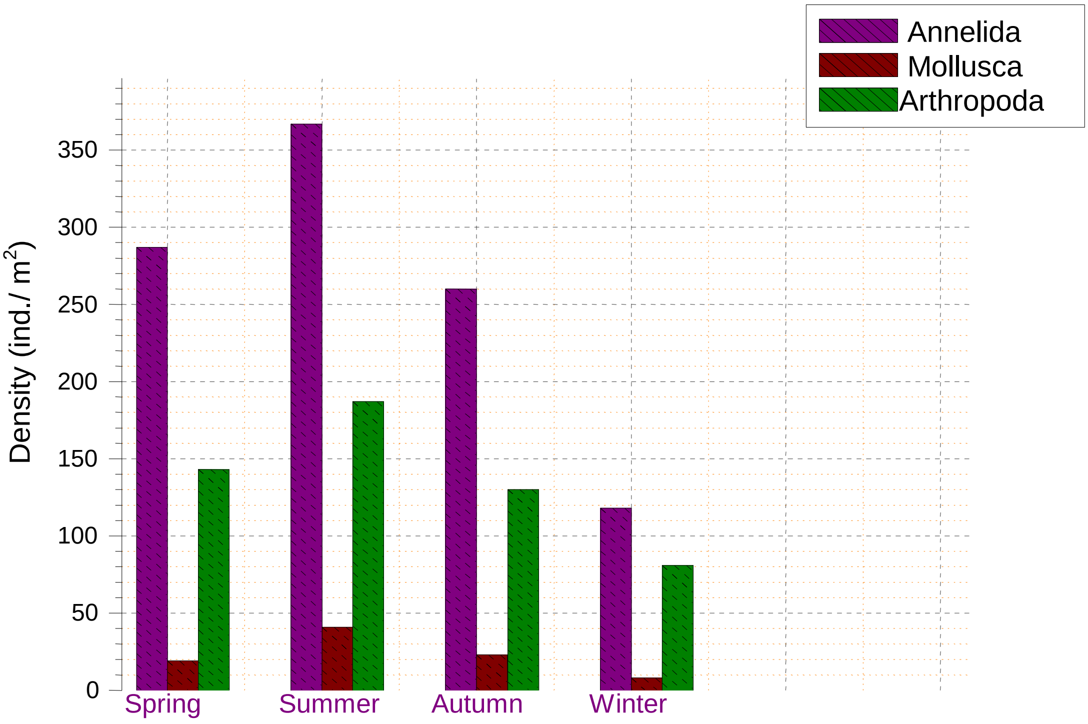


Fig. 5.3.1a: Seasonal variations in density of macroinvertebrates in Qoimoh spring from March 2011- Feb. 2012

Table 5.3.1b: Seasonal variation in density (ind/m^2) of macroinvertebrates at Parigam spring from March 2011-Feb. 2012.

Phylum	Spring	Summer	Autumn	Winter	Mean	SD
Annelida	552	802	552	314	555.00	199.25
Mollusca	12	24	18	16	17.50	5.00
Arthropoda	194	189	125	139	161.75	34.88

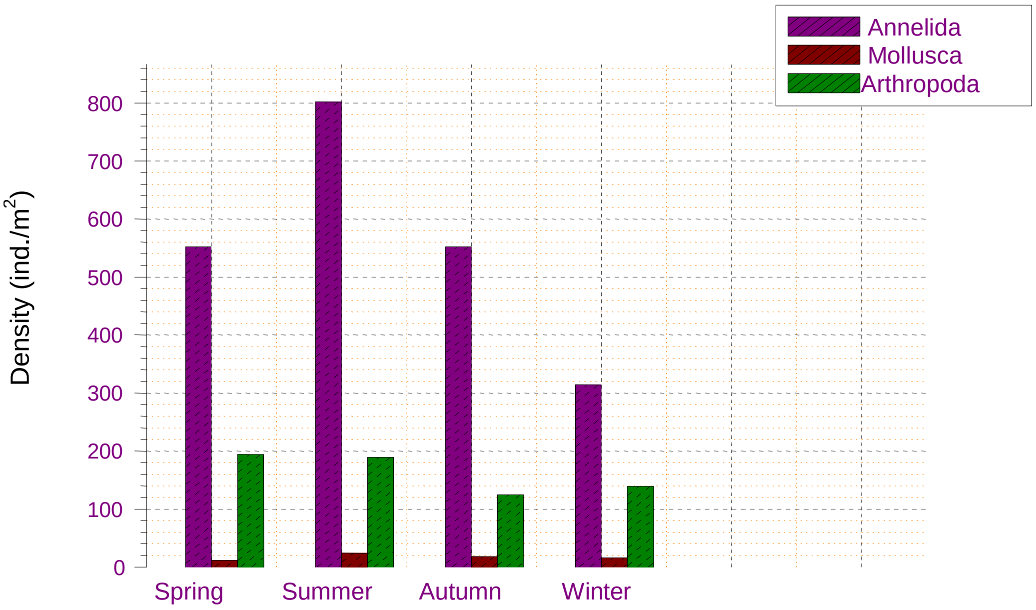


Fig. 4.2.1b: Seasonal variations in density of macroinvertebrates in Parigam spring from March 2011-Feb. 2012.

Table 5.3.1c: Seasonal variations in density (ind/m^2) of macroinvertebrates at Katrooso spring from March 2011-Feb. 2012.

