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COMPARATIVE ECOLOGICAL STUDY OF AQUATIC MACROINVERTEBRATES OF MANGLA DAM AND CHASHMA BARRAGE WETLAND AREAS.

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ABSTRACT

The physico-chemical factors of water and biological processes determine the quality of water which in turn indicates the diversity of fauna and flora that the water would support. Pond areas of Mangla Dam harbored more of pollution sensitive species like Megalopterans, Ephemeropterans, Cyclopods, Cladocerans and some species of Odonates in both the summer and the winter seasons as compared to the tolerant species which were comparatively less in number than the sensitive species. Chashma Barrage on the other hand had more of pollution tolerant species and very less diversity and number of pollution sensitive species. The major pollution tolerant organisms include Gastropods, Bivalves, coleopterans, dipterans, hemipterans, cestods, turbellarians and hydrozoans. Small number of pollution sensitive species was also observed which mainly included the cyclopods and the cladocerans mainly in the winter season. Vertical migration was observed in the water column of the study areas in both the seasons from dawn to dusk. Hence, it was obvious that Mangla Dam pond areas had much better water quality for the survival of larger diversity of fauna and flora than the Chashma Barrage study area.

Keywords: Macroinvertebartes, Aquatic Analysis, Mangla Dam, Chashma Barrage, Ecological study.

INTRODUCTION

Rivers and lakes are very important part of our natural heritage. They have been widely utilized by mankind over centuries to an extent that very few, if any are now in natural condition (PWP, 2008). Pakistan is a signatory to the Ramsar Convention on wetlands and has adopted the comprehensive wetlands definition used by the parties to this international agreement." Areas of marsh, fen, peatland or water, whether natural or artificial. Permanent or temporary, with water that is static, flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters" (PWP, 2008).

Pakistan is blessed with more than 225 significant man-made and natural wetlands spread over approximately 10% of the country. Lakes, canals, dams and reservoirs formed as a part of Pakistan's extensive Indus basin Irrigation System are classified as man-made wetlands. Natural wetlands whether, permanent or seasonal, exists as peatland, rivers, streams, lakes, marshes, estuaries, mudflats and inter-tidal areas. Pakistan's natural wetlands occur in the coastal, arid, semi-arid and alpine areas (PWP, 2008).

Today, the resources of many wetlands are in the process of being irreversibly destroyed or spent because of the unsustainable use by local communities and society as a whole. Demographic changes, increases in demand for agricultural land, for pasture and for fishing have broken traditional systems of resource use. These pressures, along with manmade changes in the wetlands, have decreased the wetland's capacity to sustain themselves. In fact, many people view the elimination of wetlands as a small price to pay for the benefits expected from wetland conversion (Hornell, 1949).

The physical and chemical characteristics of water showed seasonal fluctuations interacting with one another and have a combined effect on animals and plants whereas temperature and pH play important roles as many biological activities only occur within a narrow range (Hornell, 1949, Odum, 1971, Salam, 1999).

Dissolved oxygen is found in microscopic bubbles of oxygen that are mixed in the water and occur between molecules. Light dissolved oxygen (LDO) is a very important indicator of a water body's ability to support of aquatic life. It is a very essential component of the aquatic ecosystem because it not only supports respiration of aquatic life but also helps in the degradation of waste to recycle nutrients. The LDO for surface water ranges from 0 mg/l in extremely poor water conditions to a high of 15mg/l in zero degree Celsius (Mahboob, 1998).

Phytoplanktons are microscopic plants that are an integral part of the ecosystem. They use nutrient in the water and sunlight to grow and are the basic of the aquatic food web. Zooplanktons are tiny animals that feed on phytoplankton. They are vital to the aquatic ecosystem and form the second level in the food web. The quantity and quality of phytoplanktons and zooplanktons are good indicators of water quality (Najam, 2006).

Macroinvertebrates are an important and integral part of any aquatic ecosystem as they form the basis of the trophic levels and any negative effects caused by pollution on the community structure can in turn affect trophic relationships. These can include those that feed on them directly or indirectly, such as fish and bird populations respectively. In addition aquatic invertebrates have the ability to clean rivers, as they utilize the organic and detritus matter. Functional feeding groups have been recognized, and are able to demonstrate trends in aquatic invertebrates and highlight their abilities as feeders i.e. grazers, collectors, scrapers, shredders. These feeding groups will vary along different sections of the streams, as well as with certain influencing external factors, such as that of pollution (Pennak, 1953).

Although all the species of Plecoptera, Ephemeroptera, Odonata and Trichoptera have aquatic stages, these orders are relatively small and of little numerical significance when compared with the large orders Hemiptera, Lepidoptera, Coleoptera, Hymenoptera, and Diptera, where only a small percentage of these species are aquatic (Pennak, 1953) .

Tolerances of individual taxa to determine water quality is not a recent concept. The Saprobien System of the early 1900's is the first documentation of an empirical approach that evaluated the condition of a water body by the resident assemblages, incorporating assemblages from algae to fish (Learner, 1983).

