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RECLAMATION OF ORPHAN STRIP MINED LAND IN
"SOUTHERN ILLINOIS AND WESTERN KENTUCKY:
A FIELD STUDY OF THE PALZO PROJECT OF
WILLIAMSON COUNTY, ILLINOIS AND THE
CLEAR CREEK SWAMP OF WEBSTER AND
HOPKINS COUNTIES, KENTUCKY

By

Clara Ann Leuthart
B.S., Catherine Spalding College, 1968
M.S., University of Louisville, 1971

A Dissertation
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for the Degree of

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May 1975

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by the Following Reading Committee:

Dissertation Director

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ABSTRACT

The areas studied exhibit different aspects of the problem of orphan strip mines. The Palzo tract is a 192 acre parcel of orphaned land in southern Illinois that is being reclaimed by incorporating sewage sludge into the spoil and seeding. Seven sampling stations were established along Sugar Creek which drains the Palzo area. Six of these stations were well above the area to be reclaimed. The seventh was located below the area receiving acid mine drainage. A study of Cairn's, Simpson's, Patten's, Margalef's, Menhinick's, and Wilhm and Dorris' diversity indices at the stations showed that such indices are misleading and should be used only with knowledge of the benthic organisms' habits and habitats.

The Clear Creek swamp in western Kentucky is a result of orphan strip mines; it will never be reclaimed. Differences in benthic fauna and ecosystems which develop in acid mine drainage and freshwater runoff areas are discussed. Both of the above areas have been used as study areas for engineering students.

It was concluded from the study that when funds are made available for the reclamation of orphan strip mines, (1) the most severe problems should be reclaimed first, (2) if an area has a viable ecosystem, and/or, has no acid mine drainage problems, it should not be disturbed.

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INTRODUCTION

Strip mining, by reason of its methodology effects permanent changes upon the watershed of the area mined. The process involves removal of all overlying formations of rock, soil, and vegetation to the depth of the coal seam to be removed. This method exposes to the environment geologic deposits which took physical, chemical and biological processes over 300 million years to develop. These alterations of geology, topography, and hydrology bring about concomitant changes of the native flora and fauna. Such changes have accompanied the method from its primitive beginning in 1866 in Danville, Illinois (Bottomley, 1944) when horse-drawn plows and scrapers were used to remove the overburden and wheelbarrows and carts were used to haul the coal-- to today's mega-machinery with draglines of 220 cubic yard capacity capable of moving 4 million cubic yards of overburden per month (Anon, 1965). A major criticism of this mining process is the fate of the overburden which, until recently, was left as orphaned spoil. Estimates are that 1.5 million acres of such orphaned land accumulated in Midwest America prior to the enactment of reclamation laws in the 1950's and 1960's.

These pre-law orphaned strip mines are as varied as the geologic-topographic-hydrologic assemblages were before mining. Within an afternoon one can find instances where the vegetation now conceals the corrugated remains of an old strip mine, areas covered with toxic spoil that extend for miles, barren and lifeless, and other areas where pine

trees were planted to conceal such barrenness. The waterways draining these areas show like diversity. Some strip pits contain water of high quality and are used for many recreational activities, others have extremely poor water quality, are discolored, highly acidic, and of little value to anyone. Though not mined, low lying land, swamps and marshes are often indirectly affected.

The combination of vast acreage in need of repair and the national economic situation is prohibitive of reclamation of all but a few orphaned mines. The greater portion of this land will, in all likelihood remain orphaned forever. A detailed study of several aspects of the orphaned mines is needed to assist a judicious choice of which shall be reclaimed and to predict the future of those which are not.

Volumes have been written of the various methods of treating spoil but interdisciplinary studies of the several aspects of the problem are rare. This thesis will investigate how 1.5 million acres of Midwest America came to be strip mined, and innumerable watersheds and streams destroyed before legislation was passed to reduce the degree of destruction, and will also investigate the status of the orphaned land reclamation of today. The areas chosen for study were the coal fields of western Kentucky and southern Illinois.

These topics were studied by first starting at the beginning, 300 million years ago when the coals of the Illinois Basin were forming and studying consecutively the geology of coal formation, the history of mining and the

history of reclamation laws. The present status of orphan land reclamation was studied by going into the coal fields for it is here that the interdisciplinary aspects of the problem are assembled.