	Spring	Summer	Autumn	Winter	Mean	SD
Annelida	128	192	136	70	131.50	49.91
Mollusca	24	31	21	12	22.00	7.87
Arthropoda	128	113	98	65	101.00	26.94

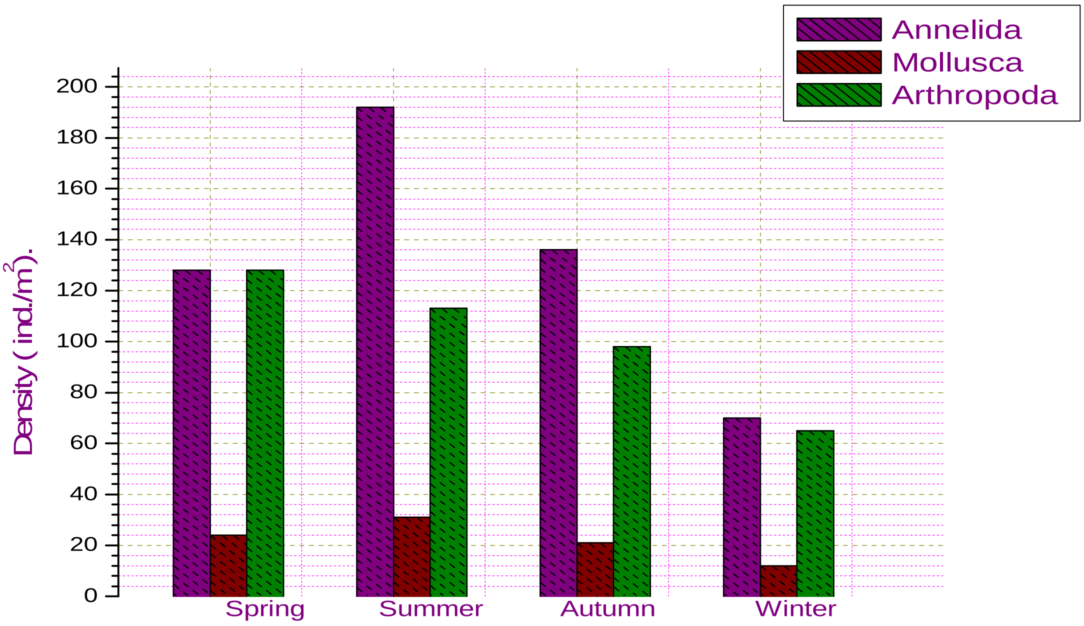


Fig. 5.3.1c: Seasonal variations in density of macroinvertebrates in Katrooso spring from March 2011 – Feb. 2012

Table 4.2.1d: Seasonal variations in density (ind/m^2) of macroinvertebrates at Khee spring from March 2011-Feb. 2012.

Phylum	Spring	Summer	Autumn	Winter	Mean	SD
Annelida	85	139	118	50	98.00	38.96
Mollusca	16	22	14	8	15.00	5.77
Arthropoda	86	125	101	58	92.50	28.05

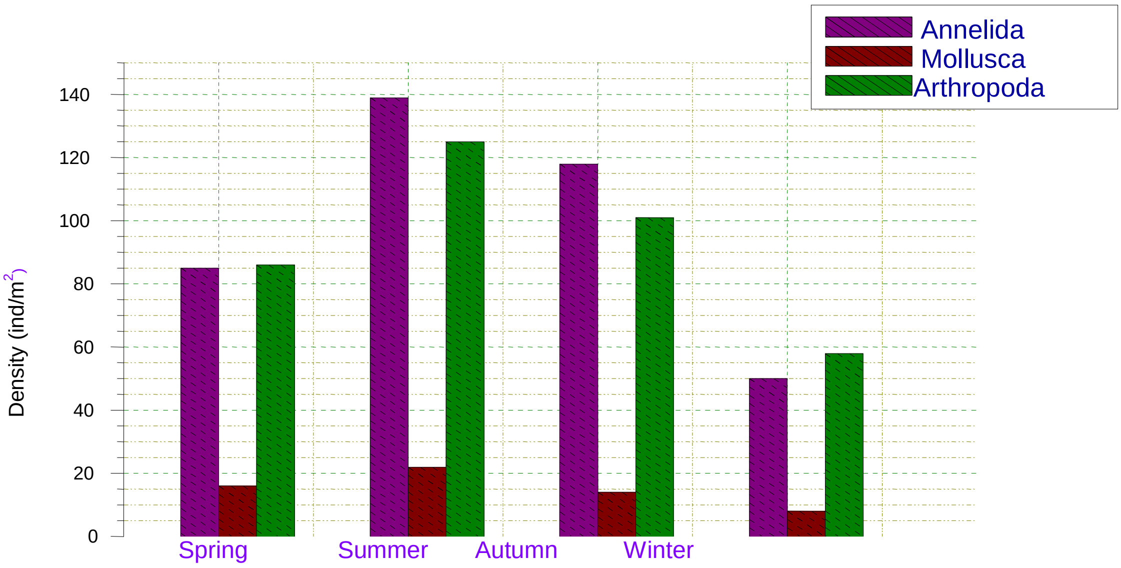


Fig 4.2.1d: Seasonal variations in density of macroinvertebrates in Khee spring from March2011-Feb. 2012

Table 5.3.1e: Seasonal variations in density (ind/m^2) of macroinvertebrates at Kulgam spring from March 2011-Feb. 2012.

