

# Community Structure of Macroenthos of a Southeast Texas Sand-Pit Lake Related to Water Temperature, pH and Dissolved Oxygen Concentration

Kemal ÇELİK

Department of Biology, Balıkesir University, 10100 Balıkesir - TURKEY

Received: 04.02.2002

**Abstract:** Water temperature (°C), pH, dissolved oxygen concentration (mg/l) and the community structure of the macroenthos of a small southeast Texas sand-pit (Barry's) lake were studied from June 1995 to February 1996, which covered climatic extremes.

The lake was a warm monomictic lake and no anoxic conditions were observed at any depth during the entire study period.

A total of 50 taxa and 5614 individuals of macroenthos were collected. The dominant organisms were *Chaoborus punctipennis* (Say), *Limnodrilus hoffmeisteri* (Claparede), and *Dero obtusa* (Udekem). The only established populations at 6.5 m were *Chaoborus punctipennis*, *Limnodrilus hoffmeisteri*, and *Chironomus* sp.

Species diversity ranged from 0.9 to 3.9 and generally decreased with depth. The number of individuals increased with depth, while the species and species diversity decreased with depth.

**Key Words:** macroenthos, sand-pit lake, temperature, dissolved oxygen and community structure.

## Güneydoğu Teksastaki Bir Kum Yatağı Gölünün Su Sıcaklığı, pH, Çözünmüş Oksijen ve Makroentoz Komünite Yapısı

**Özet:** Güneydoğu Teksastaki küçük bir kum yatağı (Barry) gölünün su sıcaklığı (°C), pH, çözünmüş oksijen konsantrasyonu (mg/l) ve makroentoz komünite yapısındaki değişiklikler iklimsel değişkenleri kapsayacak şekilde Haziran 1995 ten Şubat 1996 ya kadar çalışılmıştır.

Göl sıcak, monomiktik olup çalışma esnasında herhangi bir derinlikte oksijensiz bir duruma rastlanılmamıştır.

Toplam olarak 50 taksona ait 5614 birey toplanmıştır. Dominant organizmaları *Chaoborus punctipennis* (Say), *Limnodrilus hoffmeisteri* (Claparede), ve *Dero obtusa* (Udekem) türleri oluşturmaktadır. 6.5 metrede sadece *Chaoborus punctipennis* ve *Limnodrilus hoffmeisteri* ve *Chironomus* sp. popülasyonları tespit edilmiştir.

Tür çeşitliliği indeksi 0.9 dan 3.9'a kadar değişmiş olup ve derinliğe bağlı olarak azalmıştır. Tür çeşitliliği derinlikle ters orantılı olarak azalırken birey sayısı doğru orantılı olarak artmıştır.

**Anahtar Sözcükler:** Makroentoz, kum ocağı gölü, sıcaklık, çözünmüş oksijen ve komünite yapısı.

## Introduction

Sand-pit lakes are artificial basins resulting from excavations extending below the water table. These types of lakes are very briefly mentioned as "type 74" in Hutchinson's classic work on lake origins (1).

The number of artificial aquatic ecosystems, especially sand-pit lakes, have been increasing rapidly due to increasing needs for building materials (2). Many of these

lakes are created around towns, and thus require planning to integrate them into the urban environment for aesthetics, recreation and flood control, and for commercially raising fish.

Sand-pit lakes are common in the flood plains of large rivers and streams of southeast Texas including the Trinity River, Neches River, and Sabine River. However, no published studies on these lakes in this county are

known by this investigator. Thus, this study will provide base-line data necessary for effective management of these lakes.

The distribution patterns and abundance of macrobenthos populations have been used to monitor water quality, the effects of water treatment, and general ecosystem function (3-5). The U.S. Environmental Protection Agency encourages the use of macrobenthic communities as an indication of water quality (6).

Physicochemical conditions represent water quality at the time of sampling, while macrobenthic community structure reflects both present and past environmental conditions (5). Macrobenthos also offer many advantages in water quality surveys because (a) they inhabit all kinds of waters and are affected by many environmental disturbances, (b) they are basically sedentary and unable to avoid environmental disturbances, (c) they have long life cycles compared to other groups, which provides interpretation of temporal changes, (d) the responses to different environmental conditions by different species are known, (e) they are in the middle of the aquatic food web, and thus reflect the productivity of trophic levels below and above, and (f) the taxonomy of many of their groups is well known and keys to identification are available (5,7-9).