A third objective of this study is to aid engineering education. Strip mine reclamation is an interdisciplinary topic though seldom treated as such. It is hoped that this dissertation may be used as an outline of the basic areas of science to be covered in courses for reclamation officials and engineers dealing with the topic of strip mine reclamation. Also, it is intended that this dissertation be used as a field guide for Master of Engineering students interested in developing research topics in the Western Coalfield. In keeping with this, it should be noted that the four Master of Engineering Dissertations were completed during the years 1972-1975 as a result of the work initiated herein.

GEOLOGIC HISTORY OF THE ILLINOIS BASIN

CARBONIFEROUS TO PLEISTOCENE

The Illinois Basin encompasses most of the state of Illinois, parts of southern Indiana, and the physiographic region of Kentucky known as the Western Coalfield (Figure 1). The area has existed as a basin since pre-Cambrian times.

The southern portion was an extension of the Rome Trough during the Cambrian Period. This trough occupied the area that is now southeastern Kentucky and extended into the Appalachian Basin in southwest Virginia and northeast Tennessee. Separation of the Appalachian and Illinois Basins occurred during the late Paleozoic Era after the coal was formed. The Illinois Basin sank and trapped sediment at a rate of $2/3$ inch per thousand years from the Cambrian through Devonian Periods of the Paleozoic. Maximum sinking occurred near the Illinois--Indiana border (Figure 2) with thinner sediments on the east and west. Further alterations occurred during the Mississippian and Pennsylvanian Periods (Schwann, 1968).

Mississippian

The Michigan River was an instrumental force in shaping the Illinois Basin during the Mississippian Period. Erosion of neighboring arches--the Cincinnati and Illinois-Wisconsin--is not thought to have supplied much material to the Basin at this time. The Michigan River carried most of the detrital sediments into the Basin from northern areas in and beyond the Canadian Shield. Wanless (1969) theorized

FIGURE 1.

The Illinois Basin

FIGURE 2.

Cross-section of the Illinois Basin
from Schwann (1968)

that distributary channels of the delta formed at the mouth of the river entered the Illinois Basin from areas in northeastern Illinois. The river advanced and retreated throughout most of the Mississippian forming rocks which are one-half shale and one-fourth each sandstone and limestone, resulting in a formation of alternating limestone--shale and sandstone--shale. The sandstone member was deposited when the Michigan River again flowed into the area, often with advancement of the deltas for hundreds of miles. Limestone deposits mark the time when shallow seas reached the area as a result of sediment loss by the Michigan River and further sinking of the Basin.

This continual advance and retreat of the freshwaters and shallow seas formed about 100 cyclothems in Illinois (Dunbar, 1969). Figure 3, a diagrammatic representation of a type section of the Mississippian system, illustrates some of these cyclothems in western Kentucky and southern Illinois.

The last formation of the Mississippian Period to be deposited in the Illinois Basin was the Chesterian. Distribution and direction of cross-bedding of these sediments indicate that the entire system was uplifted, tilted up to the north and sloped downward to the southwest. The Chester sediments were carried in from the northeast and filled the Basin with sandstone, shale and conglomerates of non-marine origin (Schwann, 1968).

Pennsylvanian

Much of the geological faulting prevalent in areas of western Kentucky and southern Illinois occurred in early

Pennsylvanian times. Several of the faults were uplifted at this time while the central portion was downwarped. An erosional period then began which removed much of the Chester sediments in the northern part of the Basin. Later cycles of erosion cut deep stream channels across the previously eroded areas, some of these are as much as 200 feet deep and two or three miles wide.

Caseyville sediments, the first Pennsylvanian strata to be formed, were deposited in this area filling valleys and previously entrenched stream channels to depths of 200 feet or more. These sediments were derived from the same area and were deposited in an environment similar to that of the Chester series. This, in addition to the fact that the Caseyville sediments were deposited in areas where rocks of the Chester series had been eroded, makes differentiation of the two often difficult (Schwann, 1968).

Marine invasion seldom attained depths sufficient to reach the northward tilted slope of the Illinois Basin during early Pennsylvanian. The seas extended westward between the Jessamine and Nashville domes of the Cincinnati Geanticline to reach western Kentucky and southern Indiana, although they failed to inundate Illinois. By the Middle Pennsylvanian they again extended into Illinois (Wanless, 1969).