Macroinvertebrates can indicate the pollution ecology of streams and rivers depending on the different taxa and their relative abundance. Many studies use biotic and diversity indices to relate the response of groups of organisms to changes in water quality, and have been developed principally to detect and assess pollution (PWP, 2008). These could be divided into three major which include Class 1. Pollution sensitive organisms: these are associated with good water quality. They do not tolerate pollution well, and large numbers are observed only when good water quality is present e.g. Mayfly larvae, gilled snail, etc. Class2. Organisms somewhat pollution tolerant, they tolerate water pollution better than Class 1 organisms. We can expect to see significant numbers of these animals when the water quality ranges from good to moderate e.g. mussels, whirligig beetle, etc. Class 3.Pollution Tolerant Organisms. They are tolerant to even high levels of pollution. When these animals dominate, poor water quality is generally the reason e.g. Leeches, midge fly larvae, etc.

This study was conducted for comparing the physico-chemical factors and macroinvertebrate fauna of Chashma Barrage and Mangla Dam wetland areas due to the differences in capacities, locations, altitude, latitude and anthropogenic activities in these two man made wetlands.

Study Areas: The study area consists was Mangla Dam upstream of River Jehlum and Chashma Barrage on River Indus. In case of Mangla Dam two areas were mainly taken under consideration, the dam reservoir and the bong canal. Chashma Barrage harbors a hydroelectric power station which provides the area and the province electricity throughout the year.

Mangla Dam: Mangla Dam is a deep (91m), freshwater reservoir located at 33°12'N, 73°39'E; 30 km NNW on the Jehlum River, spanning the border between Punjab Province and Azad Kashmir, in the foothills of Pir Panjal Range. It being the twelfth largest dam in the world comprises an area of 26,500ha and is it an altitude of 630m.

Chashma Barrage: Chashma Barrage is located at 32° 25' N, 71° 22' E; southwest of Mianwali to Dera Ismail Khan Road in the Punjab province. The area of the barrage is about 33,109 hectares and it is at an altitude of about 225m (Scott, 1989).

MATERIALS AND METHODS

Sampling sites: The study sites were visited separately and were plotted with the help of "Garmin 76" a GPS receiver to develop maps by using the "Arc Map" Software. These study sites included the Chashma Barrage and the Mangla Dam. An overview map was also developed to show the study areas in the respective locations. The study areas were photographed with Fine Pix S5500 camera.

Hydrological studies: The quality of water was analyzed by the help of a rod-like quantum water sampler called the HYDROLAB. The hydrolab is a multi-probe sonde used as a water quality measuring instrument. Among the several models available MS-5 was used for more specific water quality measurements and easy handling. Besides being light-weighted and compact it is customized for profiling as well as unattended monitoring (Hach, 2006).

The sonde is connected through a data cable which attaches to the connector which is further attached to the laptop computer and the data transferred by the help of "Hydras 3 LT" software and saved as a Microsoft Excel File. When the sonde is deployed in water the protection cap is replaced by the calibration cap to protect the sensors and it is also as an anchor for the Hydrolab to stay vertical in water. The sonde weighs about 1.3 kg, has a length of about 53.3 cm and a diameter of 4.4cm. The operating temperature ranges from -5- 50 °C (Hach, 2006).

The basic parameters taken into consideration in this report include the following:

Temperature in Degree Celcius, pH in units, total dissolved solids (TDS) in grams per liter, Light dissolved oxygen (LDO) in millgrams per liter with accuracy up to 0.1mg/l, specific conductivity in mili Siemens per centimeter ($mS\cdot cm^{-1}$] with resolution of 0.0001units and salinity in parts per trillion.

Algae and Vegetation: Samples of algae were collected from the point of sampling in glass vials and identified with a help of a microscope using identification guide for algae (Vashista, 1997).

Macro-invertebrate study: study was done to collect the baseline data of these areas and report the ecological linkages and the role played by these organisms as indicators of clean or contaminated water.

Surface sampling was done using a rectangular dip net with a minute pored mesh (0.5 mm), was dragged along the boat for 10 minutes each and the contents of the mesh were emptied into a bottle containing water from the same pond.

Water samples were taken from the opposite edges and the deepest point of the pond three times in day: Morning (8am), Afternoon (2pm) and Evening (8pm). This was done to compare the quantity of invertebrates collected during the twenty hour time to confirm the occurrence of vertical migration. The water was collected in plastic containers and marked with a waypoint from the GPS receiver. The macro-invertebrates in these sample bottles were then separated, counted and placed in small sized vials containing a preservative. Composition of the preservative follows 30% of Glycerin, 20% of Distilled Water, and 50% of 70% Alcohol.

These invertebrates were observed under the Micros Austria MCX100 microscope with 4X-40X powers and photographed with a camera, (Canon. Power Shot A250) and (Canon 1D Mark III camera with Canon EF50mm, f 2.5 macro lens attachment) to be kept as a record for future use.

These were identified by the help of Atlases and Guide books of invertebrates and Zoology of macroinvertebrates.

Lab Techniques: The samples were preserved at the spot and brought back in containers in the lab these were sorted into separate bottles to be sent for identification photographs were taken and labeled to distinguish between organisms

Quantitative Analysis: The relative abundance of macroinvertebrates in the study areas was calculated by counting number of individuals multiplied by hundred and divided by total number of individuals.

Statistical Analysis: Statistical analysis of the hydrological and biological data was done and T-test was applied to calculate the significance of abiotic and biotic factors in different seasons at both the places. This test was applied using Minitab Version 13.