Shannon's species diversity index (10) is commonly used for the analysis of community structure (11). This index is dimensionless, is relatively independent of sample size, and considers the evenness of taxa distribution (5).

The objectives of this study were to determine the water temperature, pH, dissolved oxygen concentration and community structure of macrobenthos in a small southeast Texas sand-pit lake for future use in

management. These types of data are necessary for determining the appropriate time and extent of lake treatment for desired water quality and lake productivity.

## Materials and Methods

Barry's Sand-Pit Lake is located in the floodplain basin of Village Creek, approximately 16 km north of Beaumont, Texas, at latitude  $30^{\circ} 17'$  and longitude  $94^{\circ} 10'$  in Hardin County (Figure 1).

The surface area of the lake is about 1.075 ha. The length of the lake is approximately 250 m and the average width is about 43 m. The depth is fairly uniform, with an average depth of 6.5 m and maximum depth of 7 m. The source of water for Barry's Sand-Pit Lake is infiltration from the water table and local flooding.

Barry's Lake was formed by the excavation of sand approximately 300 m north of Village Creek. The bottom sediments in the lake were coarse sand, with some organic detritus along the margins and fine silt in the profundal zone.

Water temperature, pH, and dissolved oxygen concentration were measured at two sites, one at each end of the lake at meter depth intervals using an H2O Hydrolab Probe.

Macrobenthos were collected once every two months using a 15.3 x 15.3 cm Ponar Grab from three depths. During each collection eight grabs were taken at about 0.5 m, 2.0 m, and 6.5 m depths. The benthic samples were washed in the field with a No. 30 U.S. Soil Sieve in a wash bucket, placed in glass jars, and preserved with formalin containing Rose Bengal stain. In the laboratory the samples were washed using a No. 30 U.S. Standard

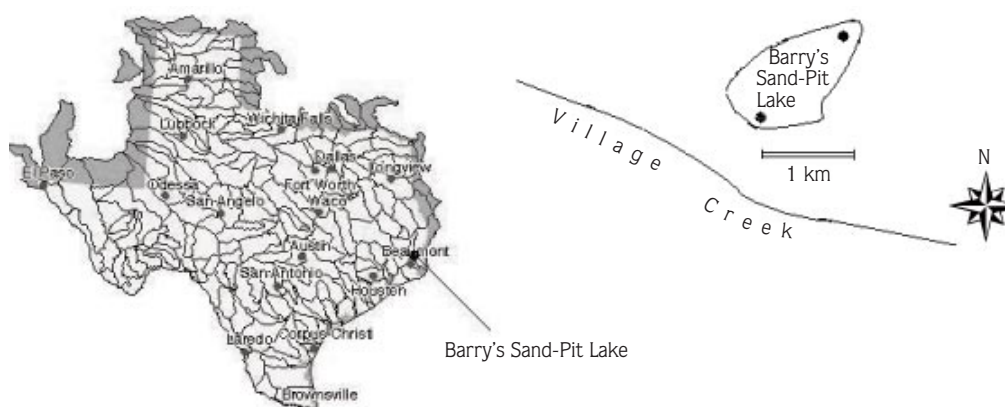


Figure 1. The Location of Barry's Sand-Pit Lake

Soil Sieve; the organisms were removed, and stored in vials containing 70 percent ethyl alcohol. CMC-10 mounting media microscope slides were made of oligochaetes and chironomids for identification.

The community structure of the macrobenthos was determined by analyses of the numbers of species, numbers of individuals, known tolerances of individual species (6), and Shannon's diversity index (10). Shannon's diversity index was calculated by the formula:

$$d = -\sum(n_i/N) \log_2(n_i/N)$$

where  $d$  is species diversity in bits,  $n_i$  is the total number of individuals of species  $i$ , and  $N$  is the total number of individuals of all species in the sample.

Correlation coefficients between species diversity and numbers of individuals, numbers of species, and dissolved oxygen concentrations were tested using the Pearson Correlation Coefficient statistical test. The differences in numbers of individuals, numbers of species, and Shannon's diversity values between the months were tested using the non-parametric Kruskal-Wallis ANOVA test (12).

