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RESEARCH ARTICLE

LIMNOLOGY OF RIVER JHELUM WITH SPECIAL REFERENCE TO ENTOMOFAUNAL DIVERSITY AND PHYSICO-CHEMICAL PARAMETERS

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Abstract

The current study was undertaken to investigate the Entomofaunal diversity and physico-chemical features of River Jhelum in Kashmir valley. Entomofauna was collected by using a handmade D-frame net, while as physico-chemical analysis of water was conducted according the standardmethods of the APHA (2004). A total of 17 insect taxa were recorded, whichbelong to 7 orders and 13 families. The average population density of entomofauna was estimated 457 ind./m^2 with order Diptera as most dominant group. Physico-chemical analysis of River waters revealed alkaline, and had hard water nature of River waters. The upper courses of River Jhelum witnessed higher Entomofaunal diversity due to less anthropogenic stress as compared to middle courses, which face higher anthropogenic stress.

Introduction:-

Aquatic insects are amongst the most abundant animals on planet Earth and constitute the essential constituents of an aquatic ecosystem. They constitute around 60%of aquatic fauna inhabiting freshwater habitats and represent the most diverse group of animals (Balian et al., 2008). It has been found that about, 76,000 known species of aquatic insects are adapted to all kinds of fresh water aquatic ecosystems including ponds, rivers,lakes, reservoirs, streams, ground water and wetlands. These insects spend their life stages, mostly eggs and larvae in the water while adults are typically terrestrial. Majority of the aquatic insects inhabit shallow waters of littoral zone, where the light penetrate the bottom zone, while as few aquatic insects inhabit limnetic and profundal zones (McCafferty, 1981). Insects are cosmopolitan in distribution and grouped in 13 taxonomic orders, of which Odonata,Trichoptera, Ephemeroptera, Plecoptera, and Megaloptera are completely restricted to fresh water with aquatic larval stages, whilethe remaining eight orders (Coleoptera, Hemiptera, Collembola, Diptera, Lepidoptera, Hymenoptera, Neuroptera and Orthoptera) are represented by terrestrial as well as aquatic or semi-aquatic species with order Diptera being the largest group, comprising nearly half of all aquatic insects(Barman, 2014).

Aquatic insects play an ecologically significant role in proper functioning of freshwater ecosystem. They contribute in decomposition and nutrient recycling, thus enhance the productivity of aquatic ecosystems. They are used as diet by most fishes, amphibians, reptiles, birds and small mammals. Thus, they are important link in food chains and food webs (Wilson, 1923).High diversity and density of aquatic insects in any water body ensure theavailability of food to other animals during specific period of time (Dudgeon, 1999). Aquatic insect fauna is known to process nutrients from coarse particulate organic matter and fine particulate organic matter that are plentiful in freshwater

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aquatic ecosystems but are not freelyaccessible for other animals as they are either too large or too small for consumption. Aquatic insect fauna may be consumed by other freshwater and terrestrial predators and thus contribute towards energy flow in the community (Nair et al., 2015). Since pre-historic times many aquatic insects are consumed by humans as a source of nutrients. The eggs, larvae, pupae and adults of over 250 species of aquatic insect fauna have been used as food in different countries around the world including Central and South America, Africa, Asia, Australia and New Zealand. These aquatic insects are an excellent source of nutrients like proteins, fats, carbohydrates, minerals (Iron, Zinc etc), vitamins and essential amino-acids (Macadam and Stockan, 2017).

The practice of employing aquatic insects as bio control agents has resulted in the control of several species of exotic aquatic weeds that have out-competed numerous native species and have become problematic in several parts of the world. Apart from weed control, few aquatic insects are known to prey upon many harmful insects like mosquito larvae, which act as vector of various diseases (Lee, 1967; Aditya et al., 2006). Aquatic insects also play role as biological indicators water quality. They respond to specific fluctuations in water parameters and thus, their presence or absence indicates the degree of pollution in aquatic ecosystem. From the past few decades there has been an increasing concerns regarding environmental problems caused by undesirable anthropogenic activities. Efforts are being made globally to keep a regular check on water quality that mainly focuses on physico-chemical analysis. Monitoring abiotic components of a water body is not satisfactory enough to fully depict its status or reliably identify adverse impacts of pollution, which greatly impactsaquatic biota. Thus, now-a-days biological monitoring is gaining reputation wherein living organisms are used to determine the well-being of an aquatic ecosystem (Gudooet al, 2020). However, it must be noted that standard physicochemical analysis cannot be completely be replaced by biomonitoring procedures alone, both can be employed in conjunction for a comprehensive assessment of water quality of freshwater ecosystems. In developed countries scientists have been using aquatic insects forbio assessment or biomonitoring, but less attention has been given in the Asian countries using aquatic insects as bio indicators(Morse et al. 2007).

Fresh water insects are model organismsevaluating the quality of an aquatic ecosystem because of their high richness and diversity in most of water bodies, community consisting of both pollution tolerant and pollution sensitive species, longer life cycles, ability to respond to multiple stresses and slight fluctuations in their environmental conditions, their easy identification and collection methods (Gudooet al, 2020). Keeping in view the above highlighted facts about aquatic insects, the current study was undertaken for a period of one years extended from March, 2019 to February, 2020 to study the diversity of aquatic insects in River Jhelum in Kashmir valley.

