ASSESSMENT OF WATER QUALITY OF BÜYÜKSU STREAM (BOLU, TURKEY) BASED ON SOME ENVIRONMENTAL VARIABLES AND IDENTIFICATION OF LARVAL CHIRONOMIDAE (DIPTERA)

DERYA AVUKA

JANUARY 2008

ASSESSMENT OF WATER QUALITY OF BÜYÜKSU STREAM (BOLU, TURKEY) BASED ON SOME ENVIRONMENTAL VARIABLES AND IDENTIFICATION OF LARVAL CHIRONOMIDAE (DIPTERA)

by
DERYA AVUKA

THESIS SUBMITTED TO THE GRADUATE SCHOOL OF NATURAL SCIENCES

OF

THE ABANT İZZET BAYSAL UNIVERSITY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCES

IN

THE DEPARTMENT OF BIOLOGY

JANUARY 2008

Approval of the Graduate School of Natural Sciences.

Prof. Dr. Nihat ÇELEBİ
Director

I certify that thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. M. Tekin BABAÇ
Head of Department

This is the certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Assoc. Prof. Dr. Muzaffer DÜGEL
Supervisor

Examining Committee Members

1. Prof. Dr. Nilgün KAZANCI ....
2. Assoc. Prof. Dr. Okan KÜLKÖYLÜOĞLU ....
3. Assoc. Prof. Dr. Muzaffer DÜGEL ....

To My Father (HALİL) and My Mother (MÜKRİME)

ABSTRACT

ASSESSMENT OF WATER QUALITY OF BÜYÜKSU STREAM (BOLU, TURKEY) BASED ON SOME ENVIRONMENTAL VARIABLES AND IDENTIFICATION OF LARVAL CHIRONOMIDAE (DIPTERA)

Avuka, Derya

M. Sc., Department of Biology

Supervisor: Assoc. Prof. Muzaffer Dügel

January 2008, 75 pages

Environmental quality of Büyüksu Stream evaluated using physicochemical and biological variables obtained from benthic macroinvertebrates. Water samples were collected from eleven different stations between April 2005 and March 2007. During the study in order to investigate pollution level of Büyüksu Stream (Bolu). Selected environmental variables such as pH, temperature, conductivity, dissolved oxygen, nitrate, nitrite, ammonium and phosphate were analyzed and benthic macroinvertebrates were determined.

As a result of this study 117 taxa were determined from benthic macroinvertebrates. Out of the 26 species of Chironomidae (4 Tanypodinae, 3 Diamesinae, 10 Orthocladiinae and 9 Chironominae), 3 species (*Diamesa insignipes* K., *Brilla modesta* (Mg.) and *Cardiocladius capucinus (Zett.)*) dominated the fauna.

Multivariate analysis methods were used for assessment of data. Frequency and abundant degrees of benthic macroinvertebrates were calculated. Similarities that are among the stations were calculated according to the Sorenson Index. Also, Belgian Biotic Index was used for water quality.

Benthic macroinvertebrate fauna which will be used in future biological monitoring studies were identified it's emphasized that water quality of streams should be determined not only with physicochemical variables but also with biological variables.

Results show that Büyüksu stream has been polluted by domestic and agricultural discharges.

Key words: Büyüksu Stream, Benthic macroinvertebrates, Chironomidae, Diptera, Water quality.

ÖZET

BÜYÜKSU (BOLU, TÜRKİYE) ÇAYI SU KALİTESİNİN BAZI ÇEVRESEL DEĞİŞKENLERLE DEĞERLENDİRİLMESİ VE LARVAL CHIRONOMIDAE (DIPTERA) TESPİTİ

Avuka, Derya

Master, Biyoloji Bölümü

Danışman: Doç. Dr. Muzaffer Dügel

Ocak 2008, 75 sayfa

Bu çalışmada Büyüksu çayının, taban büyük omurgasızlarından elde edilen biyolojik verilerle fizikokimyasal özellikleri kullanılarak su kalitesi değerlendirilmiştir. Büyüksu (Bolu) da meydana gelen kirlilik düzeyini incelemek için Nisan 2005-Mart 2007 tarihleri arasında belirlenen 11 istasyondan düzenli olarak su örnekleri toplanmıştır.

Alınan su örneklerinin aylara göre; pH, sıcaklık, iletkenlik, çözünmüş oksijen, nitrat, nitrit, amonyak ve fosfat değerleri ile taban büyük omurgasızları belirlenmiştir.

Bu araştırmanın sonucunda sucul omurgasızlara ait 117 takson bulunmuştur. Chironomidae (Diptera) familyasına ait 26 tür teşhis edilmiştir (4 Tanypodinae, 3 Diamesinae, 10 Orthocladiinae and 9 Chironominae). Büyüksu deresinde baskınlık gösteren Chironomidae türleri; *Diamesa insignipes K., Brilla modesta(Mg.)* ve *Cardiocladius capucinus(Zett.)*.

Verilerin değerlendirilmesinde çok değişkenli analiz yöntemleri kullanılmıştır. Taban büyük omurgasızlarının baskınlık, sıklık ve istasyonlar arasındaki benzerlik hesaplamaları yapılmıştır. İstasyonlar arası benzerlik hesaplamaları için Sorenson İndeksi kullanılmıştır. Ayrıca çeşitlilik değerleri için Shannon-Weaver indeksi, biyotik indeks değerleri için de Belçika Biyotik İndeksi kullanılmıştır.

Gelecekteki biyolojik izlemelerde kullanılabilecek akarsu taban büyük omurgasız faunası belirlenmiştir. Akarsuların su kalitesinin fizikokimyasal ve biyolojik değişkenlerle birlikte belirlenmesinin gerekliliği açıklanmıştır.

Çalışma sonucunda akarsuların evsel ve tarımsal alanlardan gelen atıklardan etkilendiği bulunmuştur.

ACKNOWLEDGEMENTS

I express sincere appreciation to Assoc. Prof. Dr. Muzaffer DÜGEL for his guidance and insight throughout the research. I am also greatly thankful to Assoc. Prof. Dr. Okan KÜLKÖYLÜOĞLU and Assist. Prof. Dr. Abuzer ÇELEKLİ. I would like to thank Aziz DEVECİ, Muharrem BALCI, Ali Serhan UYAR and Sinem AKYAZICI for their help in the field and laboratory. To my parent, I offer my sincere thanks for their supports during my education. I am also thankful to committee member Prof. Dr. Nilgün KAZANCI for her support increases the value of my work. This study was supported by TÜBİTAK (Project no: 104Y165)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTOGRAPHS

1 INTRODUCTION

Nowadays, rivers or streams are the most effected aquatic ecosystems of environmental pollution. Today, rivers transfer tones of water from the social areas, factories to the sea or lake. So the rivers, streams become sewer system (drain) of the cities. Streams or rivers affect the areas of where passing through inside and the rivers are used for irrigation or water supply (Dügel, l994). Initially polluted materials from the industrial, agricultural or municipal activities mix with rivers. When the populations were less, the waste materials in the river could be broken into pieces in a short distance. But after the overpopulation and industrial development, municipal and industrial wastes become increased. So, it makes impossible that the rivers can clean themselves (Kara and Çömlekçioğlu, 2004).

The factors to be evaluated to prevent the rivers from natural cycle breakdown. When the water pollution that affect aquatic organisms directly examine, determination that pollution makes environment quality decrease is a biological problem. To determine the reason of water pollution just the physicochemical variables can be misleading. Because those variables can only provide current us information at that moment. Determining the variation of water quality in a long term, an additional biological method is needed (Dügel, l994).

Studies to protect the rivers (or streams) require to follow environmental system. The information collected with certain of time can be determined for future biomonitoring. There are advantages to use biological methods. When the water samples are taken from fresh water environment, biomonitoring gives us the information in the past and existent situation (Mason, l998).

The best tools that respect the environmental structure are the organisms which face always the same effects. Benthic macroinvertebrates form the third rings of food chain in aquatic ecosystems are then be good organisms for biomonitoring studies.

Also, benthic macroinvertebrates organisms that contain the mast important part of fish nutrient are admitted to be important indicators to determine the water quality and pollution levels in aquatic habitats.

This study induces species composition which helps biological evaluation of future. Also, some analyses were used like biotic index biodiversity to follow and classify the rivers biologically.

1.1 The Previous Studies at Site

Although Büyüksu Stream (Bolu) is an important aquatic ecosystem for the city of Bolu, detailed study has not been done yet. Only a few studies and researches of stream have been done. It is not easy to establish how the river ecosystem effected of environmental problems that the streams faced.

*Külköylüoğlu et al., (2003), Water quality variations and Ostracoda (Crustacea) distribution were determined based on seasonally on Abant Lake and its environment water.

*Tanatmış, (2004), The Ephemeroptera (Insecta) fauna of the Filyos (Yenice) River basin was determined.

*Yıldırım et al., (2004), The water quality of Büyüksu (Bolu) Stream was determined according to the Qual 2E model.

1.2 The aim of the Study

The main reason of the study is to examine hydro biologically as per existing situation, to indicate main structure of the river and to determine the habitat and biodiversity on the river.

Nowadays, it is possible to say biodiversity has been decreasing especially on aquatic ecosystems and all the world, as well. It is important to get the precautions for protection, to determinate biodiversity on Büyüksu Stream ecosystem. For this reason, the main Structure were pinpointed, the factors which break the ecosystem structure were determined, the factors which break the ecosystem structure were determined and successions about ecosystem biomonitoring for the future were produced with using physicochemical and biological variables.

1.3 Stream Habitat

Freshwater sources include underground water sources and surface water sources. While surface water sources were consisting of lakes, pools and dams in lands they collect streams, rivers and valley in their structure.

Streams contact with terrestrial habitat continuously. They are affected by outside factors more than lakes. That is why streams form different environments and complex systems. (Dügel, l994).

According to the lakes, the structure of streams is active and dynamic. Moreover they flow towards the current that is occurred on stream basin.

1.4 The Importance of Water

The importance of water relies on the amount of the water which is found in human body. The establishing of each civilization at great streams or rivers is not coincidence. Because some necessities that are necessary for human life such as irrigation, providing drinking water has provided in this way (Kazancı, 1997).

The water volume (capacity) of the earth is approximately 141 milliard m^3. The water on Earth exists; about 97 percent of all water is in the oceans. In addition, 3 percent of all Earth's water that is fresh water (3%)

The ninety percent of the freshwater approximately, is found in glaciers and ice ages at the poles. (90%) This water may not be used directly. Freshwater sources which are used directly from humans are found in running water and this value changes between 0.4 and 0.5. So the ninety seven percent of freshwater is found in aquifers (Sampat, 2001). It is clearly seen that destruction of the water quality of freshwater sources may cause very important damages.

The evaluating of aquatic environment with the characteristics of physical, chemical and biological data can provide the distinct result, in studies that concern with the determination and monitoring of the water quality (Kazancı, l997).

Water quality decreases if the amounts of various substances which confuse the water increase and water pollution arises. Thus if the structure of organisms examine, the establishing of destruction of the natural structure gives distinct results (Kazancı, 2003).

More than twenty methods that consist of plankton, epiphyte and benthic macroinvertebrates have been used in the determination of the water quality studies since the beginning of l980 in Europe.

The developing studies, which are interested in the using of benthic macroinvertebrates in Europe and the determination of water quality, increases nowadays. There are so many researches that are developed in Belgian, England, Holland, Italy and Portugal. The reason of increasing the researches is the easiness that is provided by benthic macroinvertebrates (Kazancı, l997).

The controls of the water quality which are done for streams or rivers in Turkey are relying on physicochemical variables (PMEC, l988). On the other hand, there are some advantages of the biological evaluations according to the chemical evaluations. Because organisms contact with environmental conditions continuously, whereas chemical valves show the attitude in that time. This is why too much measurements should be done in order to do correct evaluation.

1.5 Water Pollution

Water pollution is defined as, the destruction of natural structure of the water sources because of physical or chemical factors (Kazancı, l997).

Some variations are formed in the characteristic and quality of the water because of factors changing and polluting water's structure and function. The organisms that live in aquatic systems are affected from these changes (Kara et al., 2004). For this reason, water pollution causes to harm the aquatic systems and extinct the capacity of water cleans up itself (Gidirişoğlu et al., l998).

By the time the substances which are related with pollution interfere the streams, they cause to decrease free oxygen in the water; so the survival chance of a lots of organisms. Furthermore by the time the organic substances, that comes from water basing with the derivatives of phosphorus and nitrogen, reach the streams, the changes occur in the structure of the water (Külköylüoğlu, 2006).

Organic pollution that arises with the interfering of organic substances to the water is the most visible pollution type. The reason of organic pollution is the wastes which come from human sources and industrial sources. In addition, decreasing of oxygen means that organic wastes contaminate the water clearly (Kazancı, l997).

1.6 Biological Structure

1.6.1 Benthic Macroinvertebrates

Benthic macroinvertebrates are organisms that inhabit the bottom substances (sediments, debris, logs, macrophytes, filamentous algae etc.,) of freshwater habitats, for at least part of their life cycle. Aquatic flatworms, oligochaetes, insects and mollusks constitute the major taxa of benthic macroinvertebrates. They are retained by mesh sizes E 200 to 500 µm (Haver and Resh, l996).

Unlike fish, benthic organism cannot move around much so that they are less able to escape the effects of sediment and other pollutants that diminish water quality. Therefore benthos can give us reliable information on stream and lake water quality. Their long life cycles allow studies conducted by aquatic ecologists to determine any decline in environmentally quality (Burden et al., 2002)

Benthic macroinvertebrate communities are valuable in the biological assessment and biomonitoring of lakes. Food is the main factor changing community composition when environmental conditions are not to severe, but when organic pollution is more intense, it is oxygen concentration rather than food that limits the species survival and determines the community composition (Rossaro et al, 2007).

The benthic macroinvertebrate community is often used as an indicator of environmental quality (Hynes, l960). There are many different ways to relate benthic macroinvertebrate community structure to water quality, with many new analysis systems proposed each year. Diversity indices have been widely used but their reability has been questioned by many investigators (Friberg et al., l977; Ziglio et al., 2006).

1.6.2 The advantages of the benthic macroinvertebrates

Benthic animals and plants are organisms that are used in biological assessment and biomonitoring in streams or rivers. But benthic macroinvertebrates are preferred than the others because of the following reasons; (Rosenberg and Resh, l992).

1. Being ubiquitous, they are affected by perturbations in all types of waters and habitats (Cummins, 1974; 1977; Hawkins and Sedell, l98l).

2. Large numbers of species offer a spectrum of responses to perturbations.

3. Their sedentary nature allows spatial analysis of disturbance effects.

4. Their long life cycles allow effects of regular or intermittent perturbations, variable concentrations, etc to be examined temporally.

5. Qualitative sampling and analysis are well developed, and can be done using simple, inexpensive equipment.

6. Taxonomy of many groups is well known and identification keys are available.

7. Many methods of data analysis for macroinvertebrate communities have been

developed (Simpson, l949; Gaufin and Tarzwell, l956 Fremling, l964; Pielu, l966; Mcintosh, 1967; Wilhm and Dorris, l968; Eberhardt, 1969; Kaester et al., 1971; Chutter, l972; Heister, l972; Sladecek, 1973; Peet, l975;Godfrey, l978; Reed, l978; De Pouw and Vanhooren, l983; Hellawell, l986; Crunkilton and Duchrow, l99l; Mattews et al., l991)

8. Responses of many common species to different types of pollution have been developed.

9. Macroinvertebrates are well studied to experimental studies of perturbation (Buikema et al., l980).

10. Biochemical and physiological measures of individual organisms stress to perturbations are being developed (Reice and Wohlenberg, l993).

1.6.3 Family Chironomidae

1.6.3.1 Linnean System of Hierarchical Classification

*Superphylum Arthropoda

*Jointed-legged metazoan animals [Gr, arthron=joint; pous=foot]

*Phylum Entoma

*Subphylum Uniramia

*L, unes=one; romus=branch, referring to the unbranched nature of the appendages

*Superclass Hexapoda

*Gr, hex=six, pous=foot

*Class Insecta

*L, insectum meaning cut into sections

*Subclass Plilota

*Infranclass Neopterygota

*Order Diptera (Williams and Feltmate, l992)

1.6.3.2 Introduction

The midge family chironomidae (order Diptera, family Chironomidae) is usually the most abundant macroinvertebrate group, in numbers of species and individuals, encountered in the majority of freshwater aquatic habitats. (Epler, l995)

Chironomidae (midges) comprise a large proportion of the macroinvertebrate species found in lotic environments (Coffman, l973), but they often are not identified beyond the family level. However a detailed analysis of the Chironomid community can yield much information on water quality. Several investigators have suggested that chironomid species assemblages can be associated with specific types of pollution (Bode and Simpson l982; Mason, l975; Winner et al, l978).

Larval Chironomidae species in freshwater are the most abundant and geographically, the most widely distributed halometabalous insects. More than 10.000 species of chironomidae are known to exist (Armitage, l995)

Larval and adult stages of chironomidae are at the lower levels of the food chain. Primarily, they are a source of food for other animal groups. Since they contain important nutrient elements in high proportions, especially proteins and are easily digestible, they are an indispensable source of food for fish. Furthermore, as a result of their perturbation capability, they prevent putrefaction on the floor and provide primary elements required for photosynthesis; thereby affecting the material cycle in a positive way (Şahin, l984).