## Results

Surface temperature increased from 30 °C in June to 32 °C in August 1995 and then gradually decreased to 12 °C in February 1996. Dissolved oxygen concentration decreased from 10 mg/l in June 1995 to 6 mg/l in August 1995 and then gradually increased to 11 mg/l in February 1996. Surface pH did not change much throughout the study period, staying at around 6. Species diversity decreased from 3.9 in June to 2.6 in August, then increased to 3.6 October 1995 and then gradually decreased to 2.6 in February 1996 (Figure 2).

At 2 m the temperature increased from 28 °C in June to 31 °C in August 1995 and then decreased to 11 °C in February 1996. Dissolved oxygen concentrations stayed at around 9 mg/l from June to October 1995 then gradually increased to 11 mg/l in February 1996. pH stayed at around 6.5 throughout the study period. Species diversity decreased from 3 in June to 0.9 in August 1995 and then gradually increased to 3.2 in February 1996 (Figure 3).

At 6.5 m the temperature increased from 15 °C in June to 17 °C in October 1995 and then gradually decreased to 9 °C in February 1996. Dissolved oxygen

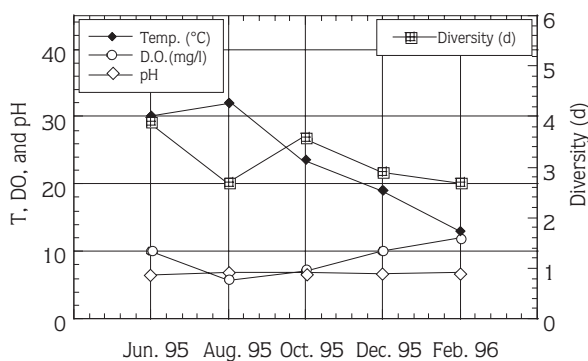


Figure 2. Variations in Temperature (°C), Dissolved Oxygen (mg/l), pH, and Species Diversity (d) at 0.5 m from June 1995 to February 1996 in a Small Southeast Texas Sand-Pit (Barry's) Lake

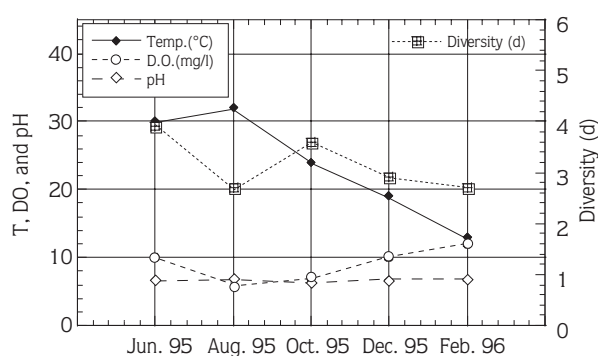


Figure 3. Variations in Temperature (°C), Dissolved Oxygen (mg/l), pH, and Species Diversity (d) at 2 m from June 1995 to February 1996 in a Small Southeast Texas Sand-Pit (Barry's) Lake

concentrations stayed at 0.5 mg/l from June to October 1995 and then gradually increased to 8.5 mg/l in February 1996. pH stayed at around 6 throughout the study period. Bottom diversity oscillated between 1.1 and 0.9 during the whole study period (Figure 4).

The total number of individuals decreased from 1170 individuals/l in August to 460 individuals/l in October, then increased to 1742 individuals/l in December 1995 and then dropped back to 1316 individuals/l in February 1996 (Figure 5). Total number of taxa fluctuated between 30 and 20 taxa/l throughout the study period (Figure 5).

A total of 5613 individuals in 50 taxa were collected during the study period. The major taxonomic groups included dipterans (58.43%), tubificid oligochaetes (30%), naidid oligochaetes (5.93%), chironomids (4.25%), crustaceans (3%), and trichopteran (1.88%) (Table).