Materials and Methods:-

Study site:

River Jhelum is a major tributary among the five major tributaries namely Jhelum, Chenab, Ravi, Beas and Satluj of Panjab region. The Jhelum River is commonly known as “Vyeth” in Kashmiri, “Vetesta” in Sanskrit and “Hydaspes” in Greek. It is situated in a longitudinal depression in great Northwestern complex of Himalayan ranges. River Jhelum originates from a famous spring of Kashmir known as “ChashmaVerinag”, which is located at the foot of PirPanjalin South Eastern part of Kahmir valley(Anantnag). It is the main water gateway, which drains the entire valley of Kashmir and finally merges with the River Indus in Pakistan. The total geographical area of Jhelum upto Indo-Pakistan border is about 34775sq.kms. with a total length of 402kms. The length of River Jhelum in India upto ceasefire line is about 165 kms. with a catchment area of approximately 17622 sq. kms and lie within the geographical coordinates of 32^0 – $58^l$to 35^0- 38^lNorthLatitude and 73 ⁻ 23^l to 75^o– 35^lEast longitude and is mainly confined to valley of Kashmir in India (Singh and Rashid, 2020; Javaid and Gowhar, 2022). The Jhelum River is encircled by mountain ranges covered with snow from the month of October to May. River Jhelum has 24 tributaries, some draining from PirPanjal ranges and join the river from left flank and some flowing from Himalayan range and join the river from right flank. During its courseuptothe town of Anantnag three major tributaries including SandranRiver, BrinjiRiver and Arapath joins its right flank. LidderRiverfed by multiple glaciers joins its right flank at 2km downstream of Khannabal town. River Vishowand Rambiara merge with Jhelum on its left flank at 4.82kms. upstream from Sangam town. In between Srinagar and Sangam, river Jhelum receives watlara and Arapal streams on the right flank and Rambiara, Sasara and Romuhistreams on its left flank. Just before river Jhelum enter the main city of Srinagar, it is joined by a stream from Dal Lake near Shergari. Below the city of Srinagar, the water flow of Dudh Ganga merges with the river and down below Sind nallah combines with it near Shadipora on its right bank. At Bonyari 20km downstream, the waters of Jhelum leads to WularLake, which controls its flow. Emerging from the lake, Jhelum river runs westward and cross PirPanjal in a george some 7000 feet deep, which ends at Khadanyar, Baramulla.. The Jhelum River divides into two channels in Khadanyar. The river then

flows through Uri town to Muzaffarbad before leading to Pakistan. (Khalida Hassan et al., 2014; ShakilRomshoo, 2016; CWC, 2011-2023).

Fig. 1:- Map of River Jhelum with Sampling stations.

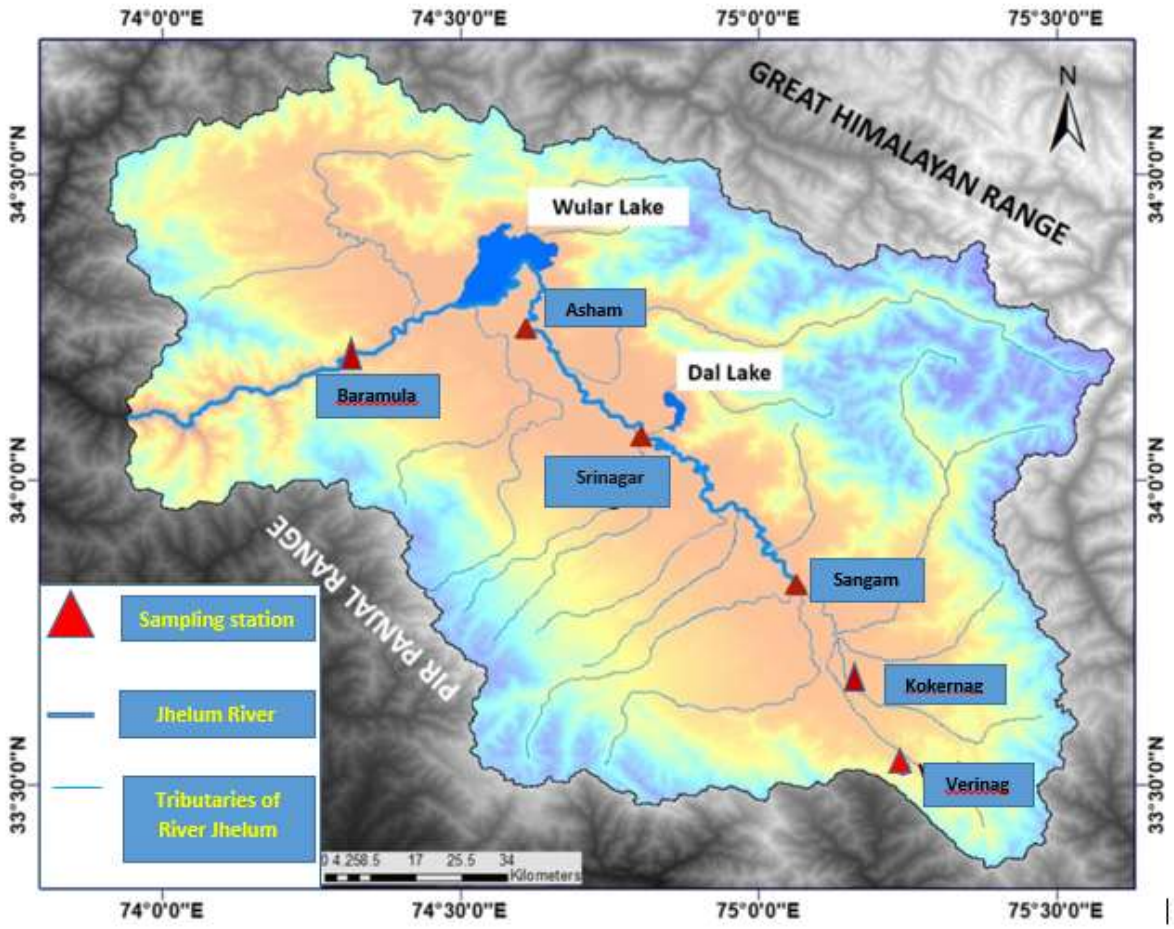


Table 1:-Description of study sites.