The chironomidae family is shown as bioindicator by same investigators because of the effects of larva’s are change from species to species in mineralization. At the same time the presence of chironomidae larva can give very important clues for their habitats (Şahin, 1991).The studies, concerning the identification of chinonomidae larva’s in Turkey, was begin about in 1967.

1.6.3.3 Life History

The most important characteristics of chironomidae family is metamorphosis. (Thienemann, 1916; Chernouskii, 1961) Like other dipterans, chironomids have four life stages; egg, larva, pupa and adult. The body of larva consists of head, thorax and abdomen. Their lengths change between 2-30 mm, and also their colors may be red, white, yellow, pink, purple or green (Şahin, 1991).

The larval stage is the long period of life-cycles of insects that belong to the family Chinonomidae. It is possible to encounter Chinonomidae larvae in almost all inland waters, including still waters (Şahin, l987; Ustaoğlu, 2005). Due to larvae’s ability to adapt to extremes of temperature, pH, salinity, depth, flow velocity and productivity, they can be found in many different environments (Ustaoğlu, 2005).

Chernovskii (1961) and Thienemann (1954) reported that, the life cycle of adult chinonomids is very short. It is not possible to see adults in unsuitable conditions. This is why especially in winter larval chinonomids are found in everywhere.

1.6.3.4 Habitat and Distribution

The family is also the most widely distributed group of insects, having adapted to nearly all types of aquatic or semi aquatic environment.

The larvae of most chironomid species live on or in sediments, where they feed on organic matter (detritus) and the associated micro fauna and flora. Because of their benthic feeding habitats, these larvae are directly exposed to contaminants in sediments through their development. (Hamilton and Saether, 1971).

The adult chironomids that live their larva and pupa periods completely in the aquatic area are not aquatic (Wetzel, l975)

Some types of chironomidae larva which are the most important food source of many freshwater fish that feed from the base, have the importance of being the sign for biological productivity (Wetzel, l975; Kırgız and Soylu, l975; Kırgız, l975; Şen and Özdemir, l990, l99l)

They can live in the recovered parts of the highest mountains and in the deepest bodies of fresh water (Armitage, l975).

1.6.3.5 Feeding

The majority appear to be opportunistic omnivores, feeding on diatoms, detritus and other small plants and animals. Chironomid larvae exhibit a variety of feeding habitats.

1.6.3.6 Ecological Importance

The predictable responses of populations of certain species to different levels of a variety of pollutants has resulted in the use of larval chironomids as biological indicators of water quality. Additionally, chironomid larvae are essential components in the efficient biological processing that takes place in the oxidation pond of sewage treatment plants.

Many larvae posses giant chromosomes and have been used extensively in genetic research. Chironomids are recorded as pests in rice fields, and are considered nuisances when large emergences occur in close proximity to human habitations. They have also been implicated in allergenic reactions in human (Epler, l995).

1.7 Site Description

The surface square of the Bolu is approximately 8301 km^2, and it covers about 1% of the surface measurement of Turkey (780.000 km^2).

Büyüksu Stream (Bolu, Turkey) is the branch of the Filyos (Yenice) River. Filyos (Yenice) River is in the west of the Black Sea region in Turkey. Moreover it is on very important migration ways that is among the Anatolia, Europe and Caucasus since glacier time. The length of Filyos (Yenice) River is approximately 347 km and also the basin region of it is l3 000 km (Tanatmış, 2004).

The water, which comes from Abant Lake (Bolu, Turkey), is the beginning of the Filyos (Yenice) River (Saraçoğlu, l990). This water combines with more spring water and flows up until Yumrukaya (Bolu). Also the length of this stream is more than 30 km, and it is called Abant Stream. (Figure 1.1).

In Yumrukaya region, the slide gates which were built by General Directorate of State Hydroulic Work in 1965 collect Abant Stream water's. After the water is waited there, it is carried out Lake Gölköy or agricultural areas in order to Irrigates the Bolu lowland. (Figure 1.2)

Abant Stream combines with Mudurnu Water at the east of Lake Gölköy (Bolu), and also after this combination the stream is called "Büyüksu". Büyüksu Stream flows up during Bolu lowland, and it combines with Mengen Stream. Finally it falls up to Black Sea from Zonguldak (Turkey) (Saraçoğlu, l990).

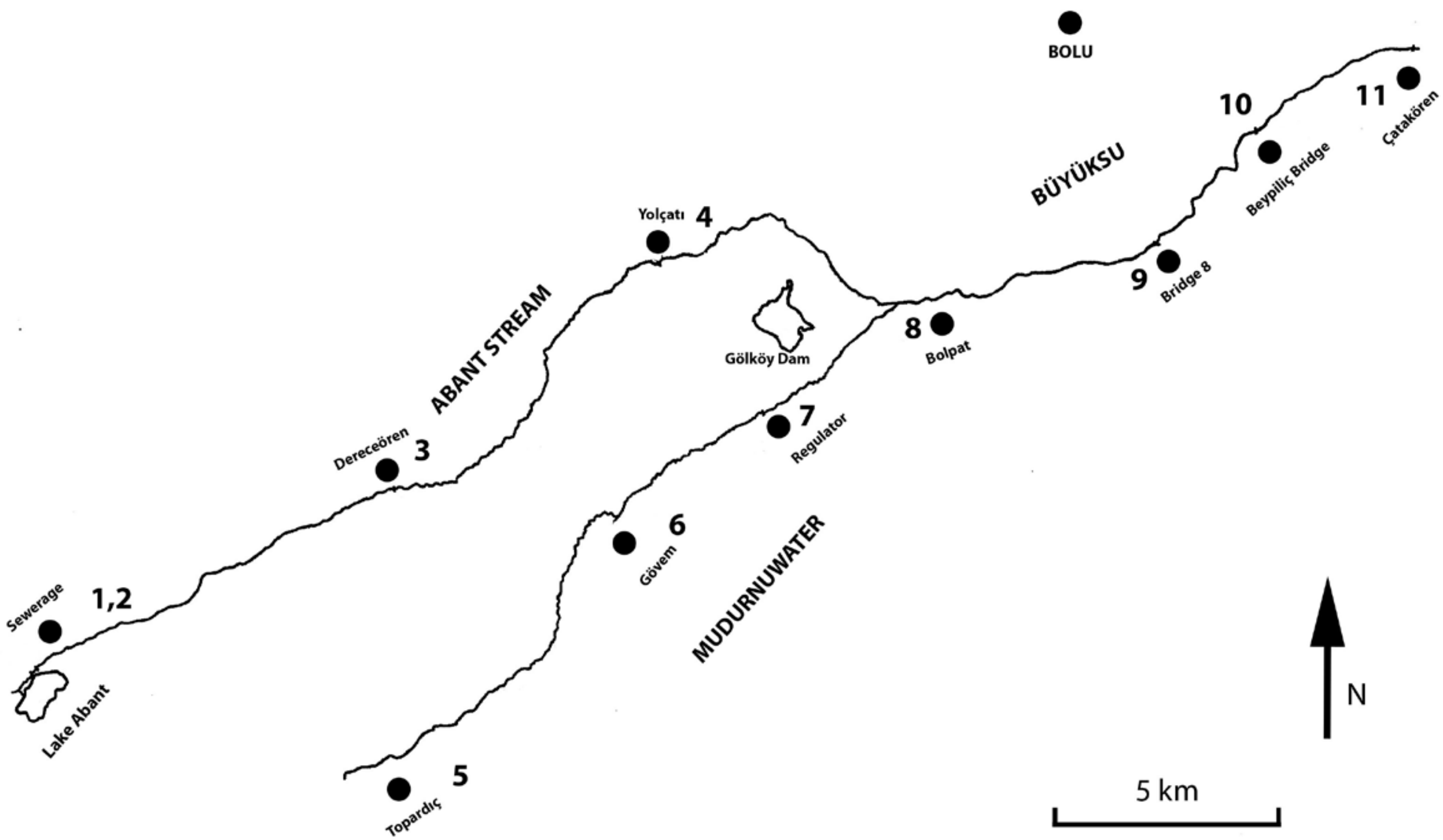


Figure 1.1 Site map. Numbers indicate sample points.

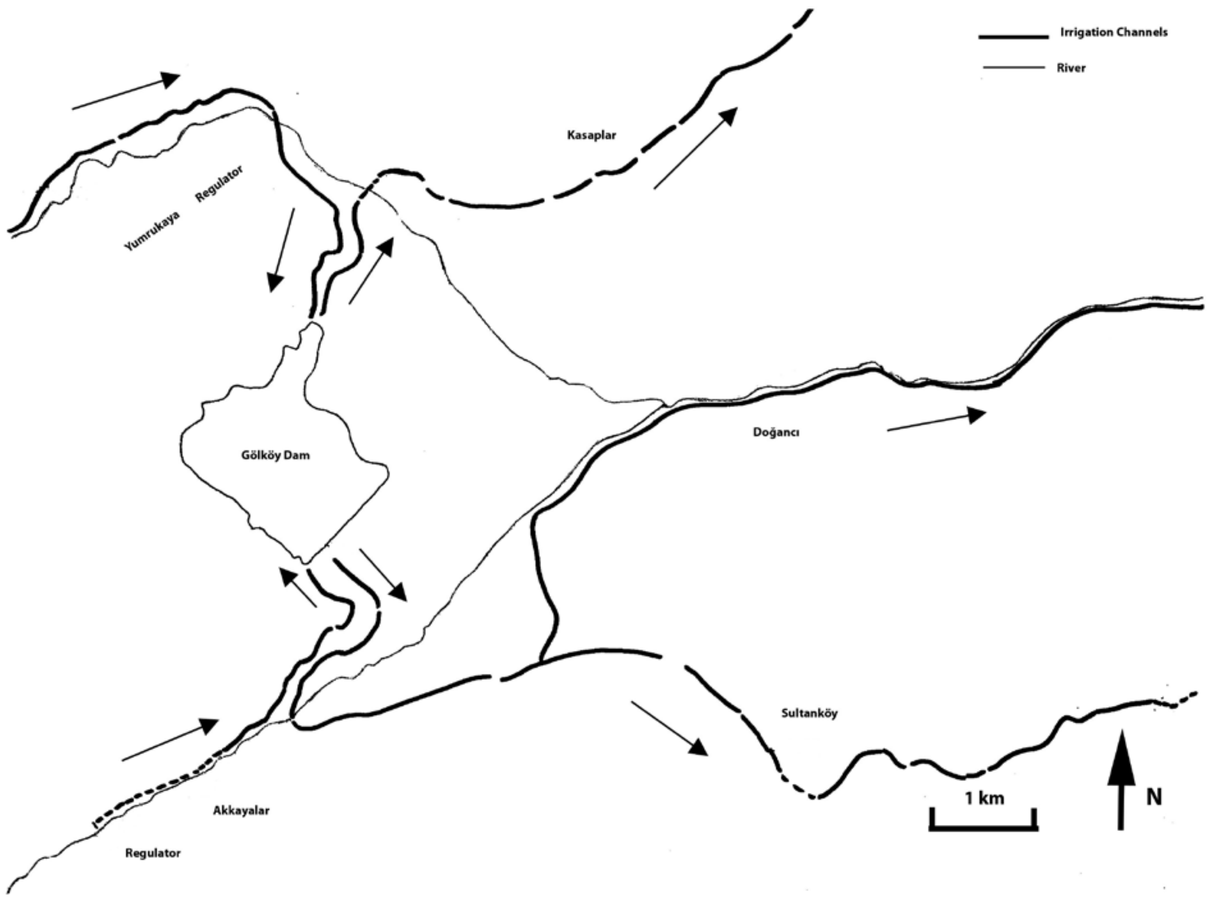


Figure 1.2 Irrigation channels and Gölköy Dam.

1.8 Sampling Sites Description

1.8.1 Before Canalization (1^{st} station)

Coordinates: 40^o 36’ 731” N 31^o 16’ 744” E Altitude: 1326 m

Location: It is next to ticket window which is entrance of the Lake Abant (Bolu, Turkey) (Photograph 1)

1.8.2 After Canalization (2^{nd} station)

Coordinates: 40^o 36’ 820” N 31^o 16’ 862” E Altitude: 1325 m

Location: It is at the exit of the canalization which is present 100 m on right side from Lake Abant. (Photograph 2)

1.8.3 Dereceören (3^{rd} station)

Coordinates: 40^o 39’ 003” N 31^o 22’ 477” E Altitude: 963 m

Location: It is near the “Cemil Restaurant” in Dereceören (Bolu) Place that is on the Abant road. (Photograph 3)

1.8.4 Yolçatı (4^{th} station)

Coordinates: 40^o 42’ 869”N 31^o 28’ 9l6” E Altitude: 800 m

Location: It is in the Yolçatı (Bolu) village. (Photograph 4)

1.8.5 Güneyfelakettin (Topardıç) (5th station)

Coordinates: 40° 35' 540" N 31° 24' 175" E Altitude: 1028 m

Location: It is on the exit of the Topardıç (Bolu) village which is on the Bolu-Mudurnu overland route. (Photograph 5)

1.8.6 Güvem (6th station)

Coordinates: 40° 39' 098"N 31° 28' 193"E Altitude: 823 m

Location: It is on the Kuzfındık-Saccılar (Bolu) road division which is on the Bolu-Mudurnu overland route. (Photograph 6)

1.8.7 Mudurnu water (Regulator) (7th station)

Coordinates: 40° 40' 356"N 31° 30 588" E Altitude: 780 m

Location: It is the entrance of the regulator which is on Akkayalar (Bolu) place. (Photograph 7)

1.8.8 Bolpat Bridge (8th station)

Coordinates: 40° 42' 270" N 31° 34' 303" E Altitude: 832 m

Location: It is under the bridge that is near the Bolpat factory (Doğancı village) (Photograph 9). Before this area, mudurun water and Abant Stream are mixed (Photograph 8).

1.8.9 Bridge 8 (9th station)

Coordinates: 40° 42' 868" N 31° 38' 572"E Altitude: 715 m

Location: It is under the bridge which is on Örencik (Bolu) road division at the Karacasu (Bolu) (Photograph 10).

1.8.10 Beypiliç Bridge (10th station)

Coordinates: 40^{o} 44’ 808”N 31^{o} 41’ 128” E Altitude: 695 m

Location: It is under the bridge that is on Yeniakçakavak (Bolu) road. (Photograph 11)

1.8.11 Gökçesu Bridge (11th station)

Coordinates: 40^{o} 47’ 275”N 31^{o} 45’ 508” E Altitude: 687 m

Location: It is under the bridge which is the exit of the Çatakören (Bolu) village (Photograph 12).

2 MATERIALS AND METHODS

2.1 The Determination of the Stations

The sampling sites were chosen from the shores of the stream to determine the general structure of the field area. Because of determination the physicochemical variables, benthic macroinvertebrates were collected and some analyses were done. In order to determine the effects of the industrial, agricultural, municipal wastewater discharges and no point sources of human wastes, the sampling sites were chosen. Additionally, the transportation possibilities were paid attention.

The study area contains three streams; Abant Stream, Mudurnu Stream and Büyüksu Stream. There are two main sources are Abant and Mudurnu Streams which are formed Büyüksu Stream. Eleven stations were chosen; four of them were on Abant Stream, three of them were on Mudurnu Stream and four of them were on Büyüksu Stream. Because the aim of this study is to determine the water quality with comparatively analyses. The stations which were determined are shown on figure 1.1.

2.2 The Determination of Variables and Sampling Frequency

Physicochemical and biological variables were obtained two periods in two years from sampling sites. The project was started on April 2005. In first year (April 2005-March 2006) field trips were realized monthly (except; November, January, February because of air conditions), in second year field trips were realized seasonally (Summer, autumn, winter and spring).

Physicochemical variables for which water samples were analyzed included temperature (t°C), pH, conductivity (EC), dissolved oxygen (DO), salinity (PPT) and percent of organic substances. All of these environmental variables were measured by using YSI model multiprobe oxygen-temperature meter. Atmospheric temperature and rainfall values were obtained for the study period from meteorology of Bolu.

Biological variables were obtained from benthic macroinvertebrates. In addition, microbiological results were obtained from the sampling sites.

2.3 Sample Collection

The sampling sites were detected by Global Position System (GPS Garmin 45 model). Water samples were taken from on April 2005 to March 2007 using 500 ml, 250 ml and 100 ml into plastic water samplers.

Water samples, which were taken from sampling sites, were filtered by using Sartorious method in order to prevent the destruction of them and the analyses were done within 24 hours.

2.4 Identification of Species

Species samples were collected with dip net from deep mud approximately 5 minutes, and species were selected with pens into the small glasses. Then, all macroinvertebrates were identified under the binocular microscope, also they were fixed in a 70% alcohol solution.

Moreover special preparation method was used for the family Chironomidae was separated into their body parts. The Olympus inverted microscope was used for identification of species. All preparations and species were preserved in hydrobiology laboratory.

Identifications were done at the genus level. Resh and Unzicher (1975) reported that the identifications, which are at the genus level, are more useful. (Resh and Unzicher, 1975).