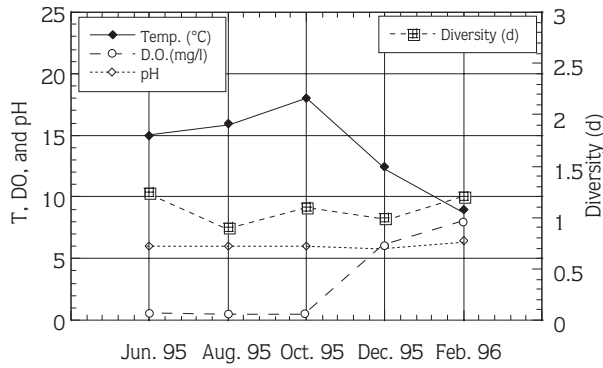


Figure 4. Variations in Temperature (°C), Dissolved Oxygen (mg/l), pH, and Species Diversity (d) at 6.5 m from June 1995 to February 1996 in a Small Southeast Texas Sand-Pit (Barry's) Lake

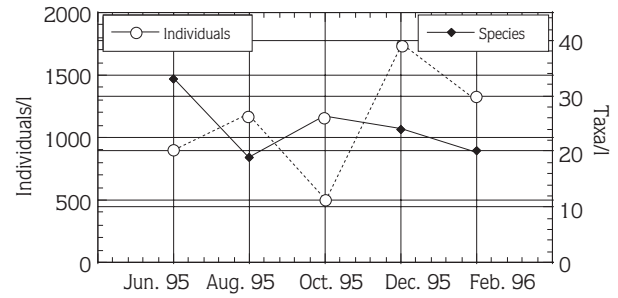


Figure 5. Variations in the Total Number of Species and Total Number of Individuals from June 1995 to February 1996 in a Small Southeast Texas Sand-Pit (Barry's) Lake

Table. List of Benthic Macroinvertebrates Collected between June 1995 and February 1996 from a Small Southeast Texas Sand-Pit (Barry's) Lake

Taxa	Jun. 1995	Aug. 1995	Oct. 1995	Dec. 1995	Feb. 1996
Cnidaria					
Hydrozoa					
Hydridae					
<i>Hydra</i> sp.			2		
Annelida					
Oligochaeta					
Naididae					
<i>Dero</i> sp.		3			
<i>Dero obtusa</i> (Undekem)	4	71	33	96	31
<i>Dero digitata</i> (Muller)		1			
<i>Stylaria fossularis</i> (Leidy)			15	4	31
<i>Pristina</i> sp.	1		1		
<i>Pristina foreli</i> (Bourne)	1				
<i>Pristina longidentata</i> (Ehrenberg)	3	2	1	4	2
<i>Pristina breviseta</i> (Bourne)	2	10	1		
<i>Pristinella jenkinsae</i> (Stephenson)	3				
<i>Haemonais waldvogeli</i> (Bretscher)	6			1	
<i>Salvina appendiculata</i> (d'Undekem)			2		
<i>Bratislavia unidentata</i> (Harman)	1	2			2
Tubificidae					
<i>Limnodrilus hoffmeisteri</i> (Claparede)	351	216	323	256	530
<i>Aulodrilus pigueti</i> (Kowaleski)	10		5		
Hirudinea					
Glossiphoniidae					
<i>Helobdella</i> sp.	24	5	12	1	3
Arthropoda					
Crustacea					
Mysidacea					
<i>Mysis</i> sp.	1				
Amphipoda					
Hyalellidae					
<i>Hyalella azteca</i> (Saussure)	6	4	9	48	15
Decapoda					
Cambaridae					
<i>Cambarellus puer</i> (Hobbs)	2	2			
Insecta					
Collembola					
Poduridae					

Table. (Continued)