Dunbar (1969) described this as a time of contest between limestone formation during invasion by the seas and deposition of sand and mud by the freshwater rivers. Records of this contest can be found in the bedrock. A shale-limestone sequence indicates the return of marine conditions.

FIGURE 3.

Type section of Mississippian system
(Dunbar, 1969)

FORMATIONS	GROUPS	STAGES
Kincaid Limestone Degonia Sandstone Clare Shale Palestine Sandstone Menard Limestone Watersburg Sandstone Vienna Limestone Tar Springs Sandstone	Elvira	Chesterian
Glen Dean Limestone Hardinsburg Sandstone Golconda Limestone Cypress Sandstone	Homberly	
Paint Creek Shale Bethel Sandstone Renault Formation Aux Vases Sandstone	New Design	
Ohara Oolite Rosiclare Sandstone Fredonia Oolite	Ste. Genevieve Ls.	Meramecian
St. Louis Limestone Salem Oolite Warsaw Formation		
Keokuk Limestone Burlington Limestone Fern Glen Limestone		Osagian
Choteau Limestone Hannibal Sandstone	Easley	Kinderhookian
Louisiana Limestone Saverton Shale	Fabius	

Sandstones, representative of non-marine conditions are usually found in coal-underclay-sandstone sequences. When the level of the seas advanced, marine limestones were interspersed between the coal-bearing sandstones. Both environments, marine and freshwater swamp, were significant to the formation of coal.

It is in the Middle Pennsylvanian strata where the greatest expanses of minable coals are found. Fossil evidence indicates that North America and Europe were located much to the south of their present positions during the Carboniferous Period and paleomagnetic data suggests that during the Carboniferous the equator passed through what is now the southern tip of Hudson Bay and the Strait of Belle Isle. Glaciation is thought to have occurred in South America during the latter stages of the Paleozoic Era which would indicate that it also was much to the south of its present position. The similarity of species of plants in coals from different parts of the world is further evidence of the continuous situation of all the continents during the Carboniferous Period. Their wide range was probably due to the air-borne spore method of dispersal as well as the similarity of climate in areas where coal was formed.

The remains of plants which thrived in the freshwater swamps, but which were destroyed when the seas again invaded the area, formed the coals. "Roofing shales" in many areas bear the structural impressions of leaves typical of the Pennsylvanian vegetation and root systems of plant life are

also preserved in the fireclays that underlie the coal seams in many areas (Dunbar, 1969). These preserved records as well as the extensive distribution of the coals give evidence to the fact that the plants grew in a moist, swamp environment where their dead remains accumulated under standing water protected from oxidation and further decay.

The presence of pyrite in some of the Pennsylvanian coal seams suggests that the swamplands where the coal was formed bordered the seas and were brackish, since sulfur-depositing bacteria are not as abundant in freshwater as they are in a marine environment (Dunbar, 1969). Iron disulfide or pyrite occurs in four basic types: euhedral crystals, coarse grained masses, coarse grained platy masses, and framboidal pyrite. Caruccio (Caruccio and Ferm, 1974) found that it is the framboidal pyrite which decomposes with enough rapidity to cause severe acid mine drainage problems and further that the conditions of rock deposition control the formation and occurrence of the framboidal pyrite. Williams and Keith (1963) showed that in the Pennsylvanian coal field, the bituminous coal becomes increasingly more sulfurous as the paleo-environment of the coal roof rock changes from continental to marine. Caruccio (1974) has found that coals overlain by strata indicative of the marine or brackish environments are rich in framboidal pyrite. Ferm (Caruccio and Ferm, 1974) further defined the situation with his finding that the rocks rich in framboidal pyrite are those of back barrier reefs and lower delta plain deposits.

These discoveries help to explain a confusion about strip mine spoil which is: Why do some seams produce acid mine drainage while others do not, and further, why is the problem more pronounced in some areas of the same seam than in other locales? It is now theorized that the severity of the problem depends on the environment of deposition.