Phylum	Spring	Summer	Autumn	Winter	Mean	SD
Annelida	113	207	148	48	129.00	66.48
Mollusca	39	75	91	40	61.25	25.95
Arthropoda	167	199	100	72	134.50	58.63

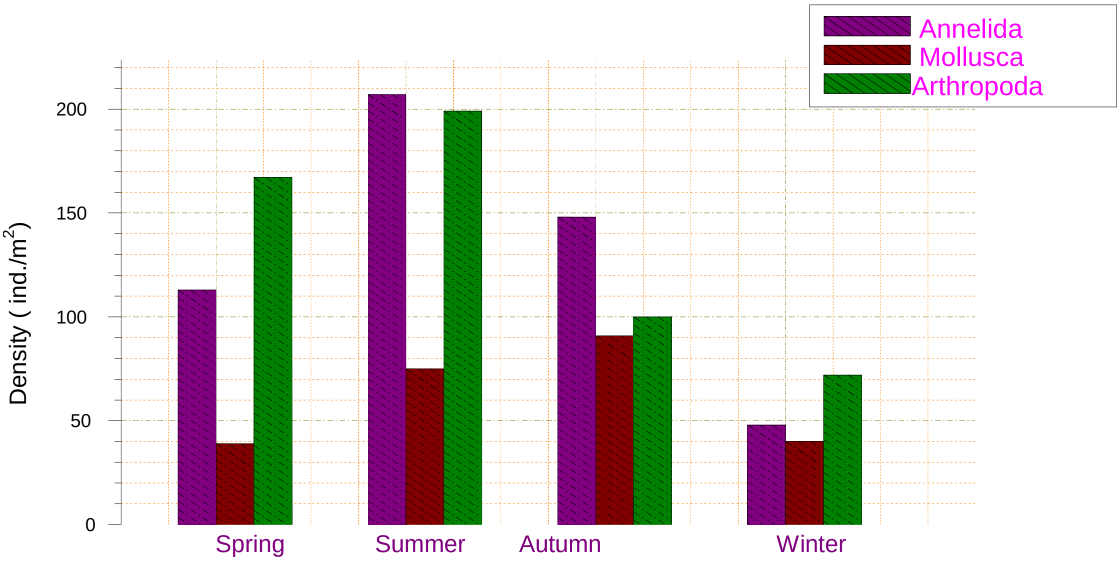


Fig. 5.3.1e: Seasonal variations in density of macroinvertebrates in Kulgam spring from March 2011-Feb. 2012

Table 4.3.2.1: Seasonal variation in relative density of macroinvertebrates at Qoimoh spring from March 2011-Feb. 2012.

Phylum	Spring	Summer	Autumn	Winter
Annelida	63.91	61.68	62.95	57.00
Mollusca	4.23	6.89	5.56	3.86
Arthropoda	31.84	31.42	31.47	39.13

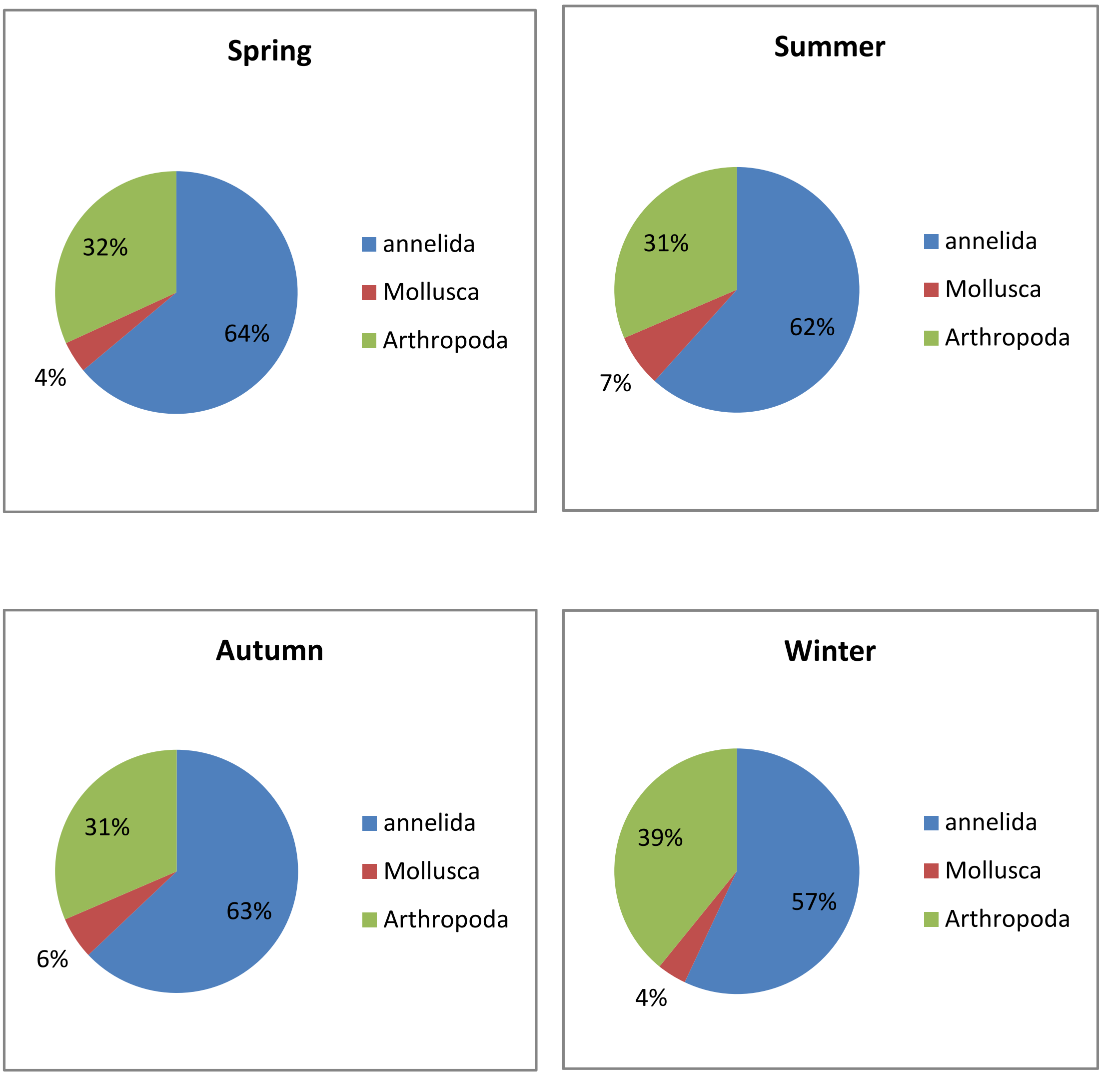


Fig. 5.3.2.1: Seasonal variations in relative density of macroinvertebrates at Qoimoh spring from March 2011-Feb. 2012

Table 5.3.2.2: Seasonal variations in relative density of macroinvertebrates at Parigam spring from March 2011-Feb. 2012.