RESULTS AND DISCUSSION

Baseline surveys of macroinvertebrates of Chashma Barrage and Mangla Dam was done to understand the Ecological Linkages and seasonal variations in the study areas.

Chashma Barrage: First survey of the Chashma Barrage on the River Indus was done on 15-17 February, 2008. The level of water in the pond under consideration had receded than the previous seasons as was evident by the markings on the bank. Algal and submerged growth was observed only at the edges. *Saccharum munja* was present at the edge of the area under study. It was all above the water forming an island in the pond.

Huge quantity of small sized dead fish was seen lining the edges and small fish were also observed in water. Cormorants in the area depicted the depth of water as it swims under water to catch small sized fish, for food, present in the pond. The weather was cold and no breeze was flowing.

Second visit to the study area was in the summers on 26-29 June, 2008. Level of water had increased and the Saccharum that was above the surface in winters had more than half of it submerged in water. Both edges had large amount of algae and water lettuce. In the evening the weather was windy and splashing waves were giving rise to surf at the sandy edges of the pond. Musket and Saccharum were observed at far away edges. Very less cormorants and almost no waterfowl were seen depicting lesser amount of small fish in the area. The hydrology of the area is mentioned in Table number 1 and 2.

Mangla Dam: First survey of Mangla Dam on River Jehlum was done on 28-30 March, 2008. The area under study consisted of the Bong Canal and the Main Reservoir, both being areas of stagnant water.

Water in the reservoir had decreased in meters from the time it used to be full to its capacity. In the bong canal the water was almost static and covered with thick algal growth.

Thick growth of Typha and Saccharum was observed at the edges of the Bong canal whereas the reservoir was bound by barren rocks.

Second visit to the Mangla Headworks was in summers on 31st October to 2nd November, 2008. The three areas under study on this survey included the Main Reservoir, the Bong Canal and the upstream main lake at Jarikus. Depth of the Main reservoir lake had increased from its level in winters and still had barren rocks and vegetation at very far ends. Shoal of fish were observed but almost no algae were sighted. Water in the Bong Canal had increased but was still stagnant in the sampling area, amount of algae had decreased and small sized fish were observed feeding on the algae present and thus the macroinvertebrates hiding and feeding on the same algae.

The hydrology of the area is given Table Number 3 and 4.

Comparison of Algae and Macrophytes in both the study areas: The algae and macrophytes present in the area were recorded and enlisted in the table above for comparison of the habitat present for the macroinvertebrates to survive. Spirogyra was found in excess in both the study areas in both the seasons. Whereas the algae found in less amounts differed in both the areas and in the seasons accordingly.

Saccharum munja was present in both the study areas at the periphery of the ponds under study. Phragmitis was present in the middle of the pond under study at Chashma Barrage in both the summer and the winter season. Chashma also harbored a floating vegetation of Water Lettuce (*Pistia stratiotes*) in the middle of the pond near the Phragmitis growth and at the undisturbed edges of the pond in the summer season. Typha was recorded at Mangla Dam in both the seasons.

Comparison of macroinvertebrates: Macroinvertebrates of both Chashma Barrage and Mangla Dam were collected, separated, properly preserved, identified and classified in their respective Classes and Orders with common names. The numerical values of these macroinvertebrates are provided in Table 6.

Vertical Migration In Macroinvertebrates: Sampling of invertebrates was done three times a day in 24-hrs time period to determine the vertical migration in the organisms present in both the summer and the winter seasons. In all the seasons at both the study areas it was observed that organisms migrate vertically throughout the day. Quantifying the organisms in the three times of the day it was observed that highest number is seen in the afternoon sample followed by the morning sample and the least number was observed in the evening time after dusk Figure 2-5.

The values of Mangla Dam in the winter season were the lowest for the evening sample.

Abundance of icthyoplanktons was observed and the vertical migration was indicated by the huge concentration of gulls and terns hunting for their prey which coincided with the time of upward migration of invertebrates.

Seasonal Variation In Pollution Tolerance Levels: The component bar chart shows the pollution sensitive and pollution tolerant species of Chashma Barrage and Mangla Dam in both the summer and the winter seasons. The Y-axis depicts the quantity of macroinvertebrates in a particular area in both the summer and the winter seasons. The graph depicts that larger quantity and diversity of pollution sensitive species inhabit the pond areas Mangla Dam in both the seasons as compared to Chashma Barrage.

The criteria of healthy water quality was based on faunal indicators such as the macroinvertebrates and there predators. As the macroinvertebrates depend on the physico-chemical factors of water throughout the year their relation with hydrology was studied keeping in mind that pollution sensitive species should be abundant along with the pollution tolerant species for healthy water quality Figure 6.

Hydrology of the areas: The temperature of water increases in the summer season as the climate changes and increases the intensity and duration of solar radiation on the pelagic waters in both the study areas. The difference of temperatures in the summer (22.94-25.29^{o}C) and winter season (18.7-22.93 ^{0}C) at Mangla Dam is less than that of Chashma Barrage(31.69-34.96 ^{0}C) in the summer season and (14.66-16.32 ^{0}C) in the winter season. This was perhaps because Mangla Dam is at a higher latitude as well as altitude. At Mangla Dam winters are cool and summers are pleasant whereas at Chashma Barrage the summers are hot and the winters are cold. Statistically a significant difference was observed in the summer and winter temperatures in both the study areas. These temperatures thus affect many Hydrological properties such as the LDO of water and also the number and diversity of the fauna specially the Macroinvertebrates.