Study Sites	Latitude	Longitude	Characteristics
Verinag	33°32'128"N	75°15'036"E	Fast current, bottom with boulders, pebbles, cobbles, gravel, sand and silt
Kokernag	33°35'.202"N	75°17'926"E	Fast current, bottom with boulders, pebbles, cobbles, gravel, sand, silt, leaf litter etc.
Sangam	33°55'25"N	74° 0'494"E	Gravel, sand Mud and organic debris
Srinagar	32°35'870"N	75°21´120" E	Gravel, sand Mud and organic debris
Asham	33°54'3"N	75°0'45"E	Gravel, sand Mud and organic debris
Baramulla	33°57'5"N	74°58'57"E	Gravel, sand Mud and organic debris

Collection and analysis of water samples:
Sampling was performed on seasonal basis for a period of one years stretched from March 2019 to February 2020. Water samples were collected in iodine treated polyethylene plastic bottles from each sampling station. Physico-chemical analysis was performed according to standard methods of APHA, 2004. Water temperature, depth, dissolved oxygen (DO), pH and free carbon dioxide were measured in the field during water sample collection, while electrical conductivity, total alkalinity,total hardness, chlorides, nitrate, and total phosphorous, were analyzed at the hydrobiology research laboratory in S.P. College, Srinagar.

Collection, preservation and identification of aquatic insects:

Aquatic insects were collected by passing a D-frame net through the vegetation present along the margins of water body. In case of flowing water body, the net was held downstream. The gravel and sand at the bottom were disturbed, so that the benthos or insects hidden under the stones move out and get trapped into the net. The insects trapped in net were then put into a white pan containing some water and were collected using forceps or brush. The insects crawling around the vegetation and pebbles were also collected by hand-picking method and forceps. Most of the surface swimming insects like water striders and wriggling beetles were collected by sweeping the net through the water surface (Hassan et al, 2014, Gudooet al, 2020, Radika Singh, 2022). At each site three samples were obtained monthly

The insect samples collected were preserved in well labelled plastic vials containing 70% alcohol with few drops of glycerine (Gudooet al, 2020, Radika Singh, 2022).Preserved samples of insect taxa were identified to the lowest possible taxonomic level according to standard taxonomic works of Edmondson (1959), Pennak (1978), Tonapi (1980) and Adoni (1985).

The density (no. of individuals/m^2) was calculated by using formula:

No. of individuals/m^2 = N×10000/A × S

Where,

N = no. of individuals in sampler.

A = area of sampler

S = no. of samples taken at each site.

Diversity indices

For calculating species diversity, Shannon-Wiener diversity index Simpson'sdiversity index was used.

Shannon-wiener diversity index (H)

It takes into account both the abundance and evenness of the species present in the given sample and it increases with increase in diversity (Gudooet al, 2020, Radika Singh, 2022).

$$H = -\sum_{I=1}^{S} pi \times \log pi$$

Where,

H = Shannon-Wiener index

Pi = Proportion of total species belonging to i^{th} species

S= number of species

∑= sum from species i to species s

Simpson's diversity index (D)

It gives more weightage to dominant species in the sample and it decreases with increase in diversity. (Gudooet al, 2020, Radika Singh, 2022).

$$D = -\sum_{I=1}^{S} (pi)^2$$

Where

D = Simpson's index

pi = Proportion of total number of individuals of each species.

S = Total number of individuals in the community

Margalef's richness index

Margalef's richness index was calculated by the formula given below:

D = (S-1) ÷ Ln (N)

Where,

D = Margalef's richness index

S = total number of species

N = total number of individuals in a sample

ln = log normal

Results and Discussion:-

Physicochemical report of River Jhelum in given in table-2

The alterations in physico-chemical parameters of water provides valuable information about the quality of water.

Water Temperature:

In an aquatic ecosystem temperature is of ecological significance as it regulates its various biotic and abiotic features (Katariaet al, 1995, Gudooet al, 2020, Radikasingh, 2022).During the present study, well-marked variations were observed in water temperature at different sampling stations. The average water temperature fluctuated from a minimum of 10.1± 3.44 C^0at Verinagsampling stationto a maximum of 11.7 ± 5.41°C at Srinagar sampling station. Water Temperature is known to be influenced directly by the temperature of air and follows same trend of alteration by exhibiting higher values in summers and a fall in winters.