Taxa	Jun. 1995	Aug. 1995	Oct. 1995	Dec. 1995	Feb. 1996
<i>Podura</i> sp.			3	4	
Ephemeroptera					
Ephemerellidae					
<i>Ephemerella</i> sp.	1				
<i>Hexagenia limbata</i> (Serville)				1	
Caenidae					
<i>Caenis</i> sp.	2		1	4	2
Heptogeniidae					
<i>Stenonema</i> sp.	2		1	2	2
Odonata					
Libellulidae					
<i>Libellula axilena</i> (Westwood)				4	
<i>Libellula</i> sp.	1		1		
Gomphidae					
<i>Progomphus</i> sp.			1	3	
<i>Dromogomphus</i> sp.		2			
Trichoptera					
Leptoceridae					
<i>Oecetis</i> sp.	1			1	
Polycentropodidae					
<i>Polycentropus</i> sp.	5	4	2	45	43
<i>Cynnellus</i> sp.	1				
<i>Neureclipsis</i> sp.			1	3	
Coleoptera					
Elmidae					
<i>Macronychus</i> sp.	1				
<i>Dubiraphia</i> sp.	1		1	4	
Hydrophilidae					
<i>Berosus</i> sp.			1	1	
Haliplidae					
<i>Haliphus</i> sp.				5	
Dytiscidae					
<i>Hydroporus</i> sp.					4
Diptera					
Tipulidae					
<i>Holorusia</i> sp.					1
Chaoboridae					
<i>Chaoborus punctipennis</i> (Say)	365	823	130	1161	572
Chironomidae					
<i>Procladius</i> sp.	62	7	1	8	3
<i>Ablabesmyia</i> sp.	11	14	1		4
<i>Chironomus</i> sp.	4		1	52	37
<i>Micropsectra</i> sp.	2				
<i>Stenochironomus</i> sp.	1				4
<i>Cryptochironomus</i> sp.	12		3	2	1
<i>Parachironomus</i> sp.			2	5	
<i>Paralauterbornie</i> sp.	1	1			
Orthoptera					
Mollusca					
Gastropoda					
Physidae					
<i>Physella</i> sp.					1
<i>Physella hendersoni</i> (Clench)		1			

Correlation coefficients (R) between the number of species and species diversity and number of individuals were 0.75 and -0.39. The number of individuals and species diversity were inversely correlated ( $R = -0.75$ ). Correlation coefficients between dissolved oxygen concentrations and total number of individuals, total number of species, and species diversity were -0.25, 0.32, and 0.50, respectively.

The differences in the number of individuals and dissolved oxygen concentrations between the months were significant ( $p < 0.05$ ), while the same differences in the number of species and species diversity were not significant ( $p > 0.05$ ).

### Discussion and Conclusion

Water temperature, pH, dissolved oxygen concentration and community structure of macroinvertebrates of Barry's Sand-Pit Lake were studied from June 1995 to February 1996, which covered the climatic extremes. The lake experiences fluctuations in water temperature, pH, dissolved oxygen concentration and biotic conditions with depth and seasons. The lake was a warm monomictic lake and mixed only during the coldest part of the year. The lake was thermally stratified throughout the study, except during the turnover.

Stratification of dissolved oxygen was observed throughout the study period, except during the turnover. No anoxic conditions were observed at any depth during the entire study period. The lower dissolved oxygen concentrations at the deeper depths must have been caused by thermal stratification, which cut off circulation, respiration of organisms, and decomposition of organic material.

Generally, the numbers of taxa decreased with depth while the numbers of individuals increased with depth. This was probably because 0.5 m and 2 m depths were in the euphotic zone and had higher dissolved oxygen concentrations, more allochthonous organic detritus, which provided food and microhabitat for colonization, whereas the 6.5 m depth contained scarce amounts of organic detritus and low dissolved oxygen concentrations, which were too harsh for most macroinvertebrates species, except for the eurytolerant *Chaoborus punctipennis* (Say) and *Limnodrilus hoffmeisteri* (Claparede).

The profundal habitat, in the hypolimnion of stratified lakes, is more homogeneous due to a lack of diverse habitat, hypoxia and anoxia in moderately to highly productive lakes. This zone of lakes is usually dominated by a number of benthic groups including chironomid larvae, oligochaete worms, and phantom midge larvae (*Chaoborus* sp.) (5). Barry's Sand-Pit Lake shows these characteristics by having high population densities of *Chaoborus punctipennis*, *Limnodrilus hoffmeisteri*, *Dero obtuse* and *Chironomus* sp. The profundal zone of the lake has low species diversity values ranging from 0.9 to 1.1, which are also an indication of an unbalanced community and domination by one or more very eurytolerant species.

Although *Chaoborus punctipennis* was not restricted to 6.5 m depth, it was collected mostly at this depth. *Chaoborus punctipennis* exhibits diurnal vertical migration, being confined to the bottom waters during the day and migrating to surface waters at night (13-15). This is a strategy probably adapted to avoid fish predation in the daytime and to feed safely at night when it cannot be detected easily.