Phylum	**Spring**	**Summer**	**Autumn**	**Winter**
Annelida	72.82	79.01	79.42	66.95
Mollusca	1.58	2.36	2.58	3.41
Arthropoda	25.59	18.62	17.98	29.63

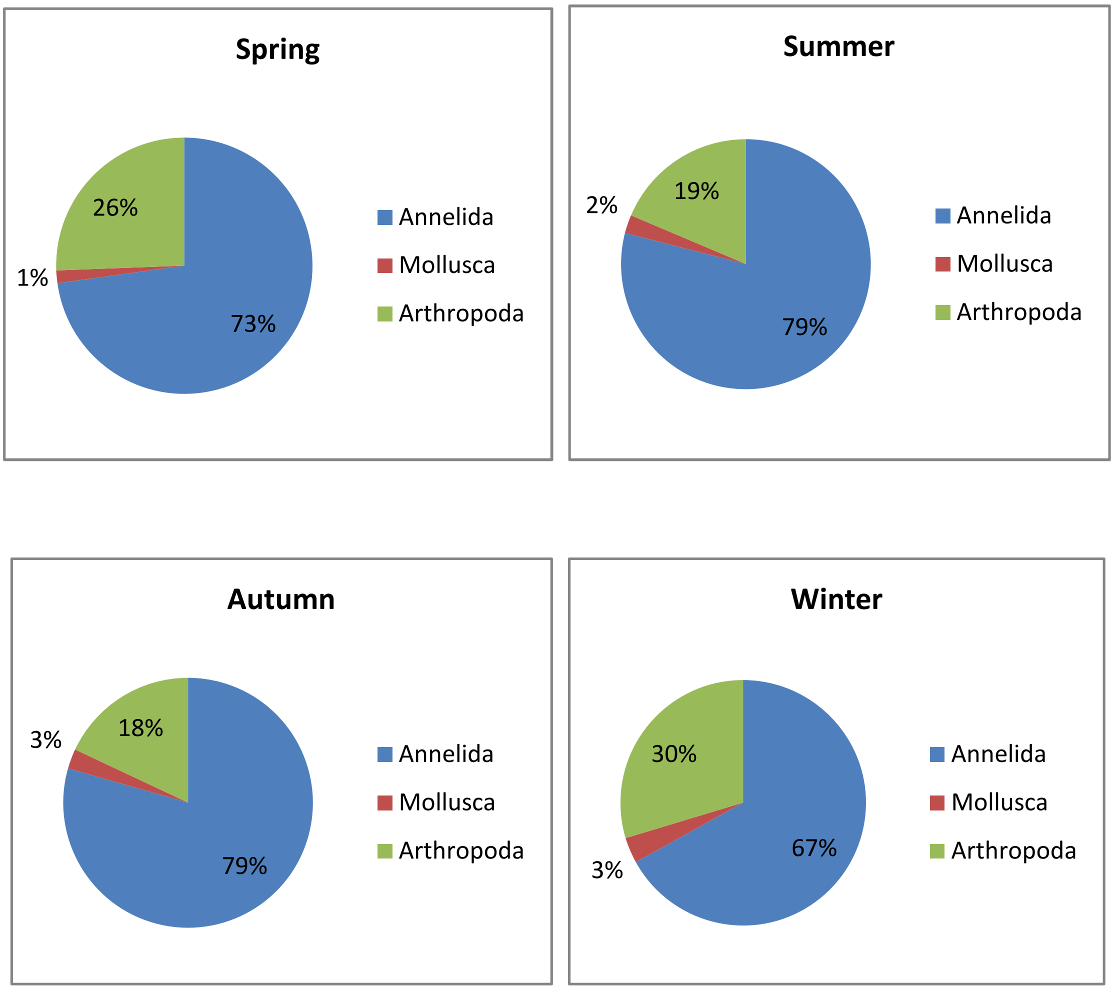


Fig. 5.3.2.2: Seasonal variations in relative density of macroinvertebrates at Parigam spring from March 2011 - Feb. 2012

Table 5.3.2.3: Seasonal variations in relative density of macroinvertebrates at Katrooso sprirng from March 2011-Feb. 2012.

Phylum	Spring	Summer	Autumn	Winter
Annelida	45.7	57.14	53.33	47.61
Mollusca	8.57	9.22	8.23	8.16
Arthropoda	45.71	33.63	38.43	44.21