Depth

The depth of water body plays a significant role in shaping the quality of water. Any variation in depth or water level in an aquatic ecosystem is mainly controlled by climatic factors including rate of evaporation, precipitation etc. The heating of water due in shallow nature ofwater bodies influence the interactions between various living and non-living components of an aquatic ecosystem (Sawhney, 2008). During current study, average depth varied from maximum of 450 cm ±120.85 at Srinagar sampling stationto minimum of 39 cm at Kokernag sampling station.

pH:

pH is the measure of hydrogen ion concentration in an aquatic ecosystem (Wetzel, 2001). It is an important physicochemical parameter affecting overall changes in hydrobiological characters (Shastree et al., 1991).pH changes are influenced by carbonates, bicarbonates and carbon complexes in water (Singh, 2022). During present survey, mean pH value of varied from minimum 7.22 ± 0.22 at Verinag sampling station to maximum of 8.1± 0.12 at Sangam sampling station.The higher pH values indicated the alkaliphilous nature of water, attributed to sewage influx from immediate catchments into the water body (Umerfaruq and Solanki 2015, Gudooet al, 2020).

Electrical conductivity:

Electrical Conductivity is the capacity of a substance or solution to conduct electrical current. During current study, conductivity ranged from maximum of 309±35.34µS cm^{-1} at Srinagar sampling station to minimum of 210.10 ± 21.71µS cm^{-1} at Verinag sampling station. High electrical conductivity particularly in Sangam, Asham, Srinagar and Baramulla is attributed to and increasing organic and inorganic loading in lakes from immediate catchments (Gudoo et al, 2018; Gudoo et al, 2020).

Dissolved oxygen (DO):

Dissolved oxygen helps in evaluating any change in quality of water and regulate the metabolic processes of all living forms in water. DO concentration of an aquatic ecosystem varies with temperature, turbulence, photosynthetic activity etc. (Gudoo et al, 2018). During current study, DO content varied from a maximum of 11.1 ± 2.67mg L^{-1} at Verinag sampling station to minimum of7.9 ± 0.31mg L^{-1} at Asham sampling station. The decrease in DO content of sampling stations except Verinag and Kokernag is due to input of organic matter into the river from catchment areas.

Free carbon dioxide:

In a water bodies carbon dioxide reacts with water and lead to formation of carbonic acid which on decomposition form carbonates and bicarbonates and thus cause alteration pH of water.During current study, mean free carbon dioxide content varied from a maximum of 11.3±1.49mg L^{-1} at Asham sampling station to minimum of8.80±1.87mg L^{-1} at Verinag sampling station. Lowervaluesoffree carbon dioxide concentration was recorded particularly in spring and summer at Verinag and Kokernag sampling station, possibly due to increased algal photosynthesis and less organic matter loading (Aura et al. 2011, Gudoo et al, 2020)

Chloride content:

Chloride content in water is an excellent indicator of organic matter load.The high chloride concentration reflect the organically polluted nature of water body. (Venkatasubramani and Meenambal., 2007, Gudoo et al, 2018). During present study, chloride content in River Jhelum ranged from maximum 13.2 ± 6.55 mg L^{-1} at Sangam sampling station to minimum 4.3 ± 2.33 mg L^{-1} . The increase in chloridecontent of sampling stations except Verinag and

Kokernag is due to higher input of organic matter into the river from catchment areas (Ahangar, 2014, Gudoo et al, 2020.)

Nitrate-nitrogen:
Nitrates are common form of inorganic nitrogen in aquatic ecosystem produced by the action of nitrifying bacteria on nitrogen rich agricultural and domestic wastes (Dar et al., 2013). During present study, Nitrate-nitrogen content ranged from maximum 312±58.33µg L^{-1}at Srinagar sampling station to minimum 31.82 ± 4.89µg L^{-1} at Verinag sampling station. Higher concentration of nitrate was found during summer seasonand minimum during winter and spring. The summer maxima may be attributed to increased rate of decomposition of organic matter (Naik 2015).

Total Phosphorous:
Phosphorus is primary cause eutrophication in aquatic ecosystem. Main sources of Phosphorous are domestic sewage and agricultural run-off containing fertilizers. During present study, total phosphorus concentration ranged from a minimum 132.32 ± 49.20 mg L^{-1} at Verinag sampling station to maximum 151 ± 62mg L^{-1} at Sangam sampling station.

Total hardness:
Hardness reflects concentration of metallic cations like Calcium, magnesium, carbonates, bicarbonates, sulphates, chlorides, nitrates, soap, detergent and organic matter in water. During the study period, total hardness of River Jhelum ranged from a minimum 166.34 ± 19.71mg L^{-1} at Verinag sampling station to maximum 233.5±25.84mg L^{-1} at Srinagar sampling station. The hardness of Jhelum water indicate its hard water nature with total hardness values greater than 150mg/l. The higher total hardness values in sampling stations exceptVerinag and Kokernag is attributed to more agricultural runoff and sewage input (Bashir et al, 2017; Gudoo et al, 2018).

Table2:-Physico-chemical report (Mean values) of River Jhelum.