The pH of water is also affected by the dilution factor as it is the amount of acidic or basic ions dissolved in the amount water that affects the pH of the water in the particular season. At Chashma Barrage the pH was basic in both the summer (8.88-9.21 units) and the winter season (9.71-9.95 units) which is considered as the healthy quality of water for the fauna and flora according to the USEPA standards. At Mangla Dam summers conditions get critical for the flora and fauna to survive as the pH range drops to a slightly acidic value (6.32-6.39 units). which could render the water of the pond unfit for healthy survival of the organisms present there this could be due to high levels of detritus in the water.

Salinity of water in the summer season (Chashma:0.09 ppt; Mangla: 0.09 ppt) is lower as compared to that of the winter season (Chashma: 0.21 ppt; Mangla: 0.14 ppt) due to the dissolution of same amount of salts in greater quantity of water in the summer season than in the winter season due to rain and glacier water. Increased amount of salts enter the ponds due sedimentation and erosion in the summer season and our deposited at the bottom in the summer season but since the level of water increased it does not effect the pond ecosystem but when the water decreases and concentrates in the winter seasons the salinity increases about two folds then that of the summer season.

LDO is a very important indicator of a water body's ability to support aquatic life because like terrestrial animals, fish and other aquatic organisms need oxygen for respiration to run their body functions. Fish breath by absorbing dissolved oxygen through their gills (Mahboob, 1998).Light dissolved oxygen of water decreases in summers (Chashma:5.27 mg/l; Mangla: 6.04 mg/l) when the temperature of the water rises due to increased intensity of solar radiation and thus the gas bubbles out of the water decreasing the dissolved oxygen in the water. In the winter season when the temperature is decreased the gas remains in the water thus increasing the amount of dissolved oxygen in the water (Chashma:16.36 mg/l; Mangla: 11.32 mg/l) thus proving that temperature of water and light dissolved oxygen are inversely proportional to each other. This is the same for both the study areas in the respective seasons. The highest level of LDO was observed at Chashma Barrage in the winter season this could be due to the extreme cold weather conditions and the winter water temperatures being lower than that of Mangla Dam.

The total dissolved solids of water decrease in the summer season (Chashma: 0.1 g/l); Mangla: 0.1 g/l) as the water gets diluted from the rain water and by the melting of glaciers. These increase in winter when the water is concentrated by dissolving the same amount of solids as were present in summer in the decreased amount of water. As no melted water from the glaciers and very less amount of rain falls in the area. The highest level was observed at the Mangla Dam in the winter season which could mainly be due to the high levels of detritus in the water.

Dilution factor, total dissolved solids, light dissolved oxygen and the climate changes affect the Specific Conductivity of water.

Comparing the hydrological factors it is proven that temperature, is inversely proportional to light dissolved oxygen, and salinity which are all directly proportional to each other.

Macroinvertebrates: The sampling was done at three times of the day to make use of the diel vertical migration that takes place in the water during the day in both the summer and the winter seasons.

Vertical migration takes place in a 24hr time span. The organisms move to the pelagic water from dawn till dusk and descend to the aphotic zone at night. This pattern was observed in the sampling of both the study areas in the both the summer and the winter season and was proven by the figures obtained after screening and preservation of macroinvertebrates from the respective pond areas three times a day.

Prime number of organisms was observed in the afternoon sample followed by the morning sample and the evening sample proving that organisms migrate vertically.

A marked effect was seen at Mangla Dam in the winter season where lesser number of organisms was seen in the winter season even during the afternoon sampling, this could be perhaps due to Mangla Dam reservoir being at a higher latitude as well as higher altitude than Chashma Barrage. This phenomenon was reported by Mackenzie (Benzie, 1984) which states that "Mature zooplankton at higher latitudes descend to deeper water for months during the winter season. While, as is generally believed, they may maintain themselves largely on energy stores accumulated during the months of extensive migration (summer season) and active oral feeding, these organisms may also continue to absorb DOM (dissolved organic matter) directly during this time. They may continue to undergo lesser degrees of vertical migration, confining themselves to the deeper water layers during the months of low phytoplankton productivity (winter), and rely more heavily on DOM-acquired nutrients during these times."

This vertical migration of the organisms could also be due to competition for food or the organisms might move to the aphotic zone for organic debris. This could also be used as a defense measure from predators as proved by Neil, (2005).

Daphnia and Cyclops were found in large numbers at Mangla Dam in the afternoon during the winter season, one of the major reasons of this could be the vertical migration of organisms and also that the benthic and profundal zones have lower temperatures as compared to the limnetic and littoral zones.

In the summer season it was reported throughout the day but comparatively larger numbers of organisms were still observed in the afternoon samples.

At Chashma Barrage these are observed in the winter afternoon and morning samples but none were observed in the evening samples as they might have descended to the depths of the pond or otherwise might have become food for carnivore fish, hydra and of larger organism that take their food from the photic zone as was observed in freshwater lakes of the salt range(Ali, 2007).