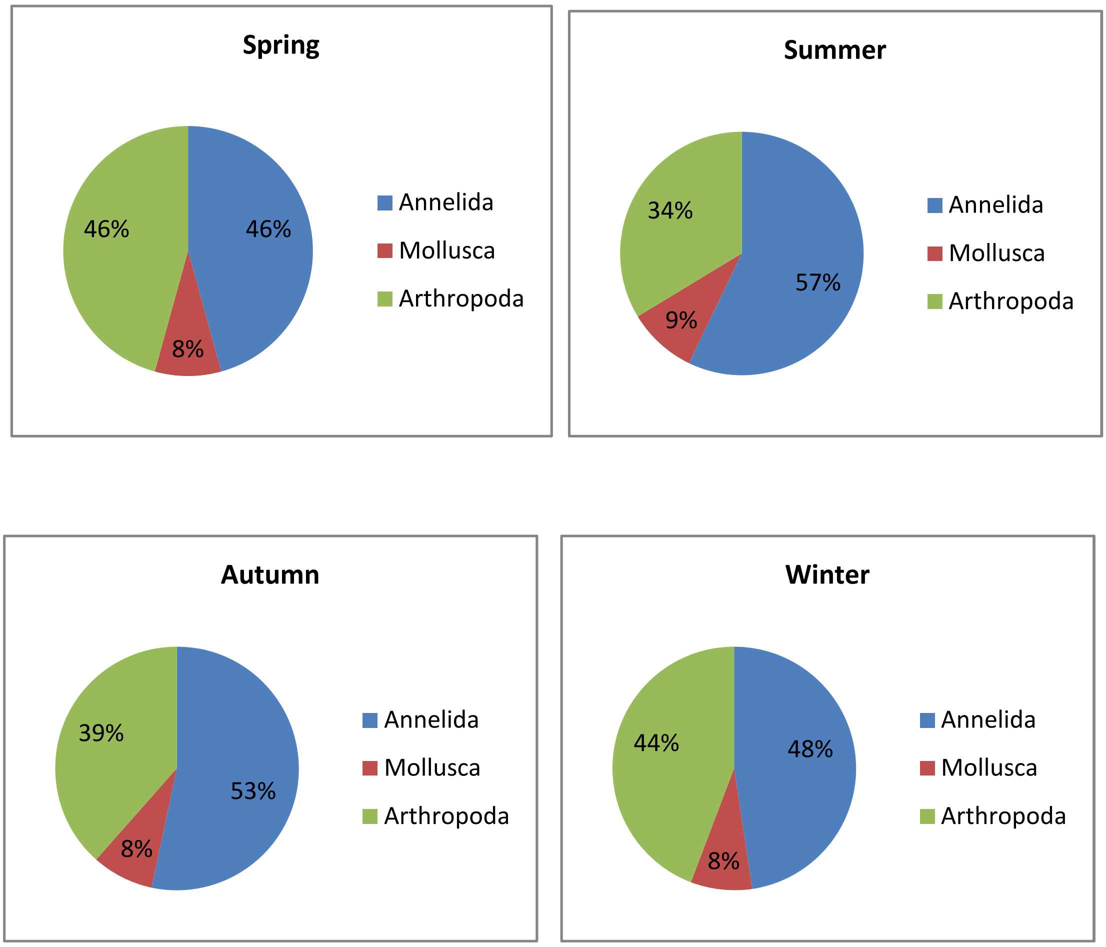


Fig. 5.3.2.3: Seasonal variations in relative density of macroinvertebrates at Katrooso spring from March 2011-Feb. 2012

Table 5.3.2.4: Seasonal variations in relative density of macrocroinvertebrates at Khee spring from March 2011-Feb. 2012.

Phylum	Spring	Summer	Autumn	Winter
Annelida	45.45	48.60	50.64	43.10
Mollusca	8.55	7.69	6.00	6.89
Arthropoda	45.98	43.70	43.34	50.00