Parameters (unit)	Verinag	Kokernag	Sangam	Srinagar	Asham	Baramulla
Water temperature (^{0}C)	10.10± 3.44	10.0. ± 3.47	11.50 ± 4.11	11.70±5.45	11.30 ± 3.12	11.60±3.14
Depth (cm)	1500	39	310 ± 123..30	450±120.85	327±131..30	344±113.34
pH	7.22 ± 0.22	7.934 ± 0.69	8.1± 0.12	7.8±0.11	8± 0.13	7.7±0.13
Conductivity (µS cm^{-1})	210.10 ± 21.71	232.70± 22.69	299 ± 28.59	309±35.34	287 ± 23.44	292±25.49
Dissolved Oxygen (mg/l)	11.1 ± 2.67	9.9 ± 1.97	8.0 ± 0.44	8.2±0.75	7.9 ± 0.31	8.1±0.,33
Carbon dioxide (mg/l)	8.80±1.87	8.89±.1.91	10.3±1.66	9±1.88	11.3±1.49	9.1±1.87
Alkalinity (mg L^{-1})	112.13±19.23	118.12±21.32	161±14.73	158±12.36	169±15.83	159±1.45
Chloride (mg/l)	4.3 ± 2.33	5.6.58± 4.35	13.2 ± 6.55	12.9±3.11	11.2 ± 5.55	11.9±5.83
Nitrate-Nitrogen (µg/l)	31.82 ± 4.89	48.70 ± 7.81	272 ±41.81	312±58.33	284 ±45.89	297±51.77
Total phosphorous (mg/l	132.32 ± 49.20	137.62 ± 98.1	151 ± 62	145±59	142 ± 44	143±51
Total Hardness (mg/l)	166.34 ± 19.71	178.32 ± 20.88	205± 27.76	233.5±25.84	225± 37.66	230±23.11

Insect fauna of River Jhelum:
During the survey extending from March, 2019 to February, 2020 a total of 17 insect taxa were recorded from 6 sampling stations of River Jhelum, representing 7 orders and 13 families. The systematic list of insects in given in table-3.

Table3:- Systematic list of Insect fauna in River Jhelum.

S.No.	Phylum	Class	Order	Family	Taxa
1	**Arthropoda**	Insecta	Diptera	Chironomidae	Chironomussp
2					Diamesinae sp.
3				Tabanidae	Tabanus sp.
4				Simuliidae	Simulium sp.
5				Ceratopgonidae	Bezzia sp.
6			Odonata	Gomphidae	Gomphus sp.
7			Ephemeroptera	Baetidae	Baetis sp.
8				Caenidae	Caenis sp.
9			Plecoptera	Perlidae	Perlidaesp
10			Coleoptera	Dytisicidae	Coptotomussp
11					Dytiscus sp.
12			Trichoptera	Limniphilidae	Limnephilus sp.
13				Ryacophilidae	Ryacophilaobscura
14					Ryacophila basalis
15			Hemiptera	Corixidae	Corixa sp.
16					Sigara sp.
17				Gerridae	Gerris sp.

The average population density of entomofauna was estimated 457ind./m^2. Order Diptera (5 species) was dominant group with mean population density of 148ind/m^2 followed by Hemiptera (3 species) with 80ind/m^2 , Coleoptera (2 species) with 68ind/m^2, Trichoptera (3 species)with 52ind/m^2, Ephemeroptera (2 species) with 51ind/m^2, Odonata (1 species)with32ind/m^2, and Plecoptera (1 species)with 27ind/m^2 (Table-3). The percent contribution by each insect order is given in fig. 2.

The total population density ofentomofauna at Verinag sampling station was estimated 333ind/$m^2$with Trichoptera as most dominant group with 102ind/m^2 followed by Ephemeroptera with 79ind/m^2, Dipterawith 50ind/m^2, Plecoptera each with 36ind/m^2, Hemiptera with 34ind/m^2,Coleoptera with 20ind/$m^2$and Odonata 12ind/m^2. (Table-3). A total of 17 species (5 Dipterans, 1 Odonata, 2 Ephemeropterans, 1 Plecopteran, 3Trichopterans, 2 Coleopterans and 3 Hemipterans) were recorded at this sampling stationincludingChironomous sp. (10ind/m^2), Diamesinae sp. (12ind/m^2), Tabanus sp. (12ind/m^2), Simulium sp. (8ind/m^2), Bezzia sp. (8ind/m^2), Gomphus sp. (12ind/m^2), Baetis sp. (34ind/m^2), Caenis sp. (45ind/m^2), Perlidae sp. (36ind/m^2), Limnephilus sp. (40ind/m^2), Ryacophilaobscura (30ind/m^2), Ryacophilabasalis ((12ind/m^2),Coptotomus sp. (12ind/m^2), Dytiscus sp. (8ind/m^2), Corixa sp. (12 ind/m^2), Sigara sp. (10ind/m^2) and Gerris sp. with 12ind/m^2.(Fig. 3).

At Verinag sampling station, Shannon wiener index, Simpson's index and Margalef's index were computed as 2.69, 0.8 and 2.75 respectively.

The total population density ofentomofauna at Kokernag sampling station was estimated 332ind/m^2withTrichoptera as most dominant group with 88ind/m^2followed by Ephemeroptera with 72ind/m^2, Diptera with 66ind/m^2, Hemiptera with 42ind/m^2, Coleoptera with 18ind/m^2,Plecopter with 32ind/$m^2$and Odonata with 14ind/m^2(Table-3). A total of 17 species (5 Dipterans, 1 Odonata, 2 Ephemeropterans, 1 Plecopteran, 3Trichopterans, 2 Coleopterans and 3 Hemipterans) were recorded at this sampling stationincluding Chironomous sp. (14ind/m^2), Diamesinae sp. (16ind/m^2), Tabanus sp. (14ind/m^2), Simulium sp. (12ind/m^2), Bezzia sp. (10ind/m^2),Gomphus sp. (14ind/m^2), Baetis sp. (36ind/m^2), Caenis sp. (36ind/m^2), Perlidae sp. (32ind/m^2), Limnephilus sp. (34ind/m^2), Ryacophilaobscura. (28ind/m^2), Ryacophila basalis (26ind/m^2), Coptotomus sp. (8ind/m^2), Dytiscus sp. (10ind/m^2), Corixa sp. (14ind/m^2), Sigara sp. (14ind/m^2) and Gerris sp. with 14ind/m^2. (Fig. 3).