In the summer season at Chashma Barrage almost no daphnia were observed as these might have been preyed upon by the icthyoplanktons and fingerlings which are numerous in these waters during this season soon after spring has passed. Both of these are pollution sensitive species and their presence depicts healthy quality of water.

Mosquito larvae, pupae and dixa species are some of the well known pollution tolerant species of stagnant and slow flowing waters. These were mainly observed in the winter season at both Chashma Barrage and Mangla Dam as the water level recedes and the water concentrates in the area. In summers lesser quantities of these were observed as they had become food for the fish fries and fingerlings which might have been numerous in these waters in the summer season. These may also be washed away with water entering the reservoir at a faster pace when the rain falls and snow melts in the north.

Mosquitoes are arial species and they live in areas around water bodies and some were collected in the water samples and could also be considered as fallen species which becomes food of organisms like beetles and water striders.

Midge larvae and chironomids or blood worms are also pollution tolerant dipterans. These were observed at both the study areas in both the seasons except for Chashma Barrage in the summer season. The major factor for this could have been that the water is diluted by the rain water and snow water entering the reservoir and these are washed away with it. As Chashma Barrage has larger pond area with increased depth as compared to Mangla Dam.

Moluscans from the study areas include Gyraulus snails, pouch snails, lymnae snails, apple snails and freshwater mussels. All of these are pollution tolerant species. They were found at Chashma Barrage in lesser numbers as that of Mangla Dam. This could be explained by the fact that the depth of the Chashma Barrage reservoir is comparatively more than Mangla Dam pond areas. These organisms were mainly detritivores and only pelagic sampling was done in both the areas thus very few were observed at Chashma Barrage.

Hydra is a pollution tolerant species organism and it was only observed in the water samples collected from Chashma Barrage in the winter season. Under the microscope it was observed feeding on daphnia and also reproducing asexually by budding off. Some of the newly budded of individuals were also observed. These grow up to about 25mm and become food of fish fries and fingerlings in the spring and summer season along with the daphnia and Cyclops.

Pigmy back swimmer is a pollution tolerant species and was present in both the study areas in both the summer and the winter seasons. They were mainly observed at Mangla Dam in the winter season at all the sampling times. There number varies in the three sampling due to the vertical migration of organisms in the water.

Order Odonata consists of dragonflies and damselflies. There larvae reside in water from one to three year time period after which they swim to look for emergent vegetation and crawl up it to form nymphs which further molt into adult flies which are aerial species.

Damselfly larvae are pollution tolerant species and these were only observed at the Mangla Dam pond areas in the summer season. This could be possible as the larvae feed on litter and could be found attached to the vegetation mainly the roots of plants as they are carnivores and mainly look for food there. So this could be a factor that they were not observed in the open of waters of Chashma Barrage water bodies. These are also a major source of food for the young herbivore and adult carnivore fish and other organisms like amphibians and filter feeder birds in the area.

Dragonfly larvae were observed from the sample at Chashma Barrage in the summer season and from Mangla Dam in the winter season. In Mangla Dam they could have become food for fish fries and fingerlings that were abundant in the area at the time of sampling, so were observed in very small number in the pelagic zone.

Fishfly larva of order Megaloptera was only observed at Chashma Barrage in the summer season. This is a pollution sensitive organism and depicts healthy freshwater quality. It was present in the sample taken from the vegetation in the middle of the pond and since the water was moving fast so other might have been taken away with it.

Three fish flies were also collected and preserved as fallen species. Whriggling beetle a coleopteran was only observed at Chashma Barrage in the summer season in the afternoon sample. These are known to survive in photic waters and feed on insects that fall into the water or insects that die in water. They may dive to the bottom of the pond to feed on litter if food supply is reduced in the pelagic waters.

Ephemeropterans include mayfly nymphs which are pollution sensitive organisms. These were only found at Mangla Dam in the winter season. These were present in the sample collected from the edge of the pond near the vegetation. The reason for its presence here might be that it prefers cool water with higher oxygen content, shady places and slow flowing waters. Thus Mangla Dam in the winter season offers optimum conditions for its survival whereas Chashma Barrage study area has no shady place and the temperature ranges from extreme cold in the winter season to extreme hot in the summer season.

Flatworms were only found in Mangla dam in the winter season in very less number. They are pollution tolerant organisms and like to stay in waters with large amount of detritus.