Following the period of coal formation, the area now known as the Illinois Basin was further downwarped. McFarlan (1943) describes the events that finalized the formation of this basin. During the contest between the Michigan River and the seas, the Eastern Coalfield of Kentucky and the Illinois Basin were contiguous across the Cincinnati Arch. Toward the end of the Paleozoic Era the Appalachian Mountains were uplifted and the Illinois Basin was further downwarped. The coal in these two areas was preserved, while in areas of remarkable uplift, such as the Cincinnati Arch, (Figure 4), tremendous thicknesses of Paleozoic strata were completely eroded. Isolated areas within the Illinois Basin not containing coal are thought to represent islands in the Pennsylvanian seas and swamps that remained unaffected by the events of that period. Sedimentary data from east and southwest parts of the Basin suggests continued sedimentation through the remainder of the Paleozoic but later erosion has destroyed any complete record.

Events of late Pennsylvanian include major fault formations and uplifts. The Basin was closed completely when the Pascola Arch (Figure 4) at the southwest flank of

FIGURE 4.

Surrounding features of the Illinois Basin

the Basin was uplifted 10,000 feet. During and after uplift it was eroded to base level.

Pleistocene Glaciation

The last natural geologic force involved in the characterization of the Illinois Basin was Pleistocene glaciation. Pleistocene ice sheets left northern regions of the Illinois Basin covered with 50-200 feet of drift. Where end moraines crossed the bedrock, the depth often reaches 400 feet or more. A series of lakes were formed in Webster and Hopkins counties Kentucky, during the Pleistocene; these two counties are particularly important to the study. The lakes were filled with silt, sand, and clay to depths reaching 200 feet in some areas and erratics, rocks unlike the bedrock on which they lie, are reported in the Clear Creek valley of Hopkins county.

The two periods of glaciation that affected the Basin the most are the Illinoian (400,000 years BP) and Wisconsin (50,000-20,000 years BP). Illinoian glaciation may not have crossed into Kentucky, but it did cover most of the state of Illinois. Ball (1942) describes the southern limit of Illinoian glaciation as having passed through Jackson, Williamson, and parts of Johnson, Saline and Gallatin counties (Figure 5).

In southern Williamson County, Illinois, an area which also figures in the present study, the terminal moraine of one of the earlier glacial epochs is found along the border of the lowland area. Yellow silt loam, thought to be part loess, is found in upland soils of Williamson county.

FIGURE 5.

Southern limit of glaciation in Illinois

The Wisconsin glacier was of importance to Illinois because of the drift it deposited. Ball (1942) described Illinois, situated in the corn belt of America, as an area unique in its definite chemical and physical boundaries. The southern boundary of the corn belt in Illinois coincides almost identically with the soil limits established by Wisconsin glaciation. The rock dust carried by ice sheets, wind, and water helped establish the rich prairie soils.

Broad-bottomed valleys filled with alluvium of both Illinoian and Wisconsin glaciers, are characteristic of the Western Coalfield (McFarlan, 1943). Sediments from melt-water and the headwaters of streams in western Kentucky fill these valleys to depths up to 150 feet, and today's streams are still eroding channels into these deposits.

Two areas of the Illinois Basin were selected for this study of orphan land reclamation. The first is the site of a large federal reclamation project in Williamson County, Illinois, and the second is in Hopkins and Webster Counties, Kentucky where shallow acid mine drainage swamps now inundate thousands of acres of once tillable land. These areas were chosen because of their dissimilarity in topography, biology and prospects of reclamation.

COAL DEPOSITS OF WILLIAMSON COUNTY, ILLINOIS

Williamson County, located in south central Illinois (figure 6), is 432 square miles in area and bordered by the counties of Franklin on the north, Saline on the east, Johnson and Union on the south and Jackson on the west. The topography of Williamson County is rolling in the north, level in the central area and broken in the south. In the northeast sector near the Williamson-Franklin county border, the highland area separates the watershed which empties into the Ohio from that which flows west to the Mississippi River. The western section is drained by the Big Muddy River which is fed by Crab Orchard Creek to the south. The eastern and southeastern areas of the county are drained by the Middle Fork and South Fork of the Saline River which empties into the Ohio River.