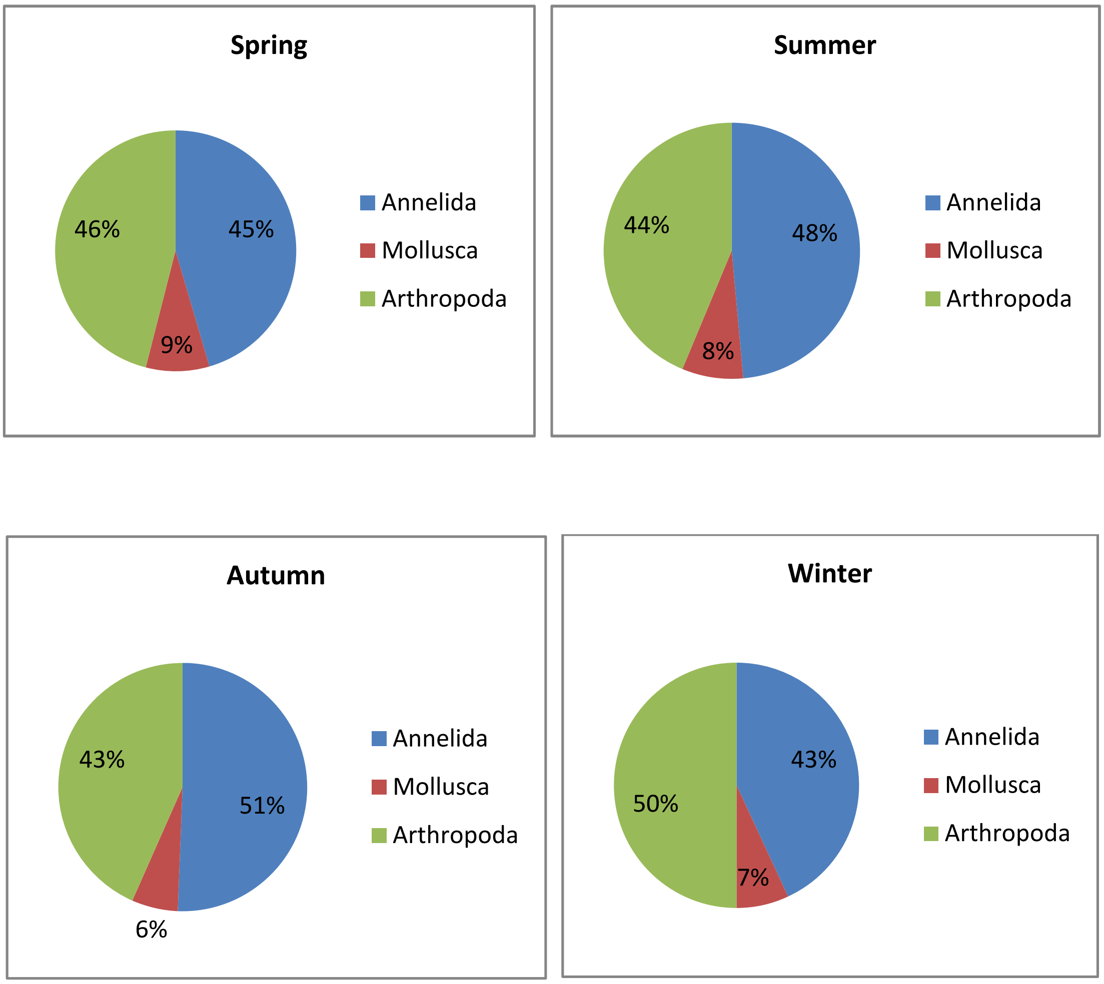


Fig. 5.3.2.4: Seasonal variations in relative density of macrocroinvertebrates at Khee spring from March 2011-Feb. 2012

Table 5.3.2.5: Seasonal variations in relative density of macroinvertebrate at Kulgam spring from March 2011-Feb. 2012.

Phylum	Spring	Summer	Autumn	Winter
Annelida	35.42	43.03	43.65	30
Mollusca	12.22	15.59	26.84	25
Arthropoda	52.35	41.37	29.49	45

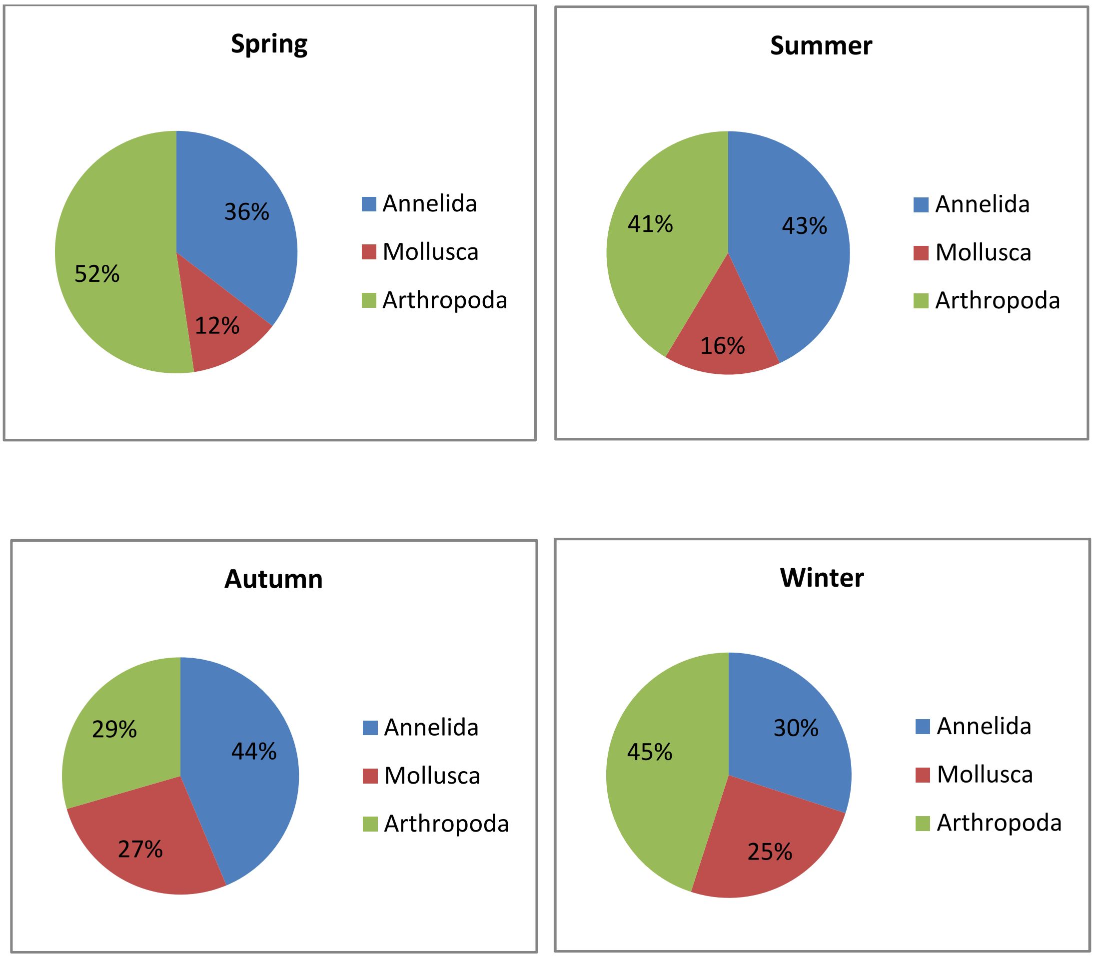


Fig. 5.3.2.5: Seasonal variations in relative density of macroinvertebrate at Kulgam spring from March 2011-Feb. 2012

Table 5.3.3: Diversity indices of macroinvertebrates

Indices	Shannon	Simpson	Margalef
Qoimoh	2.129	0.8384	2.292
Parigam	1.82	0.7889	1.878
Katrooso	2.441	0.882	2.743
Khee	2.133	0.8394	2.383
Kulgam	2.601	0.8987	3.193