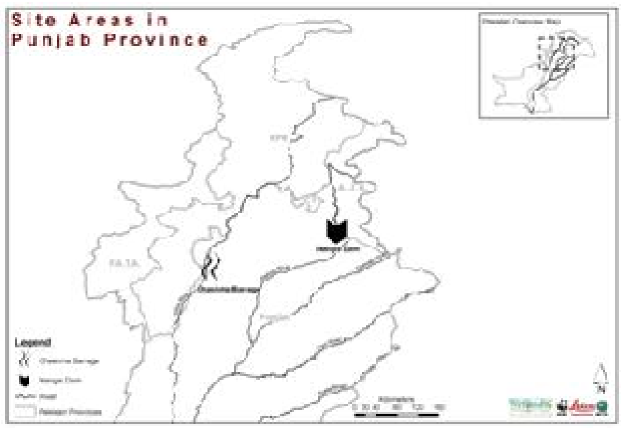

Figure 1

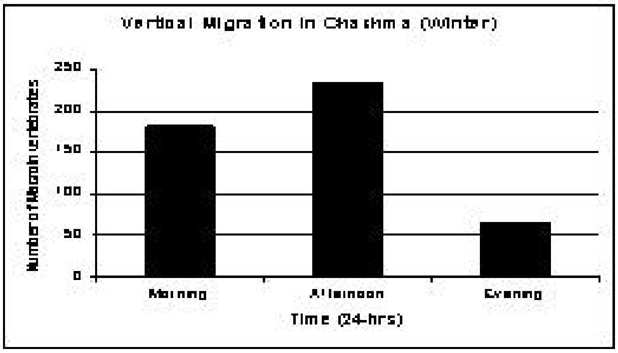

Figure 2

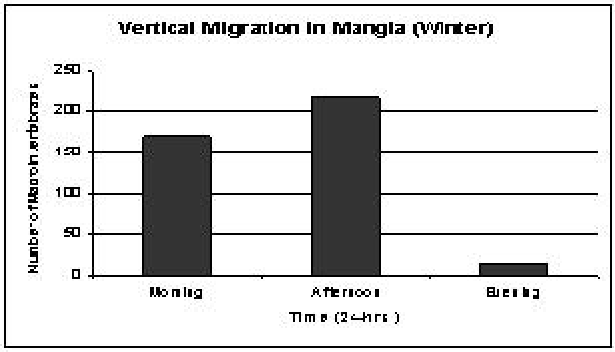

Figure 4

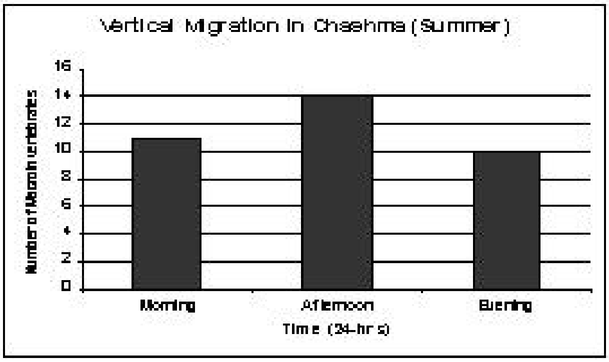

Figure 3

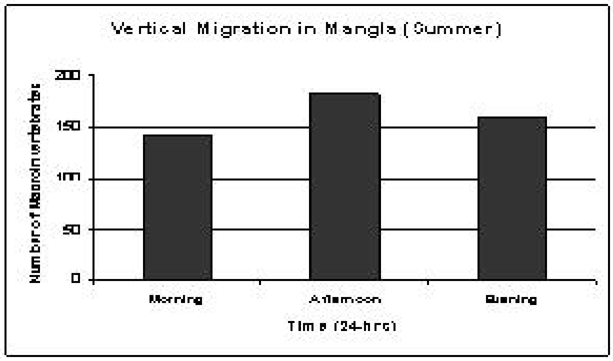

Figure 5

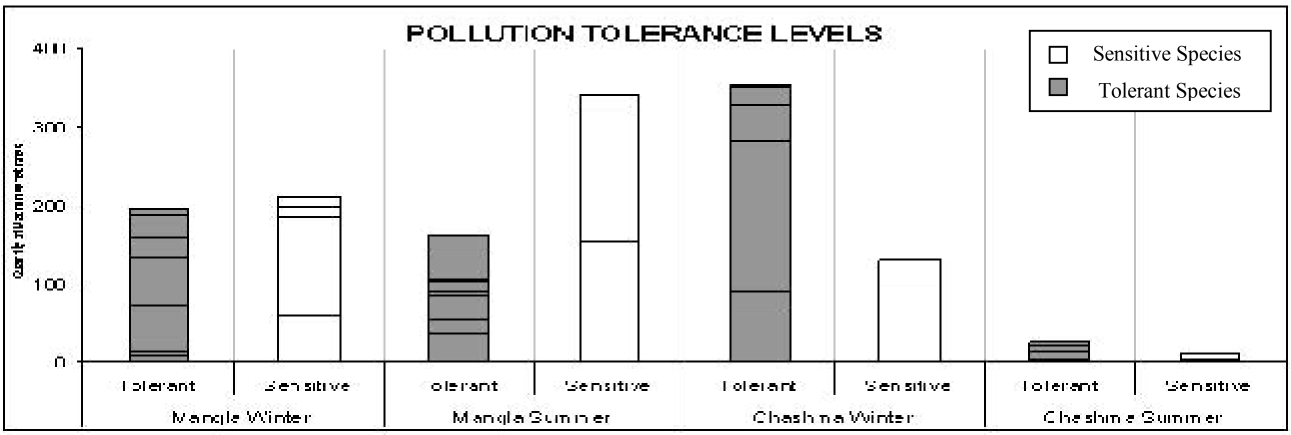

Figure 6

Tables-1. Water Parameters Recorded at Chashma Barrage Pond Areas During Winter Survey 2008