Quaternary and Lower Coal Measures comprise the geological formations of the county. The Quaternary deposits are indicated by brown and yellow clays mixed with gravel and boulders. Conglomerate and heavy bedded sandstones of the lower Coal Measures are the prevailing formations near the southern county border (Ball, 1942).

The Coal Measures of Illinois are found in three formations. Geologic strata from the surface to the top of the No. 6 seam constitute the McLeansboro Formation. The Carbondale Formation includes all between the top of No. 6 and the base of No. 2 coals, and the remaining Pennsylvanian strata beneath the No. 2 coal comprise the Pottsville Formation. These three formations will be

FIGURE 6.

Location of Williamson County

	FRANKLIN	
JACKSON	WILLIAMSON	SALINE
UNION	JOHNSON	

discussed with reference to the coal seams with their overlying and underlying strata.

The McLeansboro Formation consists mostly of shale with minor amounts of sandstone, limestone and coal. Several coals of this formation are persistent but they are not thick enough to be of commercial value. Their significance is as correlation horizons. The important stratigraphic units as listed by Cady (1916) for District VI of Illinois which includes north and northeast Williamson County are:

8. New Haven Limestone
7. Coal No. 11
6. Coal No. 10
5. Shoal Creek Limestone
4. Coal No. 9
3. Carlinsville Limestone
2. Coal No. 8
1. A hard limestone averaging 7 feet thick overlying or slightly above No. 6 coal

New Haven limestone is not reported in Williamson County. Coals No. 11 and No. 10 are present in the northeast of Williamson County but most of the county is south of the outcrop of these seams. The Shoal Creek limestone is thin and discontinuous in this area but with thicknesses of 5 to 9 feet reported in some records. This limestone stratum lies 50 feet above coal No. 9 (Cady, 1916).

Coal No. 9 outcrops in northeast Williamson County but it is not thick enough to be of commercial interest. The occurrence of this coal, 50 feet above the Carlinsville limestone and 25 feet below the Shoal Creek Limestone is of benefit in identification of these limestone strata if either one is missing.

The Carlinsville limestone is on an average, seven feet thick and is widely distributed. It does not outcrop in the area but is most important in its correlation with coal No. 9.

Coal No. 8 averages 5 to 12 inches in thickness and thus is of little commercial importance. An additional thin coal bed occurs in ranges 3 and 4 east of Williamson County, 80 feet above coal No. 6.

The basal stratum of the McLeansboro Formation is a caprock limestone 4 to 5 feet thick overlying No. 6 coal (Fisher, 1925). It is found within 25 feet of this coal seam in the eastern part of the county and at greater distances in the western sectors. A positive correlation has been noted between the thickness of No. 6 coal and the distance between the coal and cap-rock limestone. Cady (1916) gives the following interpretation of this phenomenon. Based on drill hole records, coal No. 6 was formed in a trough. Peat which eventually formed the coal was thickest in the trough and thinned towards the edges. As the peat shrank to form the coal, maximum shrinkage occurred where peat deposits were thickest. A second basin then existed atop the former. This basin eventually was filled with mud deposits which became gray shale. Limestone then was deposited on a relatively level base when the oceans again covered the area, so that where the coal is thickest, there is greatest distance between the limestone and No. 6 coal.

The Carbondale Formation ranges from 250 to 350 feet thick and includes all strata between the top of No. 6 and the base of No. 2 coals. The upper stratum, coal No. 6 or Herrin coal, is the most economically important coal seam of Williamson County, attaining thicknesses in some areas of 13 to 14 feet. An illustration of the area underlain by No. 6 coal is given in Figure 7. The original amount of No. 6 coal was estimated by Cady (1916) as 8,732,000,000 tons; 2.34% had been mined by 1916.

This coal seam has a characteristic "blueband" 18 to 30 inches above the base of the coal and consists of bone, shaley coal, or gray shale. It is an average 1.7 inches thick with variances of 0.5 to 2.5 inches. The "blueband" is used to identify the seam in the various locales and was of benefit in achieving universal nomenclature throughout the state (Cady, 1916). Impurities of No. 6 coal in addition to the blueband include a band of fire-clay 0.5 to 1.5 inches thick, occurring 10 to 28 inches above the floor (DeWolf, 1908) and occasional shale and sulfur streaks.