At Kokernag sampling station, Shannon wiener index, Simpson's index and Margalef'sindex were computed as 2.71, 0.7 and 2.75 respectively.

The total population density ofentomofauna at Sangam sampling station was estimated 545 ind/$m^2$with Diptera as most dominant group with 206 ind/m^2 followed by Coleoptera with 120ind/m^2, Hemiptera with 94ind/m^2, Odonata with 45ind/m^2, Plecopters with 32ind/m^2, Tricoptera with 26ind/$m^2$and Hemiptera with 22ind/m^2(Table-3). A total of 16 species (5 Dipterans, 1 Odonata, 2 Ephemeropterans, 1 Plecopteran, 2 Trichopterans, 2 Coleopterans and 3 Hemipterans) were recorded at this sampling stationincluding Chironomous sp. (76ind/m^2), Diamesinae sp. (54ind/m^2), Tabanus sp. (36ind/m^2), Simulium sp. (18ind/m^2), Bezzia sp. (22ind/m^2), Gomphus sp. (45ind/m^2), Baetis sp. (14ind/m^2), Caenis sp. (18ind/m^2), Perlidae sp. (26ind/m^2), Limnephilus sp. (18ind/m^2), Ryacophila sp. (4ind/m^2), Coptotomus sp. (45ind/m^2), Dytiscus sp. (75ind/m^2), Corixa sp. (34ind/m^2), Sigara sp. (28ind/m^2) and Gerris sp. with 32ind/m^2. (Fig. 3).

At Sangam sampling station, Shannon wiener index, Simpson's index and Margalef's index were computed as 2.6, 0.8 and 2.38 respectively.

The total population density ofentomofauna at Srinagar sampling station was estimated 517 ind/$m^2$with Diptera as most dominant group with 180 ind/m^2 followed by Hemiptera with 106ind/m^2, Coleoptera with 82ind/m^2, Ephemeroptera with 46ind/m^2, Odonata with 44ind/m^2, , Tricoptera with 35ind/$m^2$and Plecoptera with 4ind/m^2(Table-3). A total of 16 species (5 Dipterans, 1 Odonata, 2 Ephemeropterans, 1 Plecopteran, 2 Trichopterans, 2 Coleopterans and 3 Hemipterans) were recorded at this sampling stationincluding Chironomous sp. (76ind/m^2), Diamesinae sp. (36ind/m^2), Tabanus sp. (26ind/m^2), Simulium sp. (20ind/m^2), Bezzia sp. (22ind/m^2), Gomphus sp. (44ind/m^2), Baetis sp. (24ind/m^2), Caenis sp. (22 ind/m^2), Perlidae sp. (24ind/m^2), Limnephilus sp. (22ind/m^2), Ryacophila sp. (13ind/m^2), Coptotomus sp. (42 ind/m^2), Dytiscus sp. (40ind/m^2), Corixa sp. (34ind/m^2), Sigara sp. (34ind/m^2) and Gerris sp. with 38ind/m^2. (Fig. 3).

At Srinagar sampling station, Shannon wiener index, Simpson's index and Margalef's index were computed as 2.68, 0.7 and 2.4 respectively.

The total population density ofentomofauna at Asham sampling station was estimated 505 ind/$m^2$with Diptera as most dominant group with 200 ind/m^2 followed by Hemiptera with 91ind/m^2, Coleoptera with 86ind/m^2, Ephemeroptera with 38ind/m^2, Odonata with 34ind/m^2, , Tricoptera with 34ind/$m^2$and Plecoptera with 22ind/m^2(Table-3). A total of 16 species (5 Dipterans, 1 Odonata, 2 Ephemeropterans, 1 Plecopteran, 2 Trichopterans, 2 Coleopterans and 3 Hemipterans) were recorded at this sampling stationincluding Chironomous sp. (80ind/m^2), Diamesinae sp. (44ind/m^2), Tabanus sp. (28ind/m^2), Simulium sp. (22ind/m^2), Bezzia sp. (26ind/m^2), Gomphus sp. (34ind/m^2), Baetis sp. (18ind/m^2), Caenis sp. (20ind/m^2), Perlidae sp. (22ind/m^2), Limnephilus sp. (22ind/m^2), Ryacophila sp. (12ind/m^2), Coptotomus sp. (44ind/m^2), Dytiscus sp. (42ind/m^2), Corixa sp. (35ind/m^2), Sigara sp. (22ind/m^2) and Gerris sp. with 34ind/m^2. (Fig. 3).

At Asham sampling station, Shannon wiener index, Simpson's index and Margalef's index were computed as 2.65, 0.7 and 2.4 respectively.