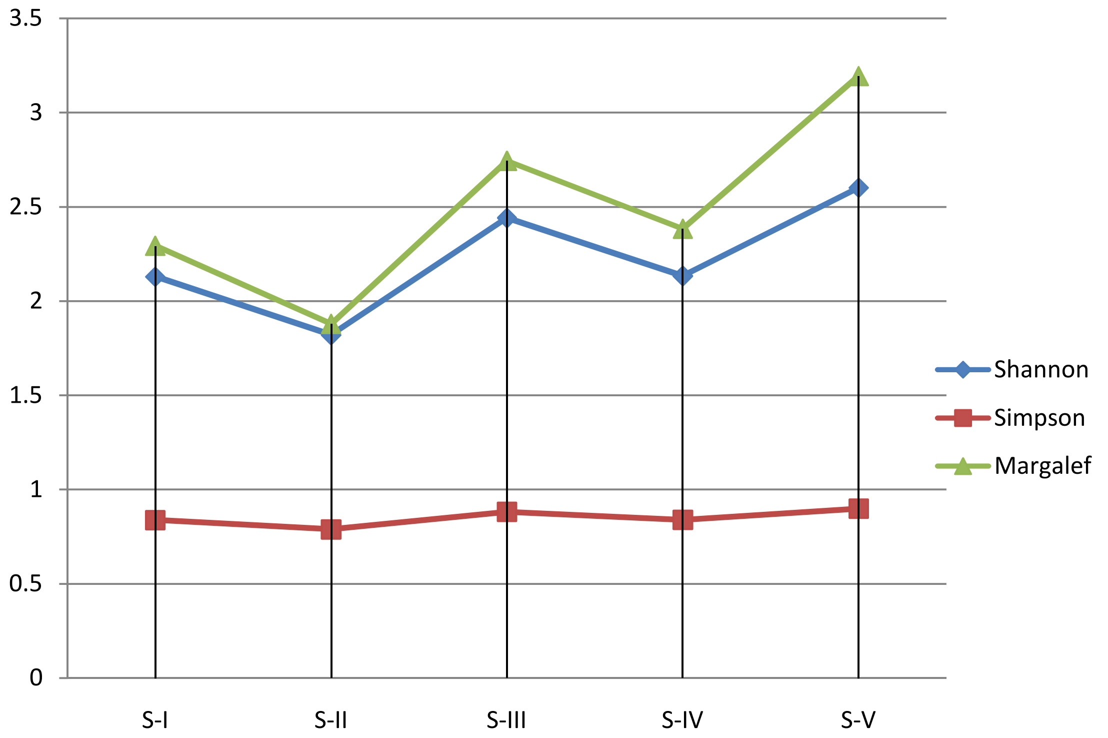


Fig. 5.3.3: Diversity comparisions between different indices during the study period

Chapter- 6

DISCUSSION

Springs are defined as the surface seepage of ground water. Fresh water springs have a great ecological and economical importance as they provide only flow to rivers and streams during the periods of extreme drought and represent a dependable but valuable supply of water in regions facing water scarcity. They exhibit great species diversity of both flora and fauna and also provide great recreational amenities. Smith (1991) classified springs according to the ground water flow rates and the topography of the ground water source area into three types: (i) helocrene (marshy holding), (ii) rheocrene (emergent ground water flows rapidly) (iii) limnocrene (pool formation occurs). The five springs of Kulgam district undertaken for present study belong to the limnocrene category as the ground water comes out to the surface in the form of pool, which is subjected to various natural and anthropogenic stresses, effecting the quality of water vis - a - vis the limnological features besides the trout it sustains. Springs like Qoimoh and Katrooso are located in the residential area and are thus directly under the influence of human habitation providing domestic pollution. While springs like Khee and Kulgam have a catchment mostly comprised of agriculture and horticulture land and thus have agriculture source of pollution Howeverparigam spring has a catchment comprised of both arable and residential area, thus is subjeated to both agriculture and domestic pollution.

Physico-chemical Characteristics of Water

The pH of the investigated spring waters was slightly towards alkaline side of neutrality with with values remaining always more than seven. It varied from 7.02-7.48. No significant variations were observed in pH of water during different seasons. The slightly higher values of pH in winter may be attributed due to less decomposition process of organic matter to release organic acids (Kononova,1961) and due to decrease in spring discharge (Bernaldez and Rey Benayas, 1992).

Chapter- 7

SUMMARY
AND
CONCLUSIONS

The high-altitude valley of Kashmir is of tectonic origin, lying between $33^{o}25'$ to $34^{o}50'$N and 74^{o} to 75^{o}E. It abounds in a vast array of freshwater bodies like lakes, wetlands, springs and streams, which have a great socio-economic and ecological importance. Among these, the vast array of springs play an important role in maintaining the hydrological regimes of the entire valley, besides providing portable water for drinking and irrigation purposes. In addition to providing recreational and aesthetic appeal, they are a repository of endemic fish species (*Schizothorax* sp.) and have great potential for trout culture in the valley. Though many springs have great religious and socio-economical importance, yet in the recent past they have remained neglected both by ecologists and common man. The valley as such is losing many of these fresh water resources due to contamination through natural as well as human interferences. In this backdrop, the present study on five fresh water springs of Kulgam have been undertaken to access the water quality and macroinvertebrate fauna via-a-vis the anthropogenic pressures. The five springs of Kulgam district situated between 74°35′ to $75^{o}11'$ E longitude and 33°39′ to $33^{o}65'$ N latitude and lying at an altitude of 1618-1758 m (a.m.s.l.) are Qoimoh, Katrosoo, Khee, Kulgam and Parigam. While the first two springs (Qoimoh and Katrosoo) are located in the densely human habitation, the third and fourth springs (Khee and Kulgam) have agriculture and horticultural land around them. The fifth spring (Parigam) has a catchment comprised of both domestic and agricultural land. Thus, the studied springs have differential sources of pollution, being domestic for Qoimoh and Katrosoo, and agricultural for Kulgam and Khee while Parigam has both domestic and agricultural sources of pollution.