In determination of species it was benefited from;

Bellman, l988;98l; Brkinkhurst and Jamieson, l97l; Edington and Hildrew, l98l; Elliat and Monn, 1979; Epler, l995; Franke, l979; Gledhill et al., l976; Gloer et al., l992; Illies, l978; Kazancı, l987; Ludwig, l993; Macan, l973; l976; l982; Mann, l962; Needham and Needham, l962; Özesmi, l988; Özkan, 2006; PYennak, l978; Pitsch, l993; Quigley, l977;

Sennika, l943; Ustaoğlu et al., 2005.

All species will be used in the preparation of the biotic index and the determination of the structure of benthic fauna.

Benthic macroinvertebrates, which were collected, were evaluated by quantity and quality. At the same time frequency, dominance, diversity and similarity values of them were obtained and also these results were commented with own places of them.

2.5 Equipments

- YSI incorporated 556 MPS Multiprobe oxygen-temperature meter.
- Spectrophotometer (DRLANGE/CADAS 50S)
- Incubator (NUVE FN 400-ES 500)
- Autoclave (NUVE OT 032)
- Binocular Microscope (OLYMPUS SZ 40)
- Inverted Microscope (OLYMPUS SZ 60)

2.6 The Evaluation of the Variables

The methods of the frequency, dominance, diversity, similarity and biotic index were used for evaluating organisms that were found on sampling areas.

2.6.1 Frequency

Frequency is explained as the percent of arising the all species in an evident area. When the more than one sampling was done in on area, a species cannot be found every time. The ratio of the number of chance to the number of samplings gives the degree of the frequency of a species. “Eq. 3. 1’ (Elliot, 1977)

$$F=\frac{Na}{N}x100 \quad (3.\ 1.)$$

F=Frequency

Na=The number of sampling sites which includes species A.

N=The number of sampling sites

Species are classified to the five groups according to the frequency;

% 1-20 The species which are found rarely.

% 21-40 The species which are found seldom.

% 41-60 The species which are found generally.

% 61-80 The species which are found usually.

% 81-100 Continuous species.

2.6.2 Dominance

Dominance is the ratio between the number of an individual that belongs a species and the total number of an individual that belongs all species, and it is defined as percent of a ratio.

'Eg. 3. 2' (Wetzel and Likens, 1990)

$$D=\frac{N_A}{N_n}x100 (3.2)$$

D=Dominance

N_A=The number of an individual that belongs species A.

N_n=The number of an individual that belongs all species.

2.6.3 Diversity

Shannon-Weaver Index:

$$H' = \sum_{i=1}^{s} \frac{ni}{N} In \frac{n:}{N} (3.3)$$

H’=Diversity

S=The total number of species

N=The total number of individuals

ni=The number of an individual that belongs species

Shannon-Weaver index is the most useful formula among the diversity index. “3.3” equation is an index which was derived from a mathematical formula in l948 by Shannon; and it was adapted to biological system (Shannon, l948). In addition a lots of diversity index were adapted from the mathematical formula which is called “Information Theory” (Mac Arthur, l965; Sager and Hasler, l969).

The advantage of this index is that it takes into account the number of species and the evenness of the species. The index is increased either by having additional unique species, or by having greater species evenness (Shannon, l948).

2.6.4 Similarity

Sorenson index was used for establishing the similarity degree that is among the samplings on the stations.

“Eq. 3. 4” (Krebs, l999)

$$q = \frac{2c}{a+b} (3.4)$$

c= The number of partner species between two sampling sites a=The number of species on the first sampling sites

b= The number of species on the second sampling sites

The similarity which is among the stations is shown in figure 3. 5 (UPGMA) and also similarity coefficients of them are shown in table 3. 11.

2.6.5 Biotic Index

The Belgian biotic index was used while the biotic index was calculating (Table 2.1). (De Pauw and Vanhooren, 1983; Metcalfe, l989; Kazancı et al., 1997). According to the index, when the value approached to 10, it means the quality of an environment may not be destroyed.

Table 2.1 Belgian Biotic Index (De Pauw and Vanhooren, 1983; Metcalfe, 1989).

Groups of fauna		*Total number of systematic units*				
		0-1	2-5	6-10	11-15	16+
		Biotic index				
1. Plecoptera or Ecdyonuridae	More S. U	-	7	8	9	10
(=Heptageniidae)	Only one S. U	5	6	7	8	9
2. Trichoptera (with case makers)	More S. U	-	6	7	8	9
	Only one S. U	5	5	6	7	8
3. Ancyldae or Ephemeroptera	More than 2 S. U	-	5	6	7	8
(except Ecdyonuridae)	2 or < 2 S. U	3	4	5	6	7
4. Aphelocherius or Odonata Gammaridae or Mollusca (except Sphaeridae)	There is no S. U. as above	3	4	5	6	7
5. Asellus or Hirudinea or Sphaeridae or Hemiptera (except Aphelocherius)	There is no S. U. as above	2	3	4	5	-
6. Tubificidae or *thummi-plumosus* Chironomidae groups	There is no S. U. as above	1	2	3	-	-
7. Eristalinae (Syrphidae)	There is no S. U. as above	0	1	1	-	-

S. U: SYSTEMATIC UNIT

2.7 Chemical Analyses

Water samples were taken from selected sites approximately 250 ml for chemical analyses. They were brought to the Hydrobiology laboratory for analyzing. Filtration method was used to determine the amount of particle in water.

Although turbidity is an environmental variable, it was measured in the laboratory before the filtration method. After filtration, some chemical analyses were verified such as nitrate (NO_3) (DIN 38405-D9), nitrite (NO_2) (DIN 38405-D10), ammonium (NH_4) (DIN 38406-E5) and phosphate (PO_4) (DIN 38405 D11) by spectrophotometric methods. (DR/50S). Chemical analyses were applied according to the DIN (Deutsches Institute für Normung) Standard method.

2.8 Microbiological Analyses

Microbiological samples are taken from all stations for determining the units of the total coliform bacteria. Water samples of approximately 100 ml were taken from within the water, and also stored in sterile whirlpak typed sealed plastic bags according to the collection and storage procedures outlined in standard methods for the examination of water and wastewater.

When the samples were taken, it was immediately inoculated with using dilution technique in the aseptic conditions on the EMB (Eosin Methylene Blue) Agar that is special agar for coli form bacteria, in the laboratory. Samples of each station were diluted. Characteristic colonies were counted on bacterial group concentrations reported on a colony-forming unit per 1-milliliter basis (cfu/1ml). After inoculation coli form bacteria are incubated at 37^{o}C for 48 hours in etuve. Then the colonies of bacteria are counted (Dufor, 1977).

3 RESULTS

Water samples, which were taken from Abant Stream, Mudurnu Stream and Büyüksu Stream, were determined based on both physicochemical and biological variables. Furthermore benthic were collected and they were utilized based distribution and diversity methods. The water qualities of them were determined with physicochemical variables, and also the results were compared with biological variables.

3.1 Meteorological Data

The total amount of air temperature and rain, which was reported by Meteorology of Bolu, is shown on table 3.1, 3.2 and 3.3.

According to the data, the average of the air temperature reached highest degree (23.2 ^{o}C) in August 2006 (figure 3.2) and the amount of rain was reported l43.0 kg/m^2 in January 2007 (Figure 3.3) at the highest level.

When the amounts of rain were examined in 2005, the highest value was reported on November (63.7 kg/m^2) (figure 3.1). During 2005, 21.7°C was measured the highest temperature value on August. Additionally the amount of rain reached the highest value (71.9 kg/m^2) on September during 2006.

Table 3. 1 The total amounth of rainfall and air temperature on the year 2005

Months (2005)	**Air temperature (°C)**	**The total amount of rain (kg/m2)**
April	10.4	72.6
May	14.4	42.8
June	16.3	59.1
July	20.9	58.1
August	21.7	8.6
September	16.6	29.9
October	10.3	52.1
November	6.6	63.7
December	4.1	39.7

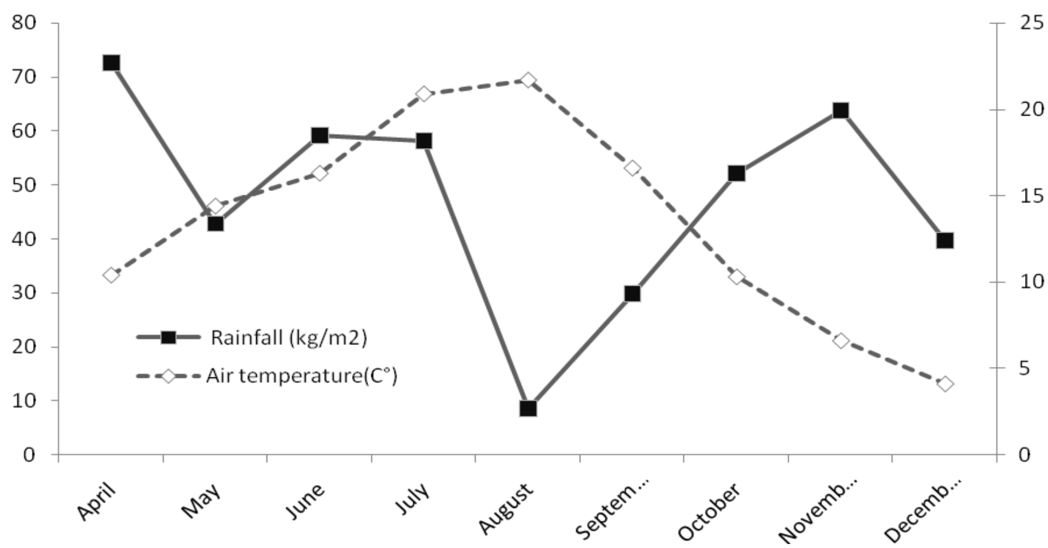


Figure 3.1 Diagram of monthly air temperature and rain values on the year 2005

Table 3.2 The total amount of rainfall and air temperature on the year 2006

Months (2006)	Air temperature (C°)	The total amount of rain (kg/m2)
January	-0.3	39.2
February	1.5	64.6
March	6.7	49.5
April	10.5	13.7
May	14	37
June	18.2	22.6
July	19.4	12.6
August	23.2	1.8
September	16	71.9
October	13	23.7
November	5.6	37.5
December	1.8	32.6

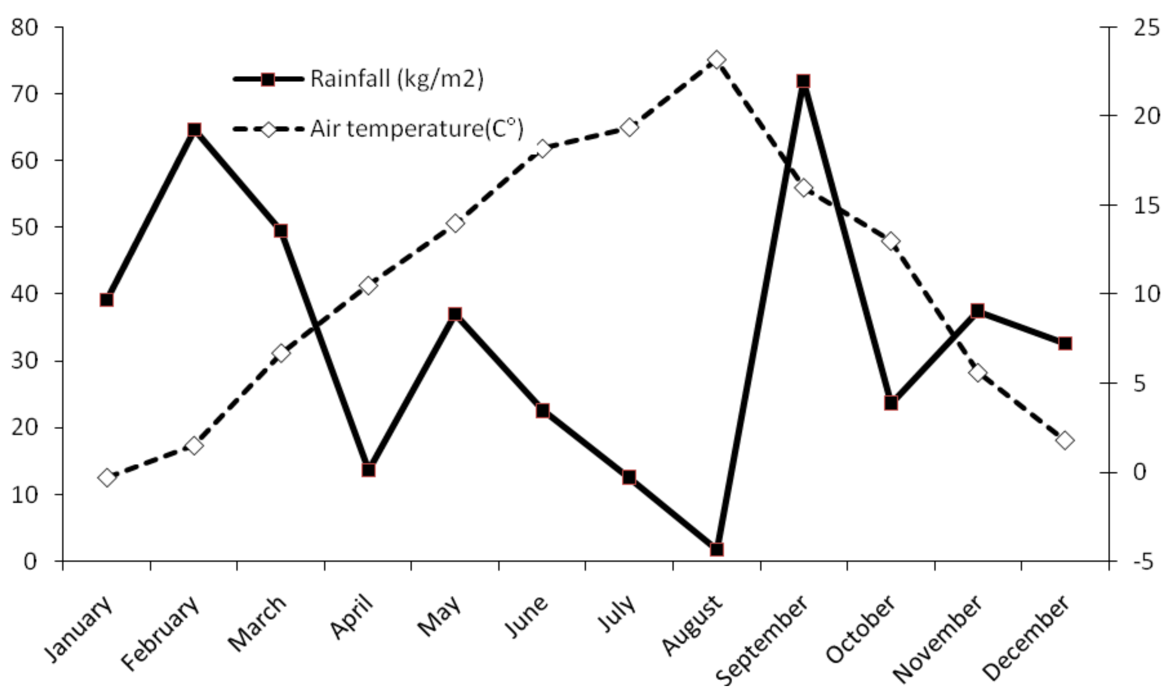


Figure 3.2 Diagram of monthly air temperature and rain values on the year 2006

Table 3.3 The total amount of rainfall and air temperature on the year 2007

Months (2007)	Air temperature (°C)	The total amount of rain (kg/m^2)
January	2.6	143
February	2.4	8.8
March	5.8	81
April	7.2	30
May	17.1	71.9
June	19.5	31.3
July	22.1	6.3
August	22	26.9
September	17.3	1

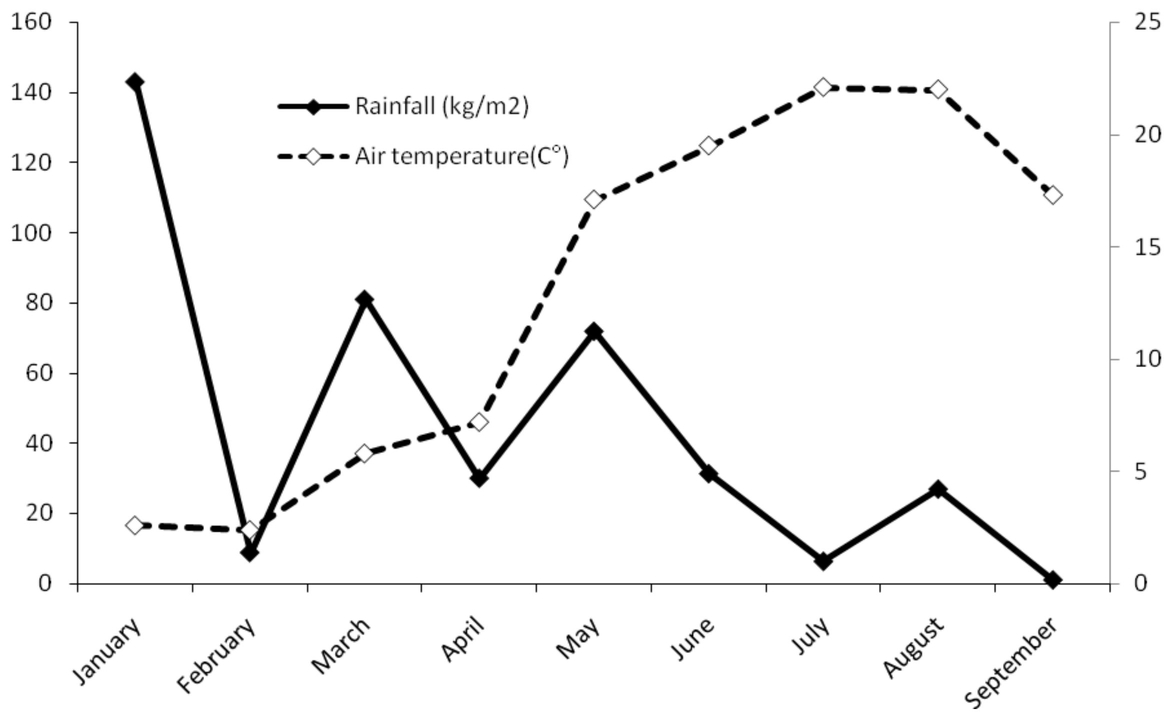


Figure 3.3 Diagram of monthly air temperature and rain values on the year 2007

3.2 Physicochemical Data

The values of physicochemical variables are shown on table 3. 4. At the same time water quality classes were determined by using them.

3.2.1 Electrical Conductivity (EC)

The conductivity of a solution is defined as the measurement of the ability of transportation electricity current. Electricity is transported by ions in a solution. This is why if the amount of ion increases, conductivity increases.

It is obviously seen that there is a positive relation between conductivity and ion. (Tchobanoglous and Schroeder, l985). The units of conductivity is $\mu S/cm^{-1}$

Maximum value of electrical conductivity was measured as 645. 5 $\mu S/cm^{-1}$ at Bridge-8 (9^{th} station), and also the minimum value (247.65 $\mu S/cm^{-1}$) was found at Before canalization (l^{st} station) which is the beginning of the Abant Stream. (Table 3.4.)

The highest values of electrical conductivity (EC) were measured generally on February and September, and the lowest values were on summer periods. Because, the amount of mineral, that comes from rain in winter, increases. So the value of electrical conductivity (EC) becomes high.

3.2.2 Electrical Potential (Eh)

The standard electrode potential was recalculated according to following formula (Stumm, 1996).

$$Eh\ (SHE) = Eh_{meas.}\ [mV] + 207 + 0.\ 7 * (25 - temp[°C]).$$

The values of the redox potential was measured between 79.81-22.15 mv. The highest mean value of it was calculated at second station as 168.104 mV and also the lowest mean value of redox potential was calculated third station (136.337 mV).