Station # GPS Coordinate	Geographical Coordinates	Altitude (ft)	Habitat Type	Temperature (^{0}C)	Salinity (ppt)	pH	LDO (mg /l)	Sp Cond (mS/ cm)	TDS (g/l)	Color of Water	Classification of Water
St # 1 06	N32.47382 E71.47027	616	Vegetation Mid Pond	16.32	0.21	9.71	16.36	0.4	0.3	Greenish	Clear
St # 2 07	N32.47286 E71.47847	615	Deep Water	14.66	0.18	9.95	14.5	0.3	0.2	Greenish muddy	Turbid
St # 3 08	N32.47212 E71.47847	609	Edge Right bank	15.96	0.19	9.82	12.8	0.4	0.23	Light Green	Very Clear

Table 2. Water Parameters Recorded at Chashma Barrage Pond Areas During Summer Survey 2008

Station # GPS Coordinate	Geographical Coordinates	Altitude (ft)	Habitat Type	Temperature (^{0}C)	Salinity (ppt)	pH	LDO (mg/l)	Sp Cond (mS/cm)	TDS (g/l)	Color of Water	Classification of Water
St # 1 06	N32.47382 E71.47027	616	Vegetation Mid Pond	32.58	0.09	8.88	5.38	0.2	0.2	Greenish	Very Clear
St # 2 07	N32.47286 E71.47847	615	Deep Water	31.69	0.1	8.89	5.27	0.2	0.1	Light Green	Clear
St # 3 08	N32.47212 E71.47847	609	Submerged Vegetation Edge, Right bank	34.96	0.09	9.21	6.48	0.2	0.1	Light Green	Very Clear

Table 3. Water Parameter Recorded at Mangla Dam During Winter Survey 2008

Station # GPS Coordinate	Geographical Coordinates	Altitude (ft)	Habitat Type	Temperature (^{0}C)	Salinity (ppt)	pH	LDO (mg/l)	Sp Cond (mS/cm)	TDS (g/l)	Colour of Water	Classification of Water
St # 1 760	N33.09847 E73.66612	783	Algae Cover Bong Canal	22.93	0.14	9.87	11.32	0.3	0.2	Greenish	Clear
St # 2 762	N33.13425 E73.66095	881	Main Reservoir	18.7	0.11	8.46	6.61	0.2	0.4	Dark Muddy	Very Turbid

Table 4. Water Parameter Recorded at Mangla Dam During Summer Survey 2008

Station # GPS Coordinate	Geographical Coordinates	Altitude (ft)	Habitat Type	Temp. (^{0}C)	Salinity (ppt)	pH	LDO (mg/l)	Sp Cond (mS/cm)	TDS (g/l)	Colour of Water	Classification of Water
St # 1 760	N33.09847 E73.66612	783	Algae Cover at edges Bong Canal	22.94	0.16	6.93	7.77	0.3	0.2	Greenish	Very Clear
St # 2 762	N33.13425 E73.66095	881	Main Reservoir	25.29	0.09	6.78	6.73	0.2	0.1	Greenish	Clear
St # 3 763	N33.13502 E73.80758	1013	Jarikus, Upstream	24.21	0.09	6.32	6.04	0.2	0.1	Greenish	Very Clear

Table 5. Comparison of macrophytes and algae

	Chashma		Mangla	
	Winter	**Summer**	**Winter**	**Summer**
Algae	Spirogyra (excess) Chlorella (Small Clusters) Closterium Oscillatoria	Spirogyra (excess) Chlorella (Small Clusters)	Spirogyra (excess) Ulothrix (mixed) Diatoms (less colonies) Volvox (very few) Tribonema Scenedesmus	Spirogyra (excess) Diatoms (very few)
Macrophytes	*Saccharum munja* Phragmitis	*Saccharum munja* Water Lettuce Phragmitis	*Saccharum munja* Typha	*Saccharum munja* Typha

Planarians are pollution tolerant organisms and these were only observed at Mangla Dam in the winter season. At this time almost no daphnia and Cyclops were observed the reason could that they are basic food of planarian. These are further preyed upon by larger invertebrates and fish and may also attain parasitic relations with other organisms residing in these waters.

Water strider is a pollution tolerant species. It was only observed at Mangla Dam in both the summer and the winter seasons. They are found in slow streams and this could be the reason that almost none were observed at Chashma Barrage study area. These are both predators and scavengers and may also feed on fallen species. These make use of surface tension of water to move about it on the surface of the water. In Chashma Barrage the wind flows at a faster pace and does not have trees around the study area that may break the wind. In Mangla trees break the flow of wind and thus it does not affect the flow of water.

Freshwater shrimps are pollution sensitive species. They feed on detritus mainly. These also prefer slow moving rivers streams and ponds and were only observed in samples collected from Mangla Dam pond area in the winter season.

Leeches are pollution tolerant species and could also survive in chemically polluted waters. These were observed at Mangla Dam in both the summer and the winter seasons. These are lethal blood sucking parasites of fish, amphibians, reptiles, birds and mammals. They are found in slow moving shallow water and thus is the habitat offered by the Mangla Dam study area.

Filter feeder birds like shovlers, wigeon, mallards, and shelducks etc, also feed upon these invertebrates. Small size fish were present in the area which also preys upon them as a major source of protein diet, fish eating birds like cormorants and pied kingfishers and mammals like the fishing cat in the area depicted the presence of small fish in the water as well.

These fish that intake millions of invertebrates in its lifetime are also caught by man as a source of food and to be sold in markets for revenue generation.