A fire-clay, sometimes 10 feet thick, lies beneath No. 6 coal; and a gray, fine-grained, 10 foot thick limestone lies beneath it. Between the limestone and lower coal bed is a bed of gray shale (Fisher, 1925). This stratigraphic sequence of coal, fire-clay, limestone and shale is a typical, and often repeated cyclothem in the Illinois Basin.

The No. 5 or Harrisburg coal has an undulatory structure, and drops from a level 350 feet above sea level to 25

FIGURE 7.

Area of Illinois underlain by No. 6 coal

feet below sea level over an eight mile span (Cady, 1925). In Williamson County, No. 5 coal lies about 30 to 45 feet beneath the No. 6 seam (Cady, 1925). In some areas No. 5 coal is as much as 66 inches thick and in other areas it is completely absent, thinning from east to west. This coal seam shows only occasional thin streaks of sulfur which rarely reach one inch in thickness (Cady, 1916). Mining conditions of No. 5 are excellent and in some areas it is mined preferable to No. 6. It is of medium hardness and the roof is of hard gray shale that needs little timbering, but concretions up to a foot in diameter are present in some areas. Coal No. 5 rests upon a fire-clay about three feet thick with a limestone bed five feet thick beneath this (DeWolf, 1908).

Coal No. 4 is one of the thinner but more persistent beds. It is about three feet thick and lies 50 to 60 feet below coal No. 5. From 35 to 40 feet above coal No. 4 and about 100 to 110 feet below coal No. 5 is a thin bed about one foot thick. The association of this coal and coal No. 4 is an aid in identification in some areas (Cady, 1916).

The basal bed of the Carbondale formation is coal No. 2. In south Williamson County coal No. 2 is split into two, 36 inch seams separated by 15 to 25 feet of shale. The parting thins to non-existence to the west and increases to 40 feet to the east (Brokaw, 1917).

The Pottsville Formation of the southern third of Williamson County consists mainly of sandstone. Three heavy cliff-making sandstones 75 to 150 feet thick, each separated

by mixed beds of soft sandstone and shale form the major part of the formation. A generalized section of the Pottsville in this area consists, according to Brokaw, (1917) of the following beds:

	Feet
7. Brown gritty shale	10-40
6. Lower cliff-making sandstones, a massive cross-bedded sandstone with conglomeratic beds.	100-250
5. Shale with thin micaceous sandy beds and local dirty coals.	40-60
4. Middle cliff-making sandstone, massive cross-bedded quartzose sandstone with local conglomeratic lenses.	40-150
3. Shale with thin sandy layers and local coal beds; one camel coal	75-125
2. Upper cliff-making sandstone, massive cross-bedded sandstone not conglomeratic, commonly iron stained.	100-200
1. Shales with thin beds of sandstone and sandy micaceous shale; local limestones and coal beds; some gypsiferous shale.	400

The top of the Palzo sandstone marks the division between the Carbondale, and the Pottsville or Tradewater formation. A few feet below this sandstone is the DeKoven coal seam. In the area of Palzo in Williamson County a layer of shale parting 30 inches thick occurs just below the middle of this coal. The Davis coal seam differing only slightly in chemical and physical characteristics lies 10-25 feet beneath the DeKoven seam and is overlain by 4 to 6 feet of black fissile shale. These two seams outcrop at the Williamson-Saline county line and are also exposed in Union County, Kentucky. DeKoven and Davis coals were the last to be mined on the 192 acre Palzo tract which is significant to this study.

A 1957 study report by Smith (1957) listing the estimates of strippable reserve coal of Williamson County is

given in Tables I and II.

TABLE I. Summary of Strippable Reserves of DeKoven and Davis Coals (in thousands of tons), Showing Overburden Depth and Reliability Classification

Class I Reserves				Class II Reserves					
Overburden Depth in Feet				Overburden Depth in Feet					
0-5	50-100	100-150	Total	0-50	50-100	100-150	Total	I & II sq.mi.	
10,996	6,457			DeKoven - Williamson County					
10,996	6,457	2,455	19,908	3,565	8,542	8,811	20.918	40,826	0.45
Davis - Williamson County									
9,483	9,618	7,230	26,331				26,331		0.48

TABLE II. Detailed Summary of Strippable Coal Reserves Showing Overburden Depth, Thickness of Coal and Reliability Classification, by County and Township