The total population density ofentomofauna at Barmula sampling station was estimated 509 ind/$m^2$with Diptera as most dominant group with 184 ind/m^2 followed by Hemiptera with 110ind/m^2, Coleoptera with 82ind/m^2, Ephemeroptera with 41ind/m^2, Odonata with 40ind/m^2, , Tricoptera with 30ind/$m^2$and Plecoptera with 22ind/m^2(Table-3). A total of 16 species (5 Dipterans, 1 Odonata, 2 Ephemeropterans, 1 Plecopteran, 2 Trichopterans, 2 Coleopterans and 3 Hemipterans) were recorded at this sampling stationincluding Chironomous sp. (72ind/m^2), Diamesinae sp. (32ind/m^2), Tabanus sp. (32ind/m^2), Simulium sp. (24ind/m^2), Bezzia sp. (24ind/m^2), Gomphus sp. (40ind/m^2), Baetis sp. (22ind/m^2), Caenis sp. (19 ind/m^2), Perlidae sp. (22ind/m^2), Limnephilus sp. (20ind/m^2), Ryacophila sp. (10ind/m^2), Coptotomus sp. (36 ind/m^2), Dytiscus sp. (46ind/m^2), Corixa sp. (38ind/m^2), Sigara sp. (32ind/m^2) and Gerris sp. with 40ind/m^2. (Fig. 3).

At Barmulla sampling station, Shannon wiener index, Simpson's index and Margalef's index were computed as 2.68, 0.7 and 2.4 respectively.

According to Danzetal., (2005), biological indicator species are ecologically very significant tools for the valuation andmonitoring of water quality and the impact of anthropogenic activities on the aquatic ecosystems. During the current, following pollution indicator species including both pollution sensitive and pollution tolerant species have been recorded.

Pollution sensitive species recorded in present study belong to order Ephemeroptera (Baetis sp. and Caenis sp.), Plecoptera (Perlidae sp.) and Trichoptera (Limnephilussp, Ryacophoraobscura and Ryacophila basalis), while as other species particularly Chironomous sp. is considered as pollution tolerant species.These observations draw support from the research of earlier workers who havealso reported these species from the non-polluted and polluted water in their studies. Jindal and Sharma 2011;Sharm andSaini, 2016, Gudoo et al, 2020). The present study shown that the EPT group was more noticeable and comparatively more abundant at Verinag and Kokernag sampling stations, which clearly indicate that they thrive better in clean water conditions with less anthropogenic stress like input of domestic sewage, agricultural wastes etc. at these sites. Similarly high abundance of pollution tolerant species particularly Chironomous species at Sangam, Asham, Baramulla and Srinagar sampling stations indicate the organically polluted conditions at the study sites, which may be attributed to input of domestic sewage , agricultural wastes into the water body from immediate catchment areas. Similar kind of findings were reported by Timm et al. 2001; Khan et al. 2007. And Gudooet al.2020 in their studies.

Entomofaunal abundance was found minimum at Verinag (333 ind./m^2) and Kokernag (332 ind./m^2) sampling stations and maximum at Sangam (545 ind./m^2), Asham (505 ind./m^2), Barmulla (509 ind./m^2) and Srinagar (517 ind./m^2) sampling stations, but opposite was witnessed with respect to Shannon's diversity index,Margalef's diversity indices shows a declining trend from Verinag to Srinagar sampling stations, which indicate that entomofaunaldiversity decrease with increase in water pollution. Conversely, population density of pollution resistant species increase with increasing anthropogenic pressure, which can be attributed to the fact that the anthropogenic pressure declines the species diversity and increase the dominance of pollution tolerant species due to abundant organic matter loading in water body from catchment areas. The fact is also supported by high DO content in head waters and low DO content in river with increasing distance from head waters. These observations coincide with the findings of Hassan et al. 2018 and Gudoo et al. 2020.

Table 3:- Population density (ind./m^2) of insect fauna at various sampling stations in River Jhelum.

Sites	**Diptera**	**Odonata**	**Ephemeroptera**	**Plecoptera**	**Trichoptera**	**Coleoptera**	**Hemiptera**	**Total ind/m^2**
Verinag	50	12	79	36	102	20	34	333
Kokernag	66	14	72	32	88	18	42	332
Sangam	206	45	32	26	22	120	94	545
Srinagar	180	44	46	4	35	82	106	517
Asham	200	34	38	22	34	86	91	505
Baramulla	184	40	41	22	30	82	110	509
Mean	**148**	**32**	**51**	**27**	**52**	**68**	**80**	**457**

Fig. 2:-Percent contribution by insect order at various sampling stations of River Jhelum.