Table 6. **Macroinvertebratae classifications and abundance (Morning, Afternoon, Evening)**

Kingdom	Phylum	Class	Order	Common Name	Mangla Winter	Mangla Summer	Chashma Winter	Chashma Summer
Animalia	Mollusca	Gastropoda	Sorbeoconcha	Horn Shells	0	29	0	0
			Pulmonata	Gyraulus Snails	1	0	0	8
				Pouch Snails	81	0	2	1
				Lymnaea	1	1	0	0
			Architaenioglossa	Apple Snails	0	20	0	0
		Bivalvia	Unionoida	Freshwater Mussel	6	4	0	0
	Arthropoda	Insecta	Coleoptera	Whrigling Beetle	0	0	0	1
				Beetle Larvae	1	0	0	0
			Diptera	Mosquito	0	4	6	0
				Mosquito Larvae	14	35	64	1
				Mosquito Pupae	8	1	26	0
				Midge (Chironomous)	62	58	14	0
				Dixa spp	0	17	190	0
			Odonata	Dragonfly Larvae	15	8	0	0
				Dragonfly Nymph	3	1	0	0
				Damselfly Larvae	0	14	0	0
				Damselfly Nymph	0	0	0	1
			Megaloptera	Fishfly	0	0	0	3
				Fishfly Larvae	0	0	0	1
			Ephemeroptera	Mayfly Nymph	9	0	0	0
			Hemiptera	Pigmy Back Swimmers	60	3	4	11
				Water Strider	3	14	0	0
		Malacostraca	Decapoda	Freshwater Shrimp	1	0	0	0
		Maxillopoda	Cyclopoida	Cyclops	125	155	30	0
		Branchiopoda	Cladocera	Daphnia	58	127	100	0
	Platyhelminthes	Cestoda	Eucestoda	Flatworm	2	0	0	0
		Turbellaria	Seriata	Planarian	24	0	0	0
	Medusozoa	Hydrozoa	Anthomedusae	Hydra	0	0	46	0
	Annelida	Clitellata	Hirudinea	Leech	1	2	0	0

Table 7. Macroinvertebrates (24-Hrs)

Organism	Chashma Barrage						Mangla Dam					
	Winter			Summer			Winter			Summer		
	Morn	Aft	Eve	Morn	Aft	Eve	Morn	Aft	Eve	Morn	Aft	Eve
Daphnia	60	40	~	~	~	~	~	58	~	15	82	55
Cyclops	30	~	~	~	~	~	~	120	5	38	77	58
Mosquito L	30	31	3	~	1	~	6	~	~	35	~	~
Mosquito P	4	18	4	~	~	~	6	~	~	1	~	~
Dixa Spp	56	81	53	~	~	~	~	~	~	17	~	~
Sinistral S	2	~	~	~	~	~	5	3	~	~	~	~
Hydra	~	46	~	~	~	~	~	~	~	~	~	~
Midge L	~	12	2	~	~	~	43	4	5	6	18	8

Mosquito	~	6	~	~	~	~	~	~	~	2	~	~
Water Bug	~	~	3	1		~	~	~	~	~	~	~
PBS	~	~	1	4	6	~	55	2	2	~	~	3
Gyraulus	~	~	~	5	2	1	1	~	~	~	~	~
Damselfly N	~	~	~	1	~	~	~	~	~	~	~	~
Fishfly L	~	~	~	~	1	~	~	~	~	~	~	~
Whriggling B	~	~	~	~	1	~	~	~	~	~	~	~
Fish Fly	~	~	~	~	3	~	~	~	~	~	~	~
Dragonfly L	~	~	~	~	~	7	2	8	3	~	~	~
Dragonfly N	~	~	~	~	~	2	2	7	~	~	~	~
Mayfly N	~	~	~	~	~	~	5	~	~	~	~	~
Flatworm	~	~	~	~	~	~	2	~	~	~	~	~
Planarian	~	~	~	~	~	~	24	~	~	~	~	~
Pouch Snail	~	~	~	~	~	~	4	5	~	~	~	~
Water Strider	~	~	~	~	~	~	14	3	~	5	3	4
FW Shrimp	~	~	~	~	~	~	1	~	~	~	~	~
Lymnae	~	~	~	~	~	~	~	1	~	1	~	~
Leech	~	~	~	~	~	~	~	1	~	2	~	~
FW Mussel	~	~	~	~	~	~	~	6	~	4	1	5
Dextral Snail	~	~	~	~	~	~	~		~	8	1	20
Horn Shells	~	~	~	~	~	~	~	~	~	8	~	8
Damselfly L	~	~	~	~	~	~	~	~	~	~	6	8
TOTAL	**182**	**234**	**66**	**11**	**14**	**10**	**170**	**218**	**15**	**142**	**188**	**169**
AREA/SEASON	**482**			**35**			**403**			**499**		

Recommendations

1. During the current research, limited Physico-chemical parameters were studied. However, substantial amount of work is required to be carried out in the study area. This includes heavy metal study and its relation to bio-accumulation in invertebrates and biomagnifications in the trophic levels above them.
2. Systematic phytoplankton and zooplankton (pelagic and benthic) investigations should be carried out in the freshwater ecosystems of the country. Most of the organisms described during the current study are widely distributed than reported in this study.

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