3.2.3 Temperature and Dissolved Oxygen

The most important variable is temperature for water quality. When the velocity of biochemical and chemical reactions increased, temperature increases. In addition, if the temperature increases, the solubility of gases decreases and the solubility of minerals increases. Moreover the development of aquatic organisms and their respiration ratios are based on temperature, too (Tchobanoglous and Schroeder, l985).

The lowest value of dissolved oxygen was measured as 4.72 mg/1 at Beypiliç (10^{th} station) and the highest level was at Dereceören (3^{rd} station), as 10.45 mg/1.

During sampling periods (April 2005-March 2007), the minimum value of temperature was measured on January 2007 as 2.90^{o}C at After canalization (2^{nd} station) and the temperature reached to the highest level on July 2005 as 24.3 $^{\circ}$C at Bolpat (8^{th} station).

3.2.4 pH

The standard pH value must be between 6.5 and 8.5 in aquatic systems. In this study, pH values changed between 7.52 and 8.23. (Table 3. 4)

The pH value of Dereceören reached to highest level (8.23) and minimum level was measured as 7.52 at Gökçesu (11^{th} station).

3.2.5 N-NO_3 Values

The mean values of the nitrate-nitrogen (N-NO_3), which were measured in the whole stations, changed between 0.02 mg/L and 0.20 mg/L (Figure 3.4). The highest value of N-NO_3 was measured as 0.67 mg/l at 7th station. (Table 3.4)

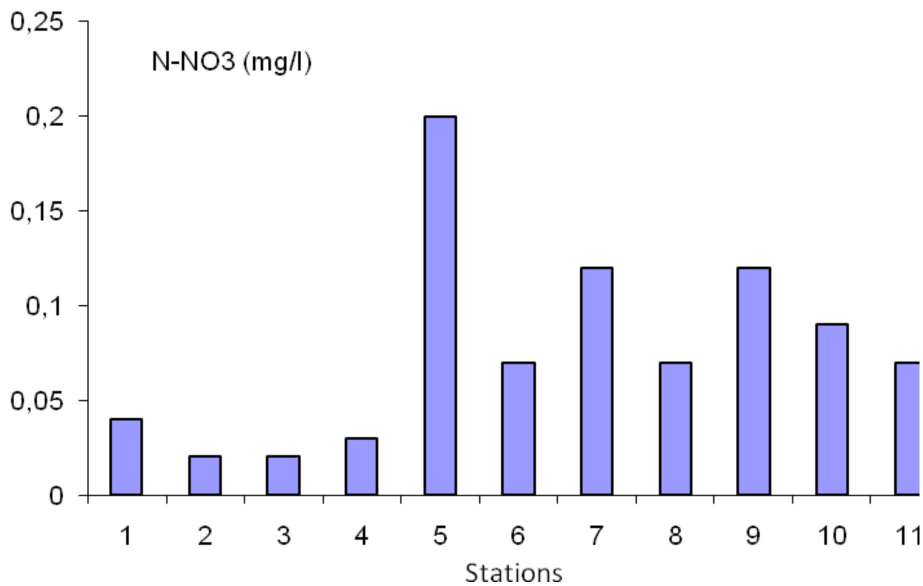


Figure 3.4 Mean values of N-NO_3 in the stations

3.2.6 N-NO_2 Values

Although the amounts of the nitrite-nitrogen were at low level, the highest value was measured as 0.72 mg/l at 9th station (Figure 3.5), as the mean value of it (0.16 mg/l). (Table 3.4.)

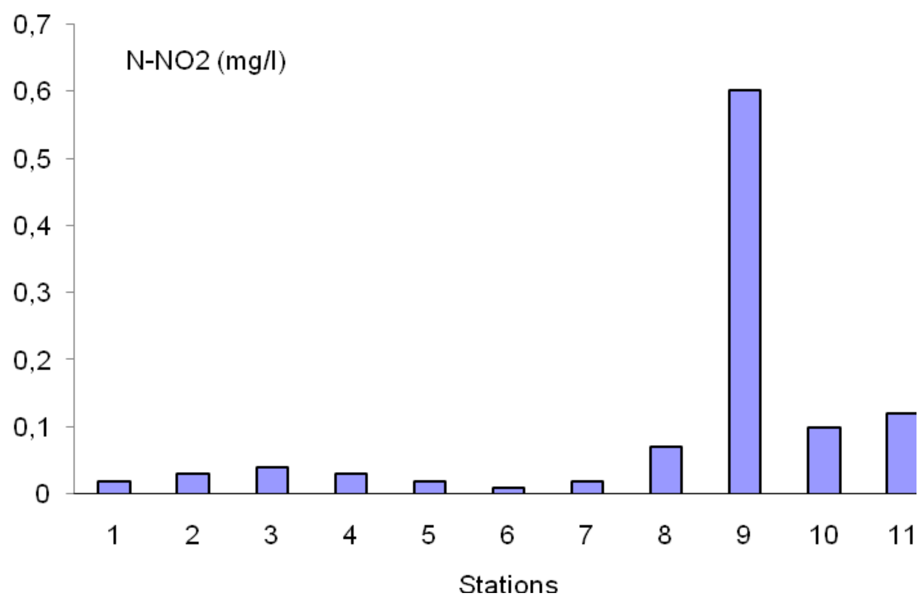


Figure 3.5 Mean values of N-NO_2 in the stations

3.2.7 N-NH_4 Values

The highest values of ammonium-nitrogen were measured at 9th, 10 th and 11th stations (4.10 mg/l, 4.26 mg/l and 4.81 mg/l). The minimum value of it was measured at 3rd station as 0.05 mg/l. (Table 3.4) (Figure 3.6)

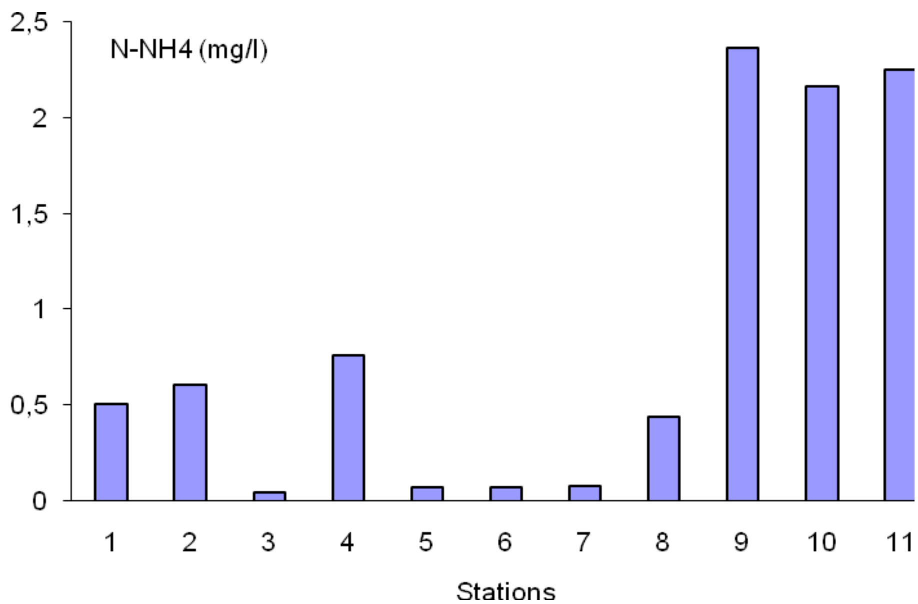


Figure 3.6 Mean values of N-NH_4 in the stations

3.2.8 P-PO_4 Values

The values of phosphate-phosphorus were found at low level generally. The mean values of it changed between 0.01 mg/l and 0.05 mg/l among the values (Figure 3.7). 8th station has the highest value of phosphate-phosphorus (0.11 mg/l) (Table 3.4.)

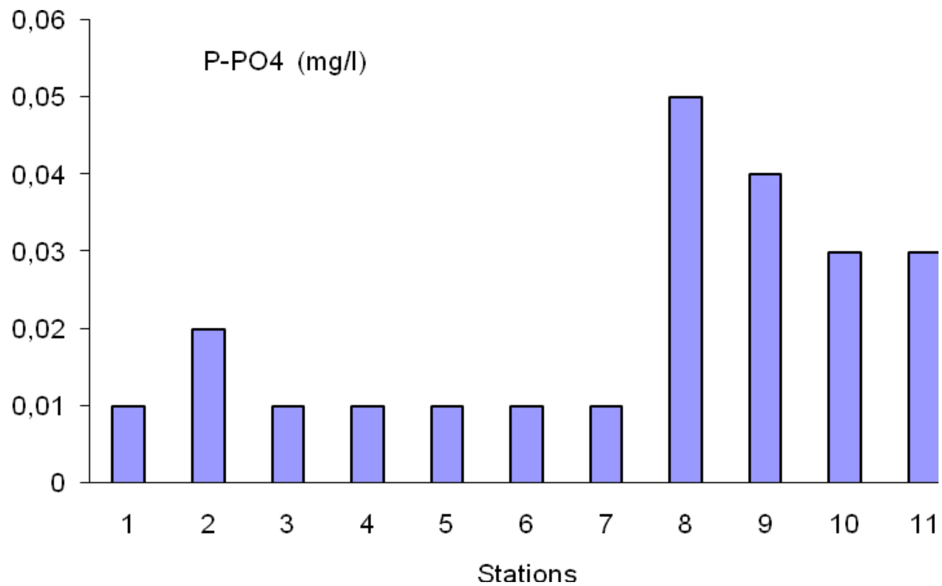


Figure 3.7 Mean values of P-PO_4 in the stations

3.3 Water Quality Classes

The water quality classes were determined with physicochemical variables by using the criterions of water quality classes that is found water pollution control directors (Prime Ministry Environment Counselor, 1988) (Table 3.4).

According to the criterions; station 8th, 9th, 10th and 11th have the most lowest quality class (class IV), but station 3rd, 4th, 5th, 6th and 7th have the first class water quality.

Table 3.4 Water quality criterion class (Prime Ministry Environmental Councellor, 1988)

The parameters of water quality	**The Classes of Water Quality**			
	1	**2**	**3**	**4**
Temperature (°C) [a]	25	25	30	>30
ph	6.5-8.5	6.5-8.5	6.0-9.0	except 6.0-9.0
Dissolved oxygen (mg/l) [a]	8	6	3	< 3
Oxygen saturation (%) [a]	90	70	40	<40
Cl (mg/l)	25	200	400 [b]	>400
SO (mg/l)	200	200	400	>400
NH_4-N (mg/l)	0. 2[c]	1[c]	2[c]	>2[c]
NO_2-N (mg/l)	0.002	0.01	0.05	>0.05
NO_3-N (mg/l)	5	10	20	>20
PO_4-P (mg/l)	0.02	0.16	0.65	>0.65
Boron (mg/l)	0.1[d]	0.1[d]	0.1[d]	0.1[d]

(a) It is enough to only one of the parameters of the percentage concentration or saturation.

(b) The concentration limits should be decreased on the irrigation of sensitive plants against the chloride.

(c) The value of concentration of the independent ammonium nitrogen should not be over 0.02 mg/1 depends on the value of ph.

(d) The criterion should be decreased until 0, 03 mg/l on the irrigation of sensitive plants against boron.

Table 3.5 Environmental variables of Büyüksu Stream

STATIONS	1	2	3	4	5	6	7
Temperature (°C)	11.23 (3.80-22.1)	11.48 (2.9-21.9)	8.69 (3.9-16.7)	11.49 (4.48-24.1)	9.67 (4.6-17.1)	9.86 (6.1-16.4)	9.74 (5.01-17.4)
$EC_{25°C}$ (µS/cm)	247.65 (214.3-383.7)	263.09 (219-482.5)	319.31 (259.8-390.6)	393.55 (385.6-522.3)	509.95 (455.6-568.7)	442.8 (398.6-507.5)	401.87 (225.6-485.64)
DO%	75.27 (45.5-114.5)	68.02 (4.5-107.8)	87.28 (68.4-114.92)	91.27 (56-110.16)	87.4 (68.1-106.11)	89.21 (64.8-11.36)	92.08 (63.5-107.2)
DO (mg/l)	8.51 (4.62-12.38)	7.78 (0.41-13.55)	10.45 (6.72-15.84)	10.16 (5.73-13.78)	9.92 (7.29-12.82)	10.11 (6.53-13.58)	10.13 (7.15-13.65)
pH	7.65 (7.17-8.23)	7.62 (7.08-8.18)	8.23 (7.56-8.75)	7.92 (6.51-8.51)	8.12 (7.36-8.63)	8.08 (7.21-8.67)	8.14 (7.18-8.71)
Eh	167.209 (120.14-208.98)	168.1044 (121.98-216.82)	136.337 (79.81-186.87)	141.677 (96.67-175.33)	138.511 (80.98-197.4)	141.288 (87.22-205.27)	138.072 (86.29-207.55)
Turbidity	3.45 (1-11.13)	3.12 (1.1-9.8)	3.69 (0.56-10.9)	7.77 (2.5-31.3)	7.25 (1.5-29.7)	5.27 (0.6-31.5)	3.99 (0.7-15.9)
ppT (salinity)	0.11 (0.09-0.13)	0.12 (0.1-0.2)	0.16 (0.1-0.19)	0.19 (0.1-0.25)	0.25 (0.2-0.23)	0.21 (0.0.2-0.25)	0.2 (0.1-0.23)
NO_3 (mg/l)	0.19 (0.00-1.26)	0.07 (0.00-0.33)	0.07 (0.00-0.33)	0.13 (0.00-0.37)	0.89 (0.02-2.44)	0.33 (0.00-1.21)	0.51 (0.00-2.96)
$N\text{-}NO_3$ (mg/l)	0.04 (0.00-0.28)	0.02 (0.00-0.08)	0.02 (0.00-0.07)	0.03 (0.00-0.08)	0.2 (0.01-0.47)	0.07 (0.00-0.27)	0.12 (0.01-0.67)
NO_2 (mg/l)	0.06 (0.00-0.17)	0.11 (0.00-0.61)	0.13 (0.00-1.45)	0.1 (0.00-0.54)	0.06 (0.01-0.14)	0.04 (0.00-0.09)	0.06 (0.01-0.28)
$N\text{-}NO_2$ (mg/l)	0.02 (0.00-0.05)	0.03 (0.00-0.19)	0.04 (0.00-0.44)	0.03 (0.00-0.16)	0.02 (0.00-0.04)	0.01 (0.00-0.03)	0.02 (0.00-0.08)
PO_4 (µg/l)	0.03 (0.00-0.07)	0.06 (0.01-0.24)	0.02 (0.00-0.05)	0.03 (0.01-0.07)	0.03 (0.01-0.08)	0.03 (0.00-0.11)	0.02 (0.00-0.05)
$P\text{-}PO_4$ (µg/l)	0.01 (0.00-0.02)	0.02 (0.00-0.8)	0.01 (0.00-0.01)	0.01 (0.00-0.02)	0.01 (0.00-0.03)	0.01 (0.00-0.04)	0.01 (0.00-0.01)
NH_4 (mg/l)	0.66 (0.01-2.86)	0.78 (0.02-4.52)	0.06 (0.00-0.25)	0.98 (0.07-3.12)	0.09 (0.01-0.31)	0.08 (0.00-0.32)	0.11 (0.00-0.52)
N-NH4 (mg/l)	0.51 (0.01-2.2)	0.61 (0.02-3.51)	0.05 (0.00-0.19)	0.76 (0.05-2.43)	0.07 (0.01-0.24)	0.07 (0.00-0.25)	0.08 (0.02-0.41)
Altitude (m)	1338	1333	975	791	1041	832	802
Water quality class	2	2	1	1	1	1	1
Diversity (H')	1.5 (0.912-2.113)	1.5 (0.699-2.517)	2.7 (1.55-3.733)	1.4 (0.439-2.322)	1.4 (0.165-3.491)	2.7 (1.95-3.485)	2.6 (1.214-3.677)
Biotic index	4 (2-5)	4 (2-6)	9 (8-10)	6 (4-9)	7 (5-10)	9 (7-10)	9 (6-10)
Coliform bacteria (cfu)	14586 (20-48600)	160499 (1000-152000)	7697 (30-48000)	182813 (220-1800000)	4888 (100-27000)	2034 (10-11200)	2525 (100-1000)

Table 3. 5. Environmental variables of Büyüksu Stream (Cont.)