Many authors argue that the diversity values cannot stand alone and should be used to compliment tabular analysis of taxa distribution and abundance with physical and chemical data and a knowledge of the organisms and the system (5,16-17).

The number of species and species diversity were positively correlated, whereas the number of individuals and species diversity were inversely correlated. This was probably due to the fact that when the number of individuals of some species increased, the number of individuals of other species decreased due to severe competition for the resources. In some cases some species even disappeared, resulting in decreases in species diversity.

The differences in the number of individuals and dissolved oxygen concentrations between the months were significant, while there were no significant differences in the number of species and species diversity. These are expected results because usually the number of species do not change much with time although the population densities of species changes with changes in physical and chemical conditions and the physical and chemical conditions change with time and space quite frequently.



Barry's Sand-Pit Lake is a young system and does not receive any direct effluent from any plant or urban system and not much agricultural activity goes on around the system. The system can serve as an ecological diversity unit in the area if it is protected from pollution and other ecological risk factors.

## References

- Hutchinson, G.E. A Treatise on Limnology (Vol. 1). New York. 1957. John Wiley & Sons. 1015 p.
- Garnier, J., Chesterikof, A., Tesard, P., Garban, B. Oligotrophication after a nutrient reduction in a shallow sand-pit lake (Creteil Lake, Paris suburbs, France): a case of rapid restoration. *Annales de Limnologie*, 28: 253-262, 1992.
- Lewis, S.P., Harrel, R.C. Physicochemical conditions and diversity of macrobenthos of Village Creek, Texas. *Southwestern Naturalist*, 23: 263-272, 1978.
- Harrel, R.C., Hall, M.A. Macrobenthic community structure before and after pollution abatement in the Neches River estuary (Texas). *Hydrobiologia*, 124: 241-252, 1991.
- Rosenberg, D.M., Resh, V.H. Freshwater biomonitoring and benthic macroinvertebrates. New York. 1993. Chapman & Hall. 488 p.
- Environmental Protection Agency. Biological field and laboratory methods for measuring the quality of surface waters and effluents (C.I. Weber, editor). Cincinnati, OH. 1973. EPA Publication No. EPA-670/4-73-001.
- Wetzel, R.G. *Limnology* (2nd ed.). Philadelphia, PA. 1975. Saunders College Publishing. 858 p.
- Garnier, J., Billen, G. Ecological interactions in a shallow sand-pit lake (Lake Creteil, Paris suburbs, France): a modeling approach. *Hydrobiologia*, 276: 97-114, 1994.
- Harrel, R.C. Effects of a crude oil spill on water quality and macrobenthos of a Southeast Texas stream. *Hydrobiologia*, 124: 223-226, 1985.
- Shannon, C.E., Weaver, W. The mathematical theory of communication. Urbana, IL. 1949. University of Illinois Press. 117 P.
- Hornbach, D.C., Deneka, T., Payne, B.S., Miller, A.C. Benthic macroinvertebrate community structure in a backwater lake of pool 2, upper Mississippi River. *Journal of Freshwater Ecology*, 5: 131-138, 1989.
- Levin, I.R. *Statistics for Management*. Englewood Cliffs, NJ. 1987. Prentice-Hall. 1026 p.
- Wilhm, J.T., Dorris, T.C. Biological parameters for water quality criteria. *Bioscience*, 18: 477-481, 1968.
- Harrel, R.C. Limnological studies on a Southeast Texas meander scar lake. *Texas Journal of Science*, 4: 517-533, 1973.
- Pennak, R.W. *Fresh-water invertebrates of the United States* (2<sup>nd</sup> ed.). New York. 1978. Wiley-Interscience Publication. 803 p.
- McCullough, J.D., Reed, C.W. A comparison of the water chemistry and benthic macroinvertebrates of two oxbow lakes in the Red River basin, Northwestern Louisiana. *Texas Journal of Science*, 39: 139-154, 1987.
- Hughes, B.D. The influence of factors other than pollution on the value of Shannon's diversity index for benthic macro-invertebrates in streams. *Water Research*, 12: 359-364, 1978.

## Acknowledgments

I would like to thank Dr. Richard C. Harrel, the major advisor for my master's degree; Dr. Michael E. Warren, Lamar University Biology Department head; and Dr. Michael W. Haiduk for their help during this work at Lamar University.