7.1. Physico-chemical Characteristics of Water

The physico-chemical characteristics of spring water were monitored on monthly basis from March 2011 to February 2011. During the study period all the investigated springs depicted alkaline pH with values remaining always more than seven (7). The monthly variation of pH values ranged from a minimum of 7.02 at Khee in March to a maximum of 7.48 at Katrooso in January. Conductivity ranged from a minimum of 164 μScm^{-1} at Qoimoh in April to a maximum of 304 μScm^{-1} at Parigam in December. The data revealed that there was a definite seasonal trend with warmer months recording lower values and colder months recording higher values for conductivity. The water temperature did not fluctuate much and remained low through out the study period. It ranged from a minimum of 6.5°C at Kulgam in January to a maximum of 11°C at Parigam in August. The free carbon dioxide values varied from a minimum of 4.2 mg/L at Qoimoh in July to a maximum of 8.6 mg/L at Parigam in March. The alkalinity of water was represented by carbonates and bicarbonates. In general, alkalinity varied from a minimum of 76 mg/L at Khee in September to a maximum of 148 mg/L at Parigam in January. Total hardness varied from a minimum of 122 mg/L at Khee in July to a maximum of 288 mg/L at Parigam in January. However, the seasonal mean values fluctuated between the lowest mean value (127.33±6.11 mg/L) at Khee in summer and the highest (258.67±27.68 mg/L) at Parigam in winter. Calcium hardness varied from the lowest of 82 mg/L at Khee in July to the highest of 208 mg/L at Parigam in January. Similarly the monthly variation of magnesium hardness ranged from a minimum of 32 mg/L at Khee in April, to a maximum of 99 mg/L at Qoimoh in January.

Spring waters are enriched by chloride mainly of anthropogenic origin and underlying rocks as salts of sodium, potassium and calcium. Chloride content fluctuated between a minimum of 14 mg/L at Qoimoh in December and a maximum of 44 mg/L at Parigam in June. Dissolved oxygen content of the investigated spring waters remained low throughout the study period due to the lack of interaction with surface. It ranged from a minimum of 2.8 mg/L at Khee in October to maximum of 7 mg/L at Kulgam in January. The monthly variations in BOD ranged from a minimum of 0.1 mg/L at Khee in January to a maximum of 1.6 mg/L at Parigam in July. The lower values of BOD from investigated springs indicate good water quality.

During the study period the minimum value of ammonical nitrogen (33µg/L) was recorded at Qoimoh in March against the maximum value of 112 µg/L at Parigam in August. On monthly basis, nitrate-nitrogen fluctuated from a minimum of 470 µg/L at Kulgam in April to a maximum of 2180 µg/L at Parigam in December. Significant spatial variations were observed for nitrate nitrogen on the basis of annual mean values and as such the maximum value of the ion was observed at Parigam (1544.6±309.07µg/L) against the minimum value (1037.9±175.27 µg/L) observed at Qoimoh. Nitrite nitrogen varied from a minimum of 3.4 µg/L at Khee in January to a maximum of 12.5 µg/L at Parigam in July. However, ortho-phosphate phosphorus (OPP) varied from a minimum of 24 µg/L (Khee) in the month of September to a maximum of 196 µg/L (Parigam) in the month of January. During the study period, the minimum value of sulphate (1.1 mg/L) was recorded at Qoimoh in July against the maximum value of 3.4 mg/L at Parigam in January.

The concentration of five heavy metals namely chromium (Cr) nickel (Ni), lead (Pb), zinc (Zn) and iron (Fe) were also recorded in spring water samples. However, the concentration of all the investigated heavy metals were found to be well within WHO permissible limits.

7.2. Macroinvertebrate Community

The macroinvertebrates, collected during the study period from March 2011 to February 2012, belonged to three phyla viz. Annelida, Arthropoda and Mollusca. The macroinvertebrate community of the five studied springs did not vary much in species composition. A total of 26 taxa were recorded from all the study sites. However, the number of taxa varied in the five springs. Phylum Annelida was represented by class Oligochaeta (3) and class Hirudinea (3). Phylum Arthropoda was represented by class Crustacea (1), class Insecta (14) and class Archnida (1). Among the Arthopoda, the species rich class Insecta is itself an assemblage of different orders (Trichoptera-4, Odonata-1, Hemiptera -1, Diptera-6, Coleoptera-1 and Ephemeroptera-1), whereas phylum Mollusca was represented by class Gastropoda and Pelecypoda. Among the spring macroinvertebrates *Chironomous* sp., *Tubifex tubifex, Limnodrillus* sp., *Erpobdella octoculata, Branchiuras owerbyii, Lymnaea auricularia* and *Gammarus pulex* were the most dominant forms, being present in all the five springs. However, species like *Dolomedes* sp., *Simulium* sp., *Corbicula* sp., *Placobdella* sp., *Rhyacophila* sp., and *Glossosoma* sp. were least represented as only few individuals were encountered. Out of 26 taxa, the highest number of species were recorded at Kulgam (24), followed by Katrooso (20), Qoimoh (18), Khee (17) and decreasing to the lowest of 16 species at Parigam.

On the basis of information acquired in the present study on five limnocrene springs it has been found that:

1. The overall water quality of all these five springs under study is quite feasible for drinking purposes.
2. The spring discharge, flow variability, substrate composition and anthropogenic disturbances are the main factors governing the composition and abundance of macrobenthic assemblages in springs.
3. The relatively high levels of inorganic salts in Paragam spring is due to indescriminate use of inorganic fertilizers in its catchment area, comprising both agriculture and horticulture land.
4. The higher density of pollution tolerant taxa such as *Chironomus* species, *Tubifex tubifex* and *Limnodrillus* species at Parigam and Qoimoh springs may be due to the presence of thick muddy sediment enriched with organic matter mainly as a result of intense anthropogenic activities associated with the springs.
5. The pollution sensitive species (Caddisflies and May flies) are getting replaced by pollution tolerant species (*Chironomus* sp. and *Tubifex tubifex*) as pollution level of the spring increases.

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