STATIONS	8	9	10	11
Temperature (ºC)	12.76 (6.60-24.3)	14.78 (8.30-23.6)	14.64 (7.8-24)	12.93 (7.30-23.7)
$EC_{25°C}$ (μS/cm)	478.62 (372.1-604.9)	645.15 (426.4-819.4)	605.45 (446.2-702.6)	615.48 427.53-748.9)
DO%	72.06 (2.1-18.97)	52.65 (14.7-97.8)	45.52 (31.5-93.5)	42.74 (4.9-107.8)
DO (mg/l)	7.93 (0.2-12.33)	5.45 (1.23-10.11)	4.72 (0.12-9.62)	5.28 (1.28-10.39)
pH	7.75 (7.05-8.76)	7.62 (7.13-8.23)	7.6 (7.14-8.11)	7.52 (7.13-7.94)
Eh	150.418 (87.44-222.15)	168.044 (112.15-214.76)	165.642 (117.69-205.7)	168.689 (123.46-208.72)
Turbidity	25.08 (6-107.9)	12.81 (5-20.3)	9.52 (4.1-26.5)	9.12 (5.2-68.6)
ppT (salinity)	0.24 (0.2-)0.3)	0.32 (0.2-0.4)	0.3 (0.2-0.36)	0.31 (0.2-0.4)
NO3 (mg/l)	0.3 (0.00-1.13)	0.54 (0.00-1.83)	0.38 (0.00-1.24)	0.32 (0.00-1.16)
N-NO3 (mg/l)	0.07 (0.01-0.25)	0.12 (0.01-0.41)	0.09 (0.02-0.28)	0.07 (0.00-0.26)
NO2 (mg/l)	0.24 (0.01-0.62)	0.51 (0.05-2.37)	0.34 (0.03-0.89)	0.41 (0.02-1.25)
N-NO2 (mg/l)	0.07 (0.01-0.19)	0.6 (0.01-0.72)	0.1 (0.01-0.27)	0.12 (0.01-0.38)
PO4 (μg/l)	0.14 (0.01-0.34)	0.13 (0.05-0.23)	0.1 (0.04-0.27)	0.09 (0.03-0.16)
P-PO4 (μg/l)	0.05 (0.01-0.11)	0.04 (0.02-0.08)	0.03 (0.01-0.09)	0.03 (0.00-0.05)
NH4 (mg/l)	0.53 (0.06-3.91)	3.04 (0.48-5.28)	2.78 (0.82-6.19)	2.89 (0.16-5.48)
N-NH4 (mg/l)	0.44 (0.05-3.04)	2.36 (0.37-4.10)	2.16 (0.63-4.81)	2.25 (0.13-4.26)
Altitude	731	717	704	688
Water quality class	4	4	4	4
Diversity (H')				
Biotic index				
Coliform bacteria (cfu)	1204480 (1020-144000000	36411 (2100-1960000)	676604 (1600-5440000)	413208 (300-4224000)

3.4 Microbiological Data

The results of bacteriological analyses showed that the total number of bacteria has increased time to time in Büyüksu Stream. Increasing the number of bacteria is related to waste water which is given directly to the Abant Stream, Mudurnu Stream and Büyüksu Stream. Results of microbiological analyses were found at high concentration of fecal coli form bacteria than recommendation that standardized by EPA (Environmental Protection Agency). The average of total coli form bacteria units were detected between $2.03 x 10^3$ cfu and l. $204 x 10^6$ cfu. In addition, the highest value of total coli form bacteria unit belongs to the Bolpat station (l$44 x 10^6$ cfu)

3.5 Biological Data

In this study, 117 taxons (in the content of 3 phylum) were found. The list of benthic macroinvertebrates obtained from sampling areas was given on Table 3.6. Moreover 26 taxa were identificated among 117 taxa belong to the family Chironomidae.

According to the results the most diverse group is Diptera (Insecta), Generally at the sampling sites Baetidae sp., Tipula sp., Simuliidae sp., and Diptera pupa were found in each station (except Bolpat, Bridge-8, Beypiliç and Gökçesu). In family Chinonomidae; *Diamesa insignipes* was found in each station. Other common species are *Krenopelopia binotata, Brilla modesta* and *Cardiocladius capucinus* ın Chinonomidae (Diptera).

Benthic macroinvertebrates were not collected for identification of benthic macroinvertebrates from Büyüksu Stream. Because there were any species could not be found on there, and also only *Tubifex* sp. was found.

Table 3.6 Benthic macroinvertebrates which found in Büyüksu Stream

	TAXON	Stations						
		1	2	3	4	5	6	7
Phylum:	**MOLLUSCA**							
Class:	**GASTRAPODA**							
Order:	**PROSOBRAHCIATA**							
Family:	**Valvatidae**							
	Valvata piscinalis		*					
Family:	**Hydrobidae**							
	Hydrobidae sp.		*					
Family	**Physidae**							
	Physidae sp.						*	
Family:	**Lymnaeidae**							
	Radix sp.				*			
	Lymnaeidae sp.		*					
Family:	**Planorbidae**							
	Gyraulus albus Müller	*	*	*	*			
	Planorbis planorbis	*	*		*			
	Gyraulus sp.	*					*	*
Class:	**LAMELLIBRANCHIATA**							
Family:	**Corbiculidae**							
	Corbicula fluminalis							
	Corbiculidae sp.							*
Family:	**Sphaeriidae**							
	Sphaeriidae sp.						*	
	Sphaerium sp.		*				*	
Phylum:	**ANNELIDA**							
Class:	**CLITELLATA**							
Order:	**OLIGOCHAETA**							
	Oligochaeta sp.	*	*		*		*	*
Family:	**Lumbricidae**							
	Lumbricidae sp.					*	*	
	Eiseniella tetraedra				*	*	*	
Class:	**HIRUDINEA**							
Family:	**Glossiphonidae**							
	Glossiphonia sp.	*						
Family:	**Erpobdellidae**							
	Erpobdella octulata L.	*	*					
	Erpobdella sp.			*	*		*	*
Phylum:	**ARTHROPODA**							
Class:	**CRUSTACEA**							
Order:	**AMPHIPODA**							
Family:	**Gammaridae**							
	Gammarus sp.	*		*				
Class:	**INSECTA**							
Order:	**EPHEMEROPTERA**							
Family:	**Baetidae**							
	Baetidae gen sp.	*	*	*	*	*	*	*
	Baetis sp.			*				

Table 3.6 Benthic macroinvertebrates which found in Büyüksu Stream (cont.)

				Stations				
		1	2	3	4	5	6	7
	Baetidae adult				*			
Family:	**Heptageniidae**							
	Epeorus sp.			*	*		*	*
	Rhitrogena sp.			*	*	*	*	*
	Iron sp.				*		*	*
	Heptagenia sp.						*	*
	Heptageniidae sp.				*	*	*	*
Family:	**Ephemerellidae**							
	Ephemerella ignata Poda		*					
	Ephemerellidae sp.					*	*	*
	Ephemerella sp.			*	*	*		
Family:	**Caenidae**							
	Caenis sp.				*			*
Family:	**Leptophlebiidae**							
	Paraleptophlebia sp.							*
	Paraleptophlebia submarginata Steph.			*				
	Habrophlebia lauta Etn.			*				
	Habrophlebia sp.						*	
Order:	**PLECOPTERA**							
Family:	**Taeniopterygidae**							
	Brachyptera cucasica turcica Zwick							
	Taeniopterygidae sp.				*	*		
Family:	**Nemouridae**							
	Nemoura sp.					*		
Family:	**Leuctridae**							
	Leuctra hippopus			*				
	Leuctra sp.			*	*	*	*	*
Family:	**Capniidae**							
	Capnia sp.							
Family:	**Perlodidae**							
	Isoperla sp.			*	*		*	*
Family:	**Perlidae**							
	Perla sp.			*		*		*
Family:	**Chloroperlidae**							
	Chloroperlidae sp.						*	
	Plecoptera adult						*	
Order:	**ODONATA**							
Family:	**Coenagrionidae**							
	Coenagrionidae sp.	*						
Family:	**Gomphidae**							
	Gomphidae sp.	*						*
Family:	**Cordulegasteridae**							
	Cordulagaster sp.				*	*		
Order:	**HETEROPTERA**							
Family:	**Gerridae**							
	Gerris sp.					*		

Table 3.6 Benthic macroinvertebrates which found in Büyüksu Stream (cont.)

		Stations						
		1	**2**	**3**	**4**	**5**	**6**	**7**
Order:	**COLEOPTERA**							
Family:	**Gyrinidae**							
	Gyrinus sp.							*
Family:	**Dytiscidae**							
	Dytiscidae sp.						*	
Family:	**Hydrobiidae**							
	Laccobius sp.	*				*		
Family:	**Hydrophilidae**							
	Hydrophilidae sp.					*		
Family:	**Elmidae**							
	Elmis sp.					*	*	*
	Elmidae sp.						*	
	Limnius sp.					*	*	*
Family:	**Chrysomelidae**							
	Donacia sp.		*					
Family:	**Helodidae**							
	Helodidae sp.					*		
Order:	**MEGALOPTERA**							
Family:	**Sialidae**							
	Sialidae sp.					*		
	Sialis morio Klingst	*						
Order:	**TRICHOPTERA**							
Family:	**Rhyacophilidae**							
	Rhyacophila sp.				*	*	*	*
Family:	**Glassomatidae**							
	Glassomatidae sp.							
	Agapetus sp.			*				
Family:	**Philopotamidae**							
	Philopotamidae sp.			*				*
	Philopotamus montarus			*				
Family:	**Hydropsychidae**							
	Hydropsyche angustipennis			*				
	Hydropsyche contubernalis			*				
	Hydropsychidae sp.			*				
	Hydropsyche sp.			*	*	*	*	
Family:	**Psychomyidae**							
	Psychomyidae sp.							*
Family:	**Limnephilidae**							
	Limnephilidae sp.			*		*	*	
Family:	**Goeridae**							
	Goeridae sp.					*		
Family:	**Lepidostomatidae**							
	Lepidostomatidae sp.			*			*	*
	Trichoptera pupa					*		*
	Trichoptera adult				*		*	

Table 3.6 Benthic macroinvertebrates which found in Büyüksu Stream (cont.)

		Stations						
		1	**2**	**3**	**4**	**5**	**6**	**7**
Order:	**DIPTERA**							
Family:	**Blephariceridae**							
	Blephariceridae sp.			*			*	*
Family:	**Tipulidae**							
	Tipula sp.	*	*	*	*	*	*	*
Family:	**Limoniidae**							
	Dicronata sp.			*	*	*	*	*
	Hexatoma sp.			*			*	*
Family:	**Psychodidae**							
	Psychodidae sp.			*	*	*	*	
	Pericoma sp.		*					
Family:	**Ptychopteridae**							
	Ptychoptera sp.				*	*		
Family:	**Simulidae**							
	Simulidae sp.	*	*	*	*	*	*	*
Family:	**Stratiomydae**							
	Stratiomys sp.			*				*
Family:	**Empididae**							
	Empididae sp.				*			
Family:	**Tabanidae**							
	Chrysops sp.				*			
	Tabanus sp.							*
Family:	**Athericidae**							
	Atherix ibis F.			*		*	*	*
Family:	**Muscidae**							
	Limnophora sp.							*
	Diptera pupa	*	*	*	*	*	*	*
	Diptera adult				*			
Family:	**Tanypodinae**							
	Arctopelopia barbitarsis Zett.		*					
	Krenopelopia binotata Wied.	*		*	*	*		*
	Krenopelopia sp.		*	*	*			*
	Macropelopia nebulosa Mg.						*	
Family:	**Diamesinae**							
	Diamesa insignipes K.	*	*	*	*	*	*	*
	Diamesa thienemanni K.				*			
	Diamesa sp.						*	
Family:	**Telmatogetoninae**							
	Orthocladinae sp.				*	*		*
	Brillia modesta Mg.		*	*	*	*	*	*
	Cardiocladius capucinus Zett.		*	*		*	*	*
	Cricotopus albiforceps K.			*				
	Cricotopus sp.				*			
	Nanocladius (Microcricotopus) sp.		*					
	Orthocladius sp.		*					

Table 3.6 Benthic macroinvertebrates which found in Büyüksu Stream (cont.)

		Stations						
		1	2	3	4	5	6	7
	Paratrichocladius rufiventris Mg.	*						
	Rheocricotopus fuscipes K.				*			
	Synorthocladius semiverens K.					*		
Family:	***Chironominae***							
	Chironomus thummi K.	*	*		*			
	Dicrotendipes tritomus K.	*						
	Fleura lacustris K.	*						
	Paratendipes albimanus Mg.			*				
	Pentapedilum exsectum K.		*					*
	Pentapedilum sp.	*	*					
	Polypedilum laetum Mg.			*	*			*
	Polypedilum sp.		*					
	Tanytarsus sp.		*				*	

3.5.1 Dominance Values

Thirteen samplings were done in eleven stations at the field areas, and then approximately l6265 individuals which belong to the 117 taxons were found. The values of dominance were shown on table 3.7.

According to the results; at the first station, *Simuliidae* sp. Is the dominant taxa as 26.47%. Secondly, dominance species is *Erpobdella octulata*, as 25.29%. *Diamesa insignipes* and *Gyraulus albus* are dominant species at the second station (22.26% and 18.13%). In addition, first station and second station relates to the each other.

The dominance value of *Rhitrogena* sp. is 40.56% at the 3rd station, which has clean and cold water. at the 4th station *Baetidae* sp. ıs the dominant taxa as 60.39%.

Current velocity is low ın fifth station and aquatic plants are found highly. That's why *Gammarus* sp. that relates this station was found there at high in level as 65.14%.

Because of resembling the fifth and sixth stations, *Gammanus* sp. is dominant at the 6th station, too as 19.12%. Moreover second dominant group is *Rhitragena* sp as 14.10%. At 7th station *Baetis* sp. is the dominant taxa as l4.46%. Finally *Tubifex* sp. was found in each period continuously at Bolpat, Bridge-8, Beypiliç and Gökçesu station.

Table 3.7 Dominance values of Benthic Macroinvertebrates in Büyüksu Stream

TAXON	**Dominance values**						
Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Valvata piscinalis		0.16					
Hydrobidae sp.		0.08					
Physidae sp.							
Radix sp.				0.02			
Lymnaeidae sp.		0.08		0.04			
Gyraulus albus Müller	4.43	18.13	0.08	0.02	0.03	0.14	
Planorbis planorbis	0.65	4.36		0.07			
Gyraulus sp.	1.43	2.33				0.14	0.23
Corbicula fluminalis							
Corbiculidae sp.							0.17
Sphaeriidae sp.						0.07	
Sphaerium sp.		0.39					
Oligochaeta sp.	0.78	0.93	0.56	0.47	0.11	1.09	0.41
Lumbricidae sp.					0.03	0.14	
Eiseniella tetraedra	0.52		0.16	0.06	0.11	0.27	
Glossiphonia sp.	0.13						
Erpobdella octulata L.	25.29	15.10		0.04			
Erpobdella sp.	15.25	7.32	0.24	0.30		0.41	0.06
Gammarus sp.	0.13		0.40		65.14	19.62	
Baetidae sp.	0.52	4.75	3.03	60.39	12.18	6.88	11.55
Baetis sp.		4.44	9.72	0.06	0.46	6.81	14.46
Baetidae adult				0.02		0.07	
Epeorus sp.			1.04	0.86		0.27	0.64
Rhitrogena sp.			40.56	8.42		14.10	8.51
Iron sp.			2.39		0.08	8.99	3.09
Heptagenia sp.					0.03	0.27	0.64
Heptageniidae sp.			0.72	3.29		3.68	7.76
Ephemerella ignata Poda		0.39					
Ephemerellidae sp.				0.07	0.03	0.27	0.06
Ephemerella sp.			0.24	0.32	0.03	0.07	
Caenis sp.				0.95		0.07	
Paraleptophlebia sp.						0.07	0.06
Paraleptophlebia submarginata Steph.			0.08				
Habrophlebia lauta Etn.			0.08				
Habrophlebia sp.						0.07	
Brachyptera cucasica turcica Zwick				0.02			
Taeniopterygidae sp.					0.03		6.82
Nemoura sp.							
Leuctra hippopus							
Leuctra sp.			3.90	0.02	0.48	8.38	3.73
Capnia sp.							2.80
Isoperla sp.			5.74	0.07		1.77	6.41
Perla sp.			0.48		0.05		1.34
Chloroperlidae sp.			0.56		0.03	0.34	0.29

Plecoptera adult						0.07	
Coenagrionidae sp.	0.13						
Gomphidae sp.	0.13						0.29
Cordulagaster sp.			0.08	0.02	0.38	0.07	
Gerris sp.					0.32		
Gyrinus sp.							0.29
Dytiscidae sp.						0.07	
Laccobius sp.	0.13				0.03		
Hydrophilidae sp.					0.05		
Elmis sp.					0.19	0.07	0.06
Elmidae sp.							0.06
Limnius sp.					0.35	2.04	0.29
Donacia sp.		0.08					
Helodidae sp.					0.16		
Sialidae sp.					0.13	0.07	0.06
Sialis morio Klingst	0.13						
Rhyacophila sp.			0.48	0.13	1.29	3.68	5.71
Glassomatidae sp.			0.08				
Agapetus sp.			0.08				
Philopotamidae sp.			0.16				0.06
Philopotamus montarus			0.40				
Hydropsyche angustipennis			0.08				
Hydropsyche contubernalis			0.08				
Hydropsychidae sp.			1.04			0.14	1.28
Hydropsyche sp.			4.22	8.32	1.97	6.27	4.72
Psychomyidae sp.						0.07	0.06
Limnephilidae sp.			0.72		0.38	2.04	0.17
Goeridae sp.					0.03		
Lepidostomatidae sp.			0.16			3.13	0.06
Trichoptera pupa				0.02			0.06
Trichoptera adult				0.02		0.07	
Blephariceridae sp.			0.16			0.20	0.12
Tipula sp.	2.22	0.54	1.43	0.07	0.54	0.34	1.57
Dicronata sp.			3.82	0.09	0.38	2.66	1.22
Hexatoma sp.			1.67	0.02	0.05	0.48	0.06
Psychodidae sp.	0.52		0.08	0.02	0.03		0.06
Pericoma sp.		0.23					
Ptychoptera sp.				0.02	0.05		
Simulidae sp.	26.47	16.42	2.23	13.47	13.69	0.75	6.41
Stratiomys sp.			0.08				0.06
Empididae sp.				0.04			
Chrysops sp.				0.02			
Tabanus sp.					0.11		0.06
Atherix ibis F.			3.98		0.35	2.11	4.61
Limnophora sp.							0.06
Diptera pupa	0.26	0.23	0.16	0.65	0.22	0.20	0.17
Diptera adult				0.11			
Arctopelopia barbitarsis Zett.		0.08					
Krenopelopia binotata Wied.	0.26		0.08	0.45	0.05		0.12
Krenopelopia sp.		0.16	0.16	0.09			0.06

Macropelopia nebulosa Mg.						0.14	
Diamesa insignipes K.	17.34	22.26	1.99	0.28	0.19	0.07	0.47
Diamesa thienemanni K.				0.04			
Diamesa sp.						0.07	
Orthocladinae sp.				0.02	0.03		0.06
Brillia modesta Mg.		0.08	1.27	0.17	0.13	0.54	0.52
Cardiocladius capucinus Zett.		0.39	4.70		0.05	0.14	1.81
Cricotopus albiforceps K.			0.24				
Cricotopus sp.				0.17			
Nanocladius (Microcricotopus) sp.		0.23					
Orthocladius sp.		0.08					
Paratrichocladius rufiventris Mg.	1.30						
Rheocricotopus fuscipes K.				0.11			
Synorthocladius semiverens K.					0.05		
Chironomus thummi K.	1.17	0.31		0.09			
Dicrotendipes tritomus K.	0.13						
Fleura lacustris K.	0.13						
Paratendipes albimanus Mg.			0.16				
Pentapedilum exsectum K.		0.16					0.17
Pentapedilum sp.	0.52	0.16					
Polypedilum laetum Mg.			0.24	0.06			0.17
Polypedilum sp.		0.08					
Tanytarsus sp.		0.08				0.54	
Max	26.47	22.26	40.56	60.39	65.14	19.62	14.46

3.5.2 Frequency Values

The frequency distribution of benthic macroinvertebrates during the study period, was given on table 3.8.