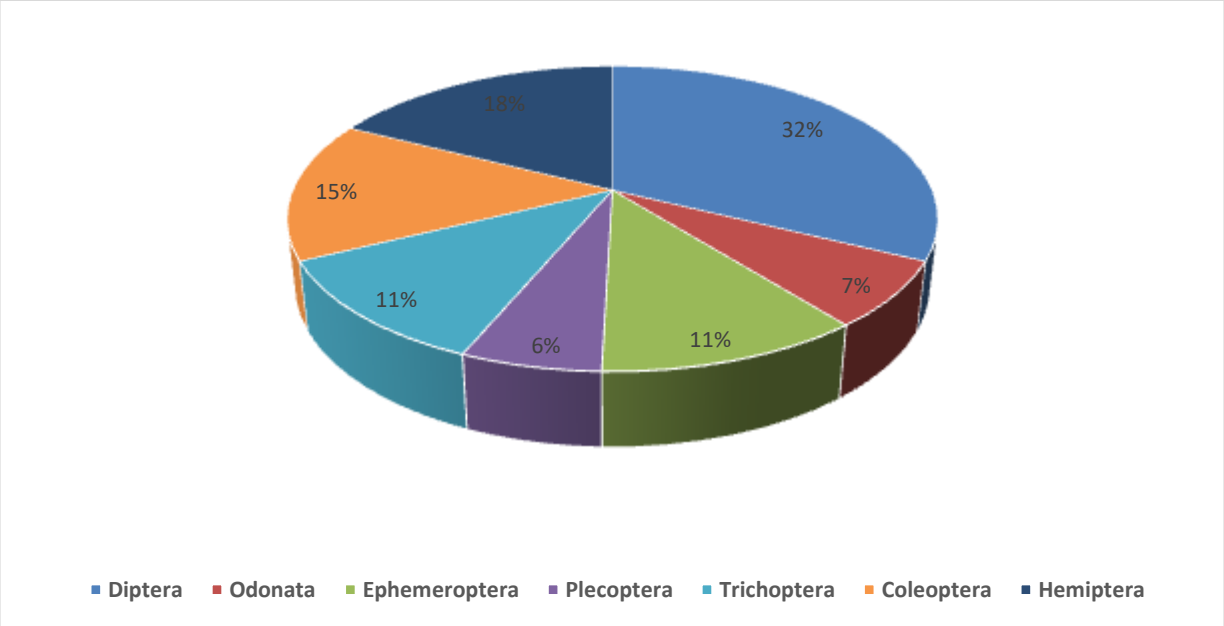
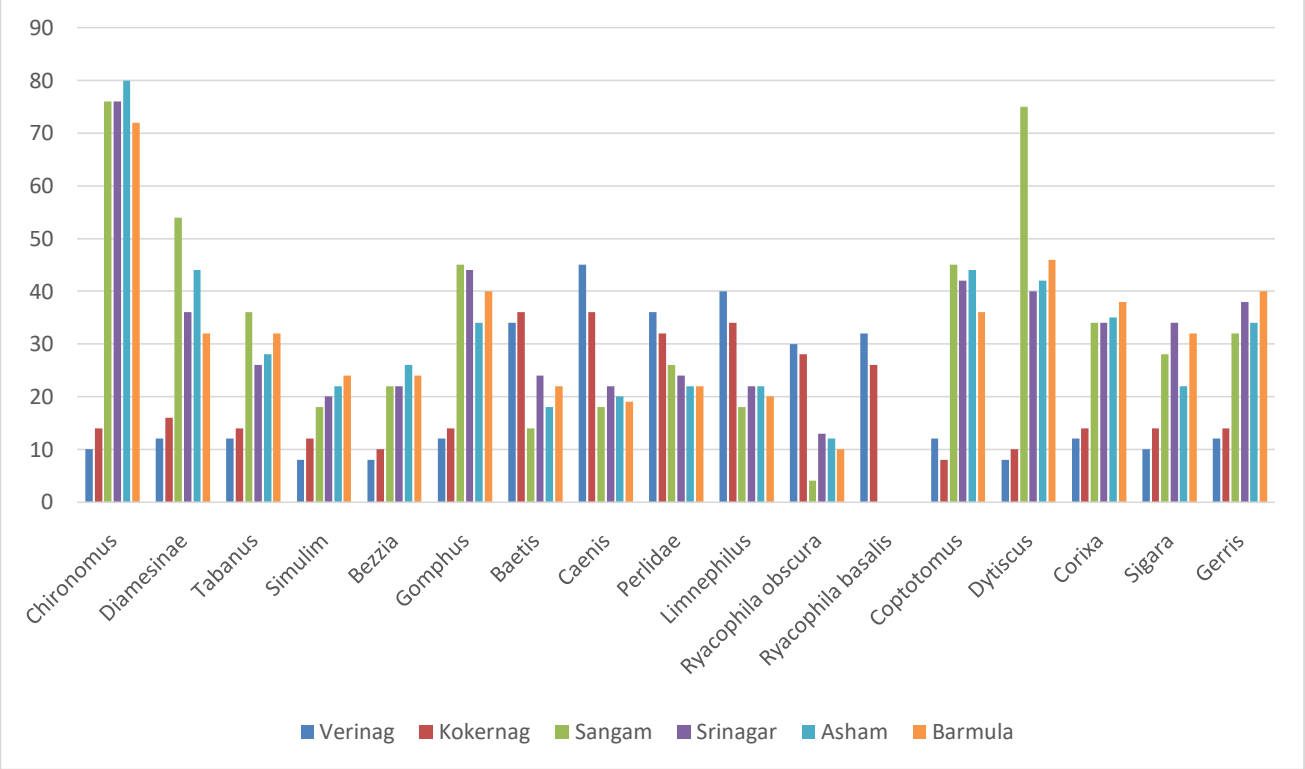


Fig. 3:- Population density (ind./m^2) of Entomofauna at various sampling stations of River Jhelum.



Conclusion:-

Based on the current study, it was witnessed that River Jhelum is capable of supporting high Entomofaunaldiversity. Order Diptera was found most diverse group with maximum number of individuals, and thus their presence can be employed as biological indicator of organically polluted waters. Similarly presence and abundance of EPT can be employed as biological indicators of clean water conditions with less anthropogenic stress.Further, anthropogenic pressure in the immediate catchment area of River water was observed as potential force behind the current

ecological conditions of river. The current work is hoped to furnish valuable information that would offer ecologically significant help in future for ecological assessment of aquatic ecosystems and ecorestoration of water bodies. Further, the response of entomofauna to changes in physico-chemical changes in water label them as excellent biological indicators of water quality.

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