The frequency value of *Erpobdella octulata* was 46% at first station. *Erpolodella octulata* has the 54% frequency value at the second station like a first station. *Rhitragena* sp and *Atherix ibis* were obtained in whale sampling periods (l00%) at the third station.

The most frequent taxa was Hydropsyche sp. at the 4th station with 92%. Also at the 5th station; *Gammarus* sp. possesses l00% frequency value depending on dominance values.

Hydropsyche sp is the most frequent taxa at the 6th and 7th Stations (l00%, 85%).

Tubifex was seen in the stations that are on Büyüksu Stream and it was found all periods.

As a result, frequency values and dominance values are depending on to each other. Moreover family Chironomidae (Insecta) was not found frequently. *Brilla modesta* was the most frequent species with 38% (3th station).

Table 3.8 Frequency values of benthic macroinvertebartes in Büyüksu Stream

TAXON	**Frequency values**						
Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Valvata piscinalis		8					
Hydrobidae sp.		8					
Physidae sp.							
Radix sp.				8			
Lymnaeidae sp.		8		15			
Gyraulus albus Müller	23	38	8	8	8	15	
Planorbis planorbis	23	46		15			
Gyraulus sp.	15	31				15	23
Corbicula fluminalis							
Corbiculidae sp.							8
Sphaeriidae sp.						8	
Sphaerium sp.		23					
Oligochaeta sp.	31	23	23	31	8	54	46
Lumbricidae sp.					8	15	
Eiseniella tetraedra	8		15	8	23	23	
Glossiphonia sp.	8						
Erpobdella octulata L.	46	54		15			
Erpobdella sp.	31	38	15	38		38	8
Gammarus sp.	8		31		100	77	
Baetidae sp.	23	38	23	77	54	54	62
Baetis sp.		8	92	15	31	62	77
Baetidae adult				8		8	
Epeorus sp.			31	23		15	46
Rhitrogena sp.			100	38		62	62
Iron sp.			62		15	54	31
Heptagenia sp.					8	23	31
Heptageniidae sp.			8	23		38	54
Ephemerella ignata Poda		8					
Ephemerellidae sp.				8	8	15	8
Ephemerella sp.			8	8	8	8	
Caenis sp.				23		8	
Paraleptophlebia sp.						8	8
Paraleptophlebia submarginata Steph.			8				

Habrophlebia lauta Etn.			8				
Habrophlebia sp.						8	
Brachyptera cucasica turcica Zwick				8			
Taeniopterygidae sp.					8		23
Nemoura sp.							
Leuctra hippopus							
Leuctra sp.			46	8	46	62	46
Capnia sp.							38
Isoperla sp.			62	15		54	69
Perla sp.			23		15		38
Chloroperlidae sp.			8		8	23	8
Plecoptera adult						8	
Coenagrionidae sp.	8						
Gomphidae sp.	8						15
Cordulagaster sp.			8	8	62	8	
Gerris sp.					23		
Gyrinus sp.							15
Dytiscidae sp.						8	
Laccobius sp.	8				8		
Hydrophilidae sp.					15		
Elmis sp.					38	8	8
Elmidae sp.							8
Limnius sp.					31	54	15
Donacia sp.		8					
Helodidae sp.					8		
Sialidae sp.					15	8	8
Sialis morio Klingst	8						
Rhyacophila sp.			46	23	46	85	69
Glassomatidae sp.			8				
Agapetus sp.			8				
Philopotamidae sp.			15				8
Philopotamus montarus			8				
Hydropsyche angustipennis			8				
Hydropsyche contubernalis			8				
Hydropsychidae sp.			31			8	46
Hydropsyche sp.			62	92	92	100	85
Psychomyidae sp.						8	8
Limnephilidae sp.			23		38	46	15
Goeridae sp.					8		
Lepidostomatidae sp.			15			31	8
Trichoptera pupa				8			8
Trichoptera adult				8		8	
Blephariceridae sp.			8			8	8
Tipula sp.	31	23	38	23	46	23	54
Dicronata sp.			77	15	31	77	54
Hexatoma sp.			54	8	8	31	8
Psychodidae sp.	15		8	8	8		8
Pericoma sp.		23					
Ptychoptera sp.				8	15		
Simulidae sp.	23	38	54	54	62	31	38

Stratiomys sp.			8				8
Empididae sp.				8			
Chrysops sp.				8			
Tabanus sp.					8		8
Atherix ibis F.			100		54	77	77
Limnophora sp.							8
Diptera pupa	15	15	15	46	23	8	23
Diptera adult				8			
Arctopelopia barbitarsis Zett.		8					
Krenopelopia binotata Wied.	15		8	15	8		8
Krenopelopia sp.		8	8	8			8
Macropelopia nebulosa Mg.						8	
Diamesa insignipes K.	15	15	8	15	15	8	8
Diamesa thienemanni K.				8			
Diamesa sp.						8	
Orthocladinae sp.				8	8		8
Brillia modesta Mg.		8	38	31	15	23	15
Cardiocladius capucinus Zett.		15	15		8	8	15
Cricotopus albiforceps K.			8				
Cricotopus sp.				8			
Nanocladius (Microcricotopus) sp.		15					
Orthocladius sp.		8					
Paratrichocladius rufiventris Mg.	8						
Rheocricotopus fuscipes K.				15			
Synorthocladius semiverens K.					8		
Chironomus thummi K.	15	15		8			
Dicrotendipes tritomus K.	8						
Fleura lacustris K.	8						
Paratendipes albimanus Mg.			8				
Pentapedilum exsectum K.		8					8
Pentapedilum sp.	8	8					
Polypedilum laetum Mg.			15	8			8
Polypedilum sp.		8					
Tanytarsus sp.		8				8	
Max	46	54	100	92	100	100	85

3.5.3 Diversity Values

The results of diversity were shown on table 3.9. The highest diversity is 2.7. and it was collated at the Dereceören station and Güvem station. Also the lowest diversity is l.4. and it was calculated at Yolçatı and Güneyfelakettin stations.

The graphic which shows the values of diversity results among stations is given as figure 3.4. In addition, the highest number of taxa was obtained on Güvem station (14.4) and first station has the lowest number of taxa (4.l) (Table 3.9).

Table 3. 9 Diversity index of the stations

	Diversity index H'							Number of Taxa						
Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
April 2005	1.178	0.959	3.247	0.797	1.704	2.872	2.611	3	2	17	11	11	15	8
May 2005	1.432	0.699	2.507	1.538	1.366	2.405	2.161	4	7	12	9	6	13	10
June 2005	2.113	1.614	1.959	2.293	1.499	2.792	1.932	8	7	13	10	12	20	13
July 2005	1.638	2.326	3.198	0.581	1.484	3.197	1.214	7	7	16	15	15	15	5
August 2005	1.501	2.517	3.733	1.633	0.782	2.391	2.394	8	16	17	10	10	12	15
September 2005	****	****	3.3	1.474	0.562	2.308	2.704	0	0	12	11	9	14	13
October 2005	1.177	1.813	1.55	0.439	0.81	2.346	3.366	4	5	12	2	11	10	18
December 2005	****	2.045	2.061	1.459	1.278	3.485	3.262	0	9	10	3	14	20	19
March 2006	1.459	1.889	2.098	1.861	1.14	1.95	2.06	3	8	7	14	14	4	17
September 2006	****	1.052	2.581	1.555	2.065	3.064	2.386	0	3	12	7	8	20	10
November 2006	2.049	0	3.22	0.978	0.165	2.891	3.677	6	1	13	3	2	17	18
January 2007	1.769	1.439	2.764	1.442	3.491	3.077	3.575	7	4	13	5	19	17	20
February2007	0.912	1.918	2.856	2.322	2.304	2.536	2.555	3	4	12	9	7	10	12
Mean	1.5	1.5	2.7	1.4	1.4	2.7	2.6	4.1	5.6	12.7	8.4	10.6	14.4	14

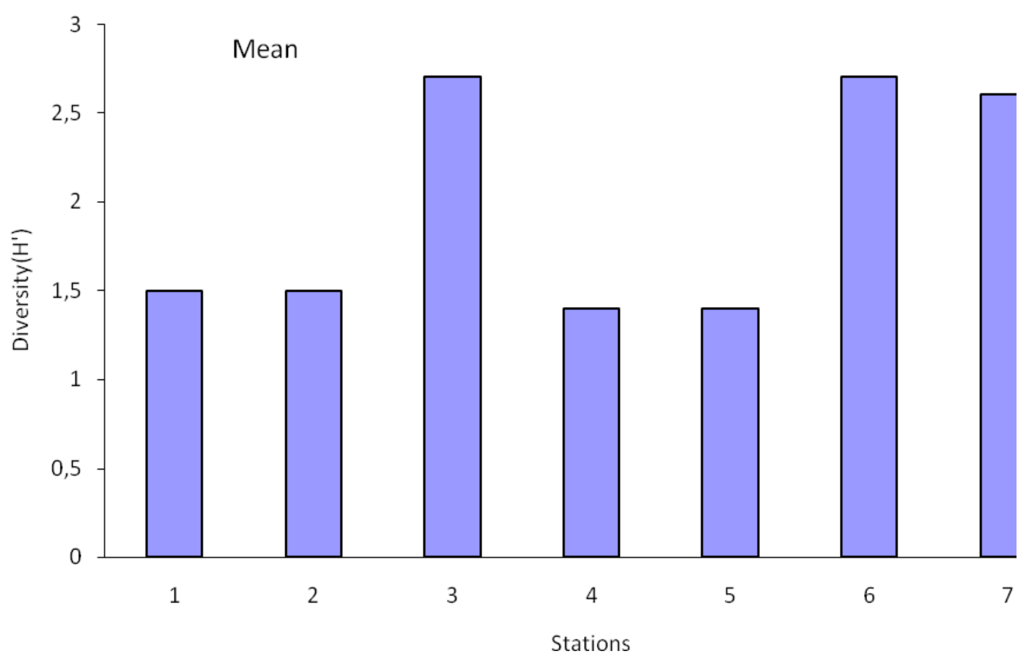


Figure 3.8 The mean values of diversity at the stations

3.5.4 Biotic Index Values

The values of biotic index were given on Table 3.l0. The lowest biotic index value is 4, it was found at the first and second stations according to the Belgian Biotic Index. So third, sixth and seventh stations have the highest biotic index value (9).

Table 3.10 Biotic index values

	1	**2**	**3**	**4**	**5**	**6**	**7**
April 05	4	2	9	9	9	8	7
May. 05	*	*	10	7	7	9	8
June 05	5	5	8	9	8	10	9
July 05	5	5	9	9	10	9	6
August 05	5	6	8	5	7	8	7
September 05	*	*	*	5	5	10	9
October 05	4	4	8	4	5	9	10
December05	2	5	9	4	9	10	10
March 06	2	5	8	9	8	7	10
September 06	*	4	10	5	5	9	7
November 06	4	3	9	4	7	10	10
January 07	5	3	9	4	9	10	10
February 07	3	3	9	7	6	7	9

* lost data

3.5.5 Similarity Values

UPGMA (Unweighted Pair Group Mean Average) which was done in order to determine the resemblance of the stations, was shown on figure 3.5. This figure shown that; third, fourth and seventh stations are in a group, especially 3rd (Dereceören) and 7th (Regulator) stations resemble to each other. Furthermore 1st (Before canalization) station and 2nd (After canalization) station resemble to each other more than others. At the same time there is a relationship between 5th station (Güneyfelakettin) and 6th station (Güvem).

Table 3.11 Similarity Coefficient of the Stations

UPGMA
Pearson Coefficient

Similarity matrix

	1	2	3	4	5	6	7
1	1						
2	0.839	1					
3	0.01	0.038	1				
4	0.118	0.188	0.192	1			
5	0.104	0.083	0.01	0.203	1		
6	-0.04	-0.001	0.568	0.29	0.674	1	
7	0.096	0.163	0.536	0.531	0.101	0.522	1

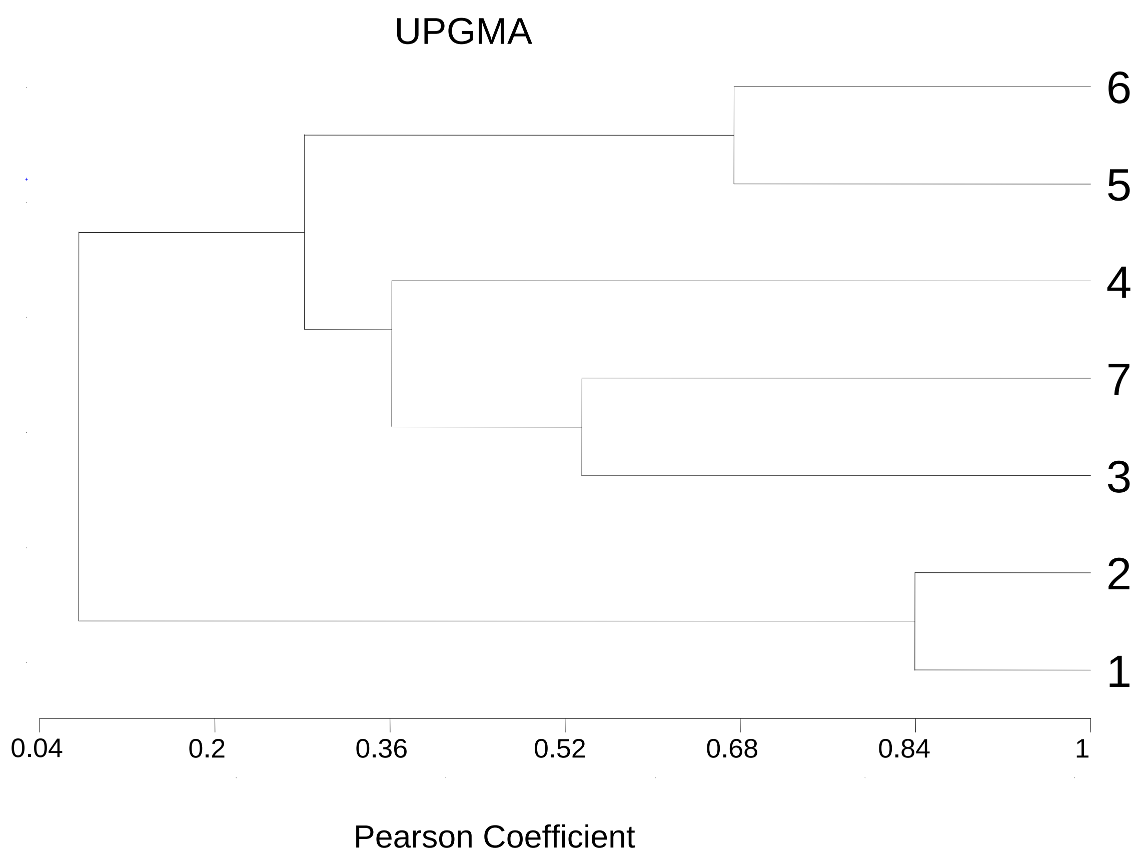


Figure 3.9 Similarity dendogram between sample points

4 DISCUSSION

Physiochemical data and species obtained with establishing of the benthic macroinvertebrate fauna showed harmony on each other. Multivariate analysis methods were used for the assessment of data in the research that was studies on the Büyüksu Stream. This study may be used as a model in the providing of the biological data for biomonitoring studies which were not applied completely in Turkey.

Before Canalization (l)

Before canalization is found at the entrance of the Lake Abant (Bolu), and it possesses the highest altitude (1338 m) among the whole stations. It is at the 5m above from sewer system of the touristy hotels which are found around Abant Lake. At the same time, the value of salinity of the station was measured 0,11 mg/l (the most lowest level).

Conductivity is defined as the changing at the concentration of the dissolved solids (Polat, l977). While the non point sources of human was causing to the high conductivity, the most lowest value of EC was obtained at Before canalization (247.65 MS/cm^{-1}), but this result cannot be expressed completely that there is a pollution or not.

In this station, *Simuliidae* sp and *Erpobdella octulata* were the dominant taxa. Depending on the dominance, *Erpobdella octulata* was collected frequently as 46%. Also *Erpobdella octulata* is resistant to organic pollution and less amount of oxygen (Hellawell, l986).

Diversity index and the number of taxa were found very low at the Before canalization. Because of low diversity a type of pollution can be shown. In addition when the $N\text{-}NO_2$ values were observed, its water quality was calculated class III.

After Canalization (2)

After Canalization, takes part rear of the first station. Samplings were verified at the sewer system of the hotels for second station. According to the $N\text{-}NO_2$ results, the water quality of it decreases until class III. In the mostly sampling periods, the smell of sewer was perceived. Sampling site of it is calm and small is that's why filamentous algae covered the area completely.

When the composition of benthic macroinvertebrate community was determined, it seen that *Erpobdella octulata* was found frequently as 54%, and also *Planorbis planorbis* was found frequently as 46%. The distribution of species of the members of Hirudinea and Mollusca were more than other stations, and this indicates the organic pollution.

Diamesa insignipes was dominant on second station (22.26%). Chironomus thummi lives generally in the area with muddy base and also in evident periods *chironomus thummi* which is an indicator of organic pollution was shown.

Faunal similarities supported that the first and second stations are related to each other. The similarity coefficient is 0.839 (Table 3.11).

Dereceören (3)

During sampling periods, the lowest water temperature (average) was measured in this station (8.23°C). Water temperature decreases gradually in winter because of snow.

There is a approximately 358 m altitude difference between Dereceören and After canalization. So the water which flows up from this altitude cleans up with aired and reaches to the Dereceören. Additionally the water current increases in the third station.

One of the important variables indicating water quality is the known as nitrogen. However, amount of oxygen is used, as well. The amounts of oxygen in streams, is very important variable for benthic macroinvertebrates.

Rhitrogena sp. which is usually found in the source of streams and clean running waters was encountered about 100% of frequency and it dominated the third station (46%).

The oxygen necessity of the *Rhitrogena* sp. is so much and it lives in currently waters (Hellawell, l986). In addition (*Isoperla* sp. was found with 62% frequency, and also *leuctra* sp was found as 46%. *Leuctra* sp. and *Isoperla* sp. belong to the family Plecoptera. They do not tolerate to the pollution, and they are used indicator of clean water. So, biological variables show that the water quality class of Dereceören is I and it has the highest diversity index (2.7.).

Yolçatı (4)

Yolçatı is the last station that was measured on Abant Stream, Yolçatı has the first class (I) water quality according to the results of physicochemical variables. However diversity index and number of taxa were found at low level less than other stations (October 2005; number of taxa 2, diversity index 0.439).

Family Baetidae (Ephemeroptera) that lives clean, cold and currently water was the dominant group as 60,39% according to the benthic macroinvertebrates composition. Additionally the member of the *Hydropsyche* sp which lives by collecting food particles was found frequently as 92%. While the stations (except Yolçatı) were similar each other, the fourth station (Yolçatı) was the most different (Figure 3.5)

Güneyfelakettin-Topardıç (5)

The fifth station is found on the Mudurnu Stream. Organic leavings that fall out from the environment affect the species composition because of shore vegetation. *Gammarus* sp (Crustacea) was the dominant as 65.14% in this station.

At the same time *Gammarus* sp was found at each sampling periods (frequency 100%), and also *Hydropsyche* sp. was found frequently as 92%. Güneyfelakettin and Yolçatı have the lowest diversity index (1.4) (Table 3.9).

Güvem (6)

Güvem and Güneyfelakettin resemble (with 67.4% of similarities) to each other according to the species composition. *Gammanus* sp was dominant taxa as 19.12%, and also *Hydropsyche* sp was collected frequently as 100%.

The values of the biotic index and diversity index were the most highest (Biotic index 9, diversity 2.7.). In addition the highest value of diversity index was similar in either Güvem or Dereceören. Moreover the number of taxa was counted of high level as 20 taxa according to the other stations (June-December 2005, 20 taxa)

Mudurnu water Regulator (7)

The seventh station is found at the regulator that gives the Mudurnuwater to Büyüksu Stream or Lake Gölköy based on season. According to the chemical variables water quality of it is class I. *Baetis* sp was dominant taxa in this station, as 14.16% and also *Hydropsyche* sp was found as 85%, *Atherix ibis* and *Baetis* sp as 77% frequently.

The diversity index of it is 2.6. This station has the highest value of the biotic index, like a third and sixth stations (Biotic index 9). The members of the family Plecoptera were seen in there, like a Dereceören. In any case, the similarity coefficient that is between Dereceören and Mudurnuwater regulator was 0.536.

The number of taxa was found at the highest value as 20 on the December 2005 and January 2007.

The sources of Büyüksu Stream are Abant Stream and Mudurnu Stream. Bolpat station is found at the place where Abant Stream and Mudurnu Stream combine to each other (near Doğancı village). On the Büyüksu Stream there are four stations; Bolpat, Bridge-8, Beypiliç and Gökçesu.

All of them possess the water quality class IV. The water quality decreases after Bolpat station according to the physicochemical and biological variables. Because the water quality has affected from pollution which comes from industrial and agricultural areas. Furthermore, the sewer system of the Bolu Municipality, that is found between Bolpat station and Bridge 8 and is carried by two canals,which affect the aquatic ecosystem negatively. The highest value of turbidity was measured at the Bolpat station as 25.08.

Tubifex sp. was found in every sampling periods frequently at each stations of Büyüksu Stream (Bolpat, Bridge 8, Beypiliç and Gökçesu). *Tubifex* sp. is known to be tolerant organic pollution at high level and less amount of oxygen. The structure of muddy basin and increasing organic particles provide the ideal environment for *Tubifex* species. So, it is used for determining organic pollution (Hellawell, l986). During the sampling periods, *Tubifex* sp.was the only animal reported

Tubifex is any of various small slender reddish freshwater worms of the genus *Tubifex*, often used as food for tropical aquarium fish. *Tubifex* arises at high level in the aquatic environments which are muddy and sewer. The most important point that is *Tubifex tubifex* is know to be a typical species of organically polluted water.

Bridge-8 is a station that has been polluted from human wastes, and also sewer system flows up from this point to the Büyüksu Stream. It includes $N\text{-}NO_2$, $N\text{-}NO_3$ and $N\text{-}NH_4$ with high level. Bridge-9 has the highest values of nitrogen among the Stations ($N\text{-}NO_2$ 0.6; $N\text{-}NO_3$ 0.12; $N\text{-}NH_4$ 2.36). The amount of dissolved oxygen was measured at the lowest level as 4.72 mg/l in the Beypiliç station. According to the percent of dissolved oxygen, Gökçesu station which is the last station has the most lowest value (42.74%).

Nitrite is not found in clean water generally. When it is found in aquatic environments continuously it indicates the industrial and human wastes because of nitrite is unstable (Girgin and Kazancı, l977). So because of nitrite (NO_2) is a toxic matter for aquatic organisms, finding it in running water is undesirable (Stevens et al, l994).

If the concentration of nitrite reaches up 0.05 mg/l and phosphate reaches up 0.65 mg/l according to the Water Pollution Regulation, it is defined as the water has become polluted.

In addition the highest mean value of *Escherichia coli* was counted in Bridge. 8 (62550 cfu in 1 ml). The average of the total coli form bacteria reached up to the highest value (l204. 480 cfu in 1 ml) at the Bolpat Station.

The source of bacteriological contamination in surface water includes municipal wastewater discharges, septic leachate, agricultural or storm runoff, wildlife populations or no point Sources of human and animal waste (An at al., 2002).

Escherichia coli is the most common member of fecal coliform bacteria, indigenous to the intestinal tract of humans or other warm-blooded animals.

The USEPA recommended that *E. coli* is a better indicator of fecal pollution than fecal coli form for purposes of evaluating ambient freshwater quality.

The presence of E. coli in freshwater indicates that the water was contaminated by fecal material of humans or other warm-blooded animals, and also indicates the potential for the presence of pathogenic organisms (An *et.al*, 2002).

Indiscriminate usage for tourism and agriculture, random urbanization, nonpoint polluted sources from human and industrial waste are the primary problems that threat the water and the living organisms in these ecosystems at our country. Consequently; ecological and biological characteristics and other factors treating water quality of Büyüksu should be determined. Besides, precautions and suggestions should be thought to protect and take care of this important ecosystem, Büyüksu. Both, physicochemical results obtained during this study and information related to living organism composition is considered for these precautions and suggestions.

Especially results of analyses suggest that the reason for the presence of pollution in the rivers and environmental waters which from time to time threatens human life is the waste water discharged from chicken farms.

Consequently, Büyüksu has a serious pollution problem because of the, nonpoint polluted sources from human, agricultural and industrial waste. If we consider both, water standard and dispersion of the living organism in the water, we can say, excess pollution is a big problem for Büyüksu. Based on finding of almost complete lack of aquatic organisms, especially at the 8. 9. 10. and 11. stations, points out the seriousness of the problem.

There is still no effective solution against the pollution resulting from increased population and developing industry in Bolu. From Bolu and its surroundings, nonpoint polluted sources from human, industrial and agricultural waste are directly discharge to the Filyos (Yenice) river and branch of the stream without any refining. All the waste from the city goes to the Black Sea.

All related establishments should realize the freshwater sources at Bolu and should take measures for protection of these sources.

5 REFERENCES

An, N. J., Kampbellb, D. H., Breidenbachc, G. P. 2002. Escherichia coli and Total Coliforms in Water and Sediments at Lake Marinas. *Environmental Pollution*. 120: 771-778.

APHA, 1989. Standard Methods for the Examination of Water and Waste water. L. S. Cleseri, A. E. Greenberg and R. R. Trussel (eds.), *American Public Health Association*, NY. p. 1268.

Armitage, P., Cranston, P. S. and Pinder, L. C. V. 1995. The Chironomidae. The Biology and Ecology of Non-Biting Midges. Chapman and Hall, London, p. 572.

Başbakanlık Çevre Müsteşarlığı, 1988. Su Kirliliği Kontrol Yönetmeliği. Ankara.

Bellmann, H. 1988. Leben in Bach und Teich. Pflanzen und Wirbellose der Kleingewässer. Steinbach Naturführer. p. 287.

Biro, K. 1981. Kleiner Bestimmungsschlüssel für Zuckmückenlarven (Diptera: Chironomidae). Wien. p. 329.

Bode, R. W. and Simpson, K. W. 1982. Communities of Chironomidae in Large Lotic Systems: impacted vs. unimpacted. Abstract, North American Benthological Society, 13^{th} Annual Meeting.

Brinkhurst, R. O., Jamieson B. G. M. 1971. Aquatic Oligochaeta of the World. Edinburg. p. 860.

Buikema, A. L., Niederlehner, B. R., Cairns, J. Jr., 1980. Use of grass shrimp in toxicity tests. *American Society for Testing and Materials*. 155-173.

Burden, F. R. Mckelvie, I., Förnstner, U. and Guenther, A., 2002. Environmental monitoring handbook. Mcgraw-Hill. p. 5. 1-5. 16.

Chernovskii, A., 1961. Identification of Larvae Of Midge Family Tendipedidae Fauna USSR. Trans. from Russian by Natl. Lending Library for Sci. Tech. Boston. 31: 1-186.

Chutter, F. M., 1972. An empirical biotic index of the quality of water in South African streams and rivers. *Water Research*. 6: 19-30.

Crunkilton, R. L., Duchrow, R. M., 1991. Use of stream order and biological indices to asses water quality in the Osage and Black river basins of Missouri. *Hydrobiologia*. 224: 155-166.

Coffman, W. P., 1973. Energy Flow in a Woodland Stream Ecosytem: 11. The Taxonomic Composition and Phenology of the Chironomidae as Determined by the Collection of Pupal Exuviae. Arch. Hidrobiologia. 71: 281-322.

Cummins, K. W., 1975. The Ecology of Running Waters, Theory and Practice. In: project Sandusky River Basin Symposium, International Joint Commision. p. 277-294.

Cummins, K. W., 1977. From head water streams to rivers. *American Biology Teacher*. p. 305-312.

De Pauw, N., Vanhooren, G., 1983. Method for biological quality assessment of watercourses in Belgium. *Hydrobiologia*. 100: 153-168.

DIN 38405-11, Publication date: 1979-05 German standard methods for examination of water, waste water and sludge; anions (group D), determination of orthophosphate ion (D11)

DIN 38406-5, Publication date: 1983-10 German standard methods for the examination of water, wastewater and sludge; cations (group E); determination of ammonia-nitrogen (E 5)

DIN 38405-9, Publication date: 1979-05 German standard methods for examination of water, wastewater and sludge; anions (group D), determination of nitrate ion (D9)

DIN 38405-10, Publication date: 1979-05 German standard methods for examination of water, wastewater and sludge; anions (group D), determination of nitrite ion (D10)

DSİ, 1988. Su Kalitesi Gözlem Yıllığı. İçme Suyu ve Kanalizasyon Dairesi Başkanlığı. p. 510.

Duffor, A. P., 1977. Escherichia coli: the fecal coliform. In: Hoadley, A. W., Dutka, B. J. (Eds), Bacterial Indicators/Health Hazards Associated With Water. ASTM. Philadelphia. p. 48-58.

Dügel, M., 1994. Determination of Water Quality of Running Waters Inflowing to Köyceğiz Lake Based on Physicochemical and Biological Parameters. MSc Thesis. Department of Biology, Hacettepe University, Bolu.

Eberhardt, L. L., 1969. Some aspects of species diversity models. *Ecology*. 50 (3): 503-505.

Edington, J. M., Hildrew A. G., 1981. Caseless Caddis larvae of the British Isles. *Freshwater Biological Association Scientific Publication*. No: 43, p. 92.

Elliot, J. M., Mann K. H., 1979. *A* key to British Freshwater Leeches. *Freshwater Biological Association Scientific Publication* No: 40, p. 72.

Elliot, J. M., Mann K. H., 1993. Some Methods for the Statistical Analysis of Samples of Benthic Invertebrates. *Freshwater Biological Association Scientific Publication*. No: 25, p. 156.

Epler, J. H., 1995. Identification Manual for the Larval Chironomidae (Diptera) of Florida. State of Florida Department of Environmental Protection Division of Water Facilities, Tallahassee. p. 110.

Franke, U., 1979. Bildbestimmungsschlüssel mitteleurapischer libellen larven (Insecta: Odonata) Pictorial key for the Nymphs of Central Europe. Stuttgarter Beitr. Naturk. 333: 1-17.

Fremling, C. R., 1964. Mayfly distribution indicates water quality on the upper Mississippi River. *Science*. 46: 1164-1166.

Friberg, F., Nilsson, L. M., Otto, C., Sjostrom, P., Svensson, B. W. Svensson, B. J. Ulfstrand, S. 1977. Diversity and Environments of Benthic Invertebrate Communities in South Sweden Streams. Arc. *Hidrobiologia*. 81: 129-154.

Gaufin, A. R., Tarzwell, C. M., 1956. Aquatic macro-invertebrate communities as indicators of organic pollution in Lytle Creek. *Sewage and Industrial Wastes*. 28 (7): 906-924.

Gidirişlioğlu, A., Çakır, R., Tok, H. H., Ekinci, H., Yüksel, O. 1998. Ergene Nehri ve Kollarının Evsel ve Endüstriyel Atıklarla Kirlenmesi ve Toprak Üzerine Etkileri. *Köy Hizmetleri Kırklareli Araştırma Enstitüsü Müdürlüğü*, Kırklareli, p. 308-321.

Gledhill, D., Sutaliffe, W., Williams W. D., 1976. A revised key to British species of Crustacea: Malacostraca occuring in Freshwater. *Freshwater Biological Association Scientific Publication* No: 32, p. 71.

Glöer, P., Meier Brook, C., Ostermann O., 1992. Süsswasser mollusken: *Ein Bestimmung-sschlüssel für die Bundesrepublic Deutchland*. Hamburg. p. 111.

Godfrey, P. J., 1978. Diversity as a measure of benthic macroinvertebrate community response to water pollution. *Hydrobiologia*. 57 (2): 111-122.

Hamilton, A. L. and Saether, O. A. 1971. The occurrence of characteristic deformities in the chironomid larvae of seveeral Canadian Lakes. *Can. Entomol*. 103: 363 - 368.

Heister, R. D. Jr., 1972. The biotic index as a measure of organic pollution in streams, *The American Biology Teacher*, p. 79-83.

Hellawell, J. M., 1986. Biological Indicators of Freshwater Pollution and Environmental Management. *Elsevier Publishers*, London. p. 546.

Hynes, H. B. N., 1960. The Biology of Polluted Waters. Univ. Toronto Press, Toronto. p. 202.

Illies, J., 1978. Limnofauna Europea. *Gustav Fisher Verlag*. p. 532.

Kaesler, R. L., Cairns J. Jr., Bates, J. M., 1971. Cluster analysis of non-insect macroinvertebrates of the upper Potomac River. *Hydrobiologia*. 37 (2): 173-181.

Kara, C., Çömlekçioğlu, U., 2004. Investigation of Karaçay's (Kahramanmaraş) Pollution with Biological and Physicochemical Parameters. *K. S. Journal of Science and Engineering* 7 (1).

Kazancı, N. 2001. Ephemeroptera Fauna (Insecta) of Gümüşhane, Erzurum, Erzincan, Artvin, Kars Provinces. Imaj Press, Ankara, p.80.

Kazancı, N. *et al*. 1997. Inland Waters of Turkey Series II (eds. N. Kazancı). Biotic index methods for evaluating environmental quality of runningwaters. Imaj Press p. 100.

Kazancı, N., D. Oğuzkurt., Dügel, M., 2003. Inland waters of Turkey Series VII (eds. N. Kazancı): Limnology, Environmental quality and conservation of biodiversity of largest freshwater lake of Turkey, Beyşehir Lake. Ankara. Imaj Press, p. 148.

Kırgız, T. ve Soylu, E., 1975. Apolyont ve Manyas Göllerinde Su Ürünleri Prodüksiyonunu Etkileyen Dip Fauna Elementlerinin Yıllık Görünüm ve Yayılışları. *Tubitak V. Bilim Kong. Tebl.,* Ankara, p. 387-393.

Kırgız, T., 1988. Seyhan Baraj Gölü Chironomidae (Diptera) Larvaları Üzerinde Morfolojik ve Ekolojik Bir Çalışma. *Doğa T. U Zool. Derg.,* 12 (3): 245 – 255.

Krebs, C. J., 1999. Ecological Methodology, Benjamin Cummins, p. 620.

Kubilay, A. ve Timur, G., 1992. Eğridir Gölü Köprü Avlağı Chironomidae Larvaları ve Bu Larvaların Mevsimsel ve Zonlara Göre Dağılımı Üzerine Bir Araştırma. *XI. Ulusal Biyoloji Kongresi,* Elazığ, p. 155-165.

Külköylüoğlü, O., Kılıç, M., Dügel, M., and Usta, E., 2003. Seasonal Water Quality Changes and Osracoda (Crustacea) Distribution in Lake Abant (Bolu, Turkey). TUBİTAK, YDABAG-101Y030 project.

Külköylüoğlu, O., 2006. Çevre ve Çevre:İnsan-Doğa İlişkisi. AİBÜ Printinhouse Adminisitration, Bolu. p. 276.

Lenat, D. R., 1983. Chironomid Taxa Richness: Natural Variation and Use in Pollution Assessment. *Fresh Invertebrate Biology*. 2, 4: 192-198.

Ludwig, H. W., 1993. Tiere in Bach, Fluss, Tümpel, See, Merkmale, biologie, Lebensraum Gefährdung BLV Bestimmungsbuch p. 255.

Macan T. T., 1976. A key to British Water Bugs. (Hemiptera, Heteroptera*). Freshwater Biological Association Scientific Publication* No: 16, p. 77.

Macan, T. T., 1973. A key to the adults of the British Trichoptera Freshwater. *Biological Association Scientific Publication* No: 28, p. 151.

Macan, T. T., 1982. A guide to Freshwater Invertebrate Animals. *Longman*. p. 118.

MacArthur, R. H., 1965. Patterns of species diversity. *Biological Reviews*. 40: 510-533.

Mann, K. H., 1962. Leeches (Hirudinea) Their Structure, Physiology, Ecology and Embryology. Pergamon Press. p. 201.

Mason, W. T., JR. 1975. Chironomidae as Biological Indicators of Water Quality. In: Organisms and Biological Communities as Indicators of Environmental Quality. Ohio State University. p. 40-51.

Mason, C. F., 1998. Biology of Freshwater Pollution. Longman, p. 356.

Matthews, G. B., Matthews, R. A., Hachmöller, B., 1991, Mathematical analysis of temporal and spatial trends in the benthic macroinvertebrate communities of a small stream, *Canadian Journal of Fish Aquatic Science*, 48, 2184-2190.

McIntosh, R. P., 1967. An index of diversity and the relation of certain concepts to diversity. *Ecology*. 48 (3): 392-404.

Metcalfe, J. L., 1989. Biological water quality assessment of running waters based on macroinvertebrate communities: History and present status in Europe, *Environmental Pollution*. 60: 101-139.

Needham, J. G., Needham P. R., 1962. A guide to the study of Freshwater Biology. San Francisco. p. 107.

Özdemir, Y. ve Şen, D., 1991. Keban Baraj Gölü Ova Bölgesinde Bulunan *Procladius (Holotaypus) sp.* ve *Chironomus halophilus* Larvalarının mevsimsel dağılımları. *Ege Üniv. Su Ürün. Derg***.** Ege Üniv. Press, Bornova-İzmir. 8 (29-30): 60-65.

Özesmi, U., 1988. Sultan Sazlığı'nın Sucul heteroptera ve Coleoptera türleri üzerinde bir faunistik araştırma. TÜBİTAK BAYG-Proje yarışması Araştırma Raporu.

Özkan, N., 2006. The larval Chironomidae (Diptera) Fauna of Bozcaada (Tenedos). *G. U. Journal of Science*. 19 (1): 57-67.

Peet, R. K., 1975. Relative diversity indices. *Ecology*. 56: 496-498.

Pennak, R. W., 1978. Freshwater Invertebrates of the United States. *John Wiley and Sons Publication*. p. 803.

Pielou, E. C., 1966. The measurement of diversity in different types of biological collections, *Journal of Theoretical Biology*, 13: 131-144.

Pitsch T., 1993. Zur larval taxonomie, Faunistik und Ökologie mitteleuropäischer Fliesswasser-Köcherfliegen (Insecta, Trichoptera). Berlin. p. 316.

Polat, M., 1997. Akarsu ve Göllerde İzlenen Fiziksel ve Kimyasal Parametreler. Su Kalitesi Yönetimi Semineri Bildiri Kitabı, Ankara, p. 45-57.

Quigley. M., 1977. Invertebrates of Streams and Rivers. A key to Identification. London. p. 874.

Reed, C., 1978. Species diversity in aquatic microecosystems. *Ecology*. 59 (3): 481-488.

Reice, S. R. Wohlenberg, M., 1993. Monitoring Freshwater Benthic Macroinvertebrates and Benthic Processes: Measures for Assessmenti of Ecosystem Health, In: *Freshwater Biomonitoring and Benthic Macroinvertebrates,* Eds. Rosenberg D. M. And Resh, V. H. p. 287-305.

Resh, H. V. and Unzicker, J. D., 1975. Water Quality Monitoring and Aquatic Organisms: The Importance of Species Idendification. *Journal of W. P. C. F*. 47 (1): 1-19.

Rosenberg, D. M., Resh, V. H, 1992. Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman and Hall. New York, p. 488.

Rossaro, B., Marziali, L., Cardoso, A. C., Solimini, A., Free, G., Giacchini, R., 2007. *A Biotic Index Using Benthic Macroinvertebrates for Italian Lakes*. *Ecological Indicators*. 7: 412-429.

Sager, P. E., Hasler, A. D., 1969. Species diversity in lacustrine phytoplankton I: The components of the index of diversity from Shannon’s formula, *The American Naturalist*, 103 (929): 51-59.

Sampat, P., 2001. Pollution in Underground Water. L. R. Brown, C. Flavin, H. French (eds.) Worldwatch Institude Report.

Saraçoğlu, H., 1990. Bitki örtüsü akarsular ve göller. öğretmen kitapları dizisi. MEB. Press. 130-131: 404_405.

Sennika, S. A. B., 1943. Contributions to the Ecology and Biology of the Danish Freshwater Leeches (Hirudirea). Københaum Denmark. p. 109.

Shannon, C. E., 1948. A mathematical theory of communication. *The Bell System Technical Journal*. 27 (3): 379-423, 623-656.

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

Sladecek, V., 1973. The reality of three British biotic indices. *Water Research*. 7: 995-1002.

Stumm, W., Morgan, J. J., 1996. Aquatic Chemisitry: Chemical Equilibria and Rates in Natural Waters. Wiley Inter Science, USA. p. 1022.

Şahin, Y., 1984. Doğu ve Güneydoğu Anadolu Bölgeleri Akarsu ve Göllerindeki Chironomidae (Diptera) Larvalarının Teşhisi ve Dağılışları. Anadolu. Üniv. Yay. No: 57, Fen-Ed. Fak. Yay. No: 2, Eskişehir. p. 145.

Şahin, Y., 1991. Türkiye Chironomidae Potamofaunası. TÜBİTAK Proje No: TBAG-869. Ankara. p. 88.

Şen, D., ve Özdemir, Y., 1990. Haringet Çayı Chironomidae (Diptera) Larvalarının Mevsimsel Dağılımları. *Ege Üniv. Su Ürün. Derg.*, Ege Üniv. Basımevi, Bornova-İzmir. 7: (25-26-27-28)60-64.

Tanatmış, M., 2004. *The Ephemeroptera (Insecta) Fauna of the Filyos (Yenice) River Basin*. Turk. J. Zool., 28 (3): 229_240.

Tchobanoglous, G., E. D., Schroeder, 1985. Water Quality, Mass. Addison-Wesley, p. 768.

Thienemann, A., Zaurel, J., 1916. Die Metamorphose der Tanypinen, Arch. *Hidrobiol., Suppl.* 2: 566-654.

Thienemann, A., 1954. Chironomus, Binnengewaesser. 20: 1-834.

USEPA, 1986. Ambient water quality criteria for bacteria_. EPA440-584_002. US EPA, Washington, DC.

Ustaoğlu, M. R., Balık, S. and Taşdemir, 2005. Chironomidae Fauna (Diptera-Insecta) of Gümüldür Stream (İzmir). *Turkish Journal of Zoology*. 29: 269-274.

Wetzel, R. G., Likens, G. E., 1990. Limnological Analysis. Springer-Verlag, NewYork. p. 391.

Wetzel, R. G., 1975. Limnology, *W. B. Saunders Company Philadelphia***,** London-Toronto, p. 743.

Williams, D. D, and Feltmate, B. W., 1992. Aquatic insects. CAB International. ISBN: 0-85198-782-6. xiii, p. 558.

Wilhm, J. L., Dorris, T. C., 1968. Biological parameters for water quality criteria. *Bioscience*. 18 (6): 477-481.

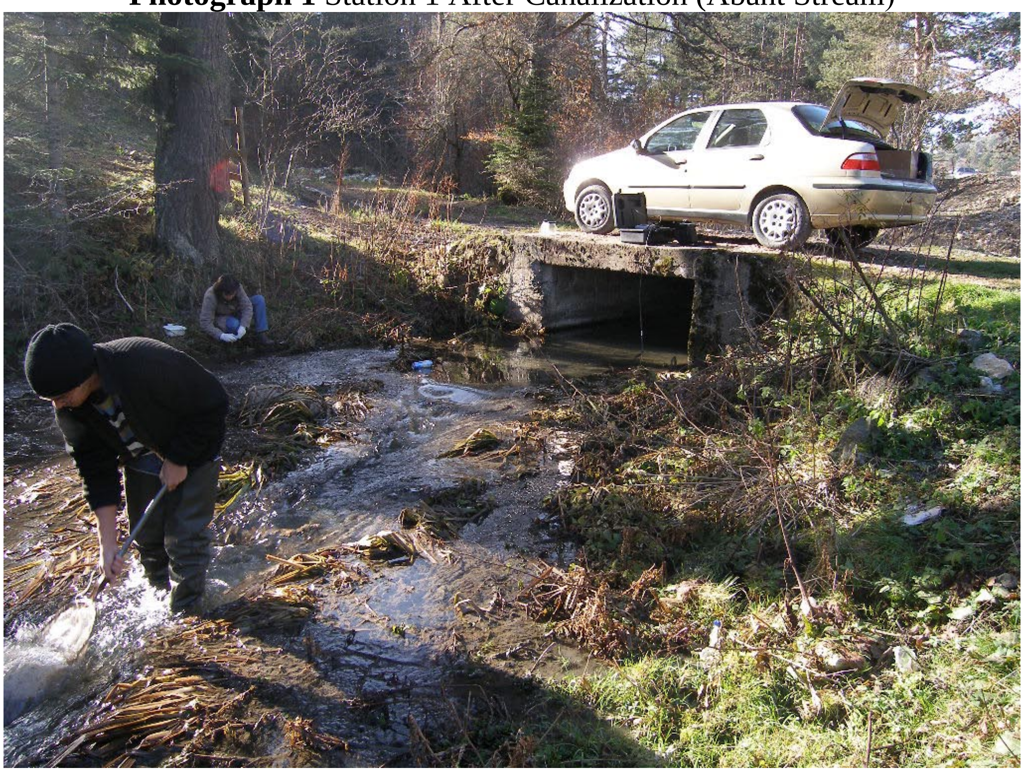
Winner, R. W., Boesel, M. W. and Farrell, M. P., 1980. Insect Community Structure as Index Of Heavy metal Pollution in Lotic Ecosystems. *Can. J. Fish. Aquat. Sci*. 37: 647-655.

Yıldırım, M., Şen, E., (2004). Water quality of Büyüksu (Bolu) Stream. MSc Thesis. Department of Chemistry, Abant İzzet Baysal University Press, Bolu.

Ziglio, G., Siligardi, M., Flaim, G., 2006. Biological Monitoring of Rivers: Applications and Perspectives. *Jhon Wiley and Sons*. p. 469.

6 PHOTOGRAPHS

Photograph 1 Station 1 After Canalization (Abant Stream)



Photograph 2 Station 2 Before Canalization (Abant Stream)

Photograph 3 Station 3 Dereceören (Abant Stream)

Photograph 4 Station 4 Yolçatı (Abant Stream)

Photograph 5 Station 5 Topardıç (Mudurnu Water)

Photograph 6 Station 6 Güvem (Mudurnu Water)

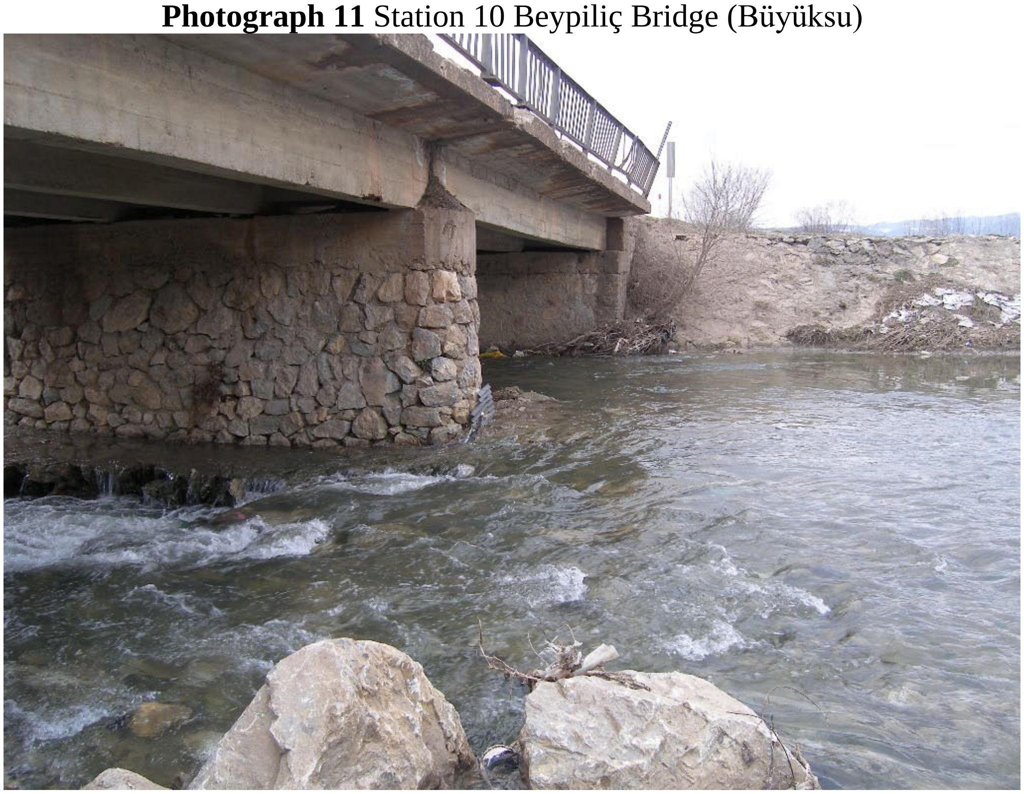
Photograph 7 Station 7 Regulator (Mudurnu Water)

Photograph 8 Mixing area of Mudurnu water ve Abant Stream.

Photograph 9 Station 8 Bolpat Bridge (Büyüksu)

Photograph 10 Station 9 Bridge 8 (Büyüksu)

Photograph 11 Station 10 Beypiliç Bridge (Büyüksu)



Photograph 12 Station 11 Çatakören (Büyüksu)