Coal Township Thickness	Class I Reserves at Overburden Depth (ft)				Class II Reserves at Overburden Depth (ft)				I&II	sq.mi.
	0-50	50-100	100-150	Total	0-50	50-100	100-150	Total		
No. 5										
10S-4E 48"	90	90	-	180	-	-	-		180	0.31
DeKoven										
10S-4E 36"	10,996	6,457	2,455	19,908	3,565	8,542	8,811	20,918	40,826	0.45
Davis										
10S-4E 36"	9,483	9,618	7,230	26,331	-	-	-		26,331	0.48

COAL DEPOSITS OF WEBSTER AND HOPKINS
COUNTIES, KENTUCKY

The Western Coalfield of Kentucky encompasses an area of 4,680 square miles and forms the southeastern tip of the Illinois Basin (Figure 8). This physiographic region is a topographic as well as a structural basin, rimmed by a stretch of Caseyville outcrop which also surfaces at the Rough Creek uplift (Figure 9).

The three major geologic formations of Illinois, the McLeansboro, Carbondale, and Pottsville are stratigraphic counterparts of the Dixon, Lisman, Carbondale, Tradewater and Caseyville of Kentucky. Figure 10 (Maxwell and Devaul, 1962) illustrates the major stratigraphic sections in these formations for Webster and Hopkins Counties correlated with the southern Illinois stratigraphy.

The Dixon Formation is the uppermost geologic formation of Hopkins and Webster Counties. Major constituents are shale and sandstone but there are no significant coal seams. The youngest bed is the 20 to 30 foot thick Mt. Gilead Sandstone. It grades into the Mt. Gilead Shale, a fossiliferous marine shale with a thin limestone layer. The medium-coarse grained Vanderburg Sandstone lies beneath the Mt. Gilead Shale and above the Bald Hill Shale. This is a calcareous mudstone shale containing marine fossils within the upper few inches. A thin coal seam lies beneath this shale. The basal bed of the formation is the Dixon Sandstone, a medium to fine grained sandstone.

FIGURE 8.

Western Coalfield of Kentucky

FIGURE 9.

Major fault zones of the Western Coalfield
region of Kentucky

FIGURE 10.

Correlation of Webster and Hopkins counties,
Kentucky and southern Illinois stratigraphy
from Maxwell and Devaul (1962)

WEBSTER AND
HOPKINS COUNTIES
STRATIGRAPHY

ILLINOIS STRATIGRAPHY

NO. 6 COAL

NO. 5 COAL

NO. 2 COAL

DEKOVEN COAL

WILEY (DAVIS) COAL

CURLEW LIMESTONE

FINNIE SANDSTONE

MADISONVILLE
LIMESTONE

ANVIL ROCK
SANDSTONE

PROVIDENCE
LIMESTONE

NO. 11 COAL

NO. 9 COAL

PLEASANTVIEW
SANDSTONE

SCHULTZTOWN
COAL

SEBREE
SANDSTONE
NO. 7 COAL

NO. 6 COAL

NO. 4 COAL

CURLEW
SANDSTONE

CURLEW LIMESTONE

ABERDEEN
SANDSTONE

FINNIE SANDSTONE

1000±

0-150

230±

350-500

NO. 2 COAL
GRINDSTAFF
SANDSTONE
NO. 1A COAL

BEE SPRINGS
SANDSTONE

BATTERY ROCK
COAL

LOWER
CONGLOMERATE
MEMBER

The Lisman Formation extends from the base of the Dixon Sandstone to the base of the Anvil Rock Sandstone. Lisman Shale with occasional thin beds of coal, sandstone, and limestone extends for 650 feet beneath the Dixon Sandstone. The Madisonville Limestone of Hopkins and Webster Counties occurs as three, blue to grey, sparingly fossiliferous limestone ledges. Each ledge is 7-9 feet thick in a section 25-40 feet thick. The only workable coals of this formation are No. 14 coal of Hopkins County and a commercial seam in Webster County correlated with No. 13 coal.

No. 14 is a non-persistent seam and is thought (Hodgson, 1963) to have been formed in small inter-connected basins and later subjected to stream channelizing. A sand filled channel rests on or occupies the coal in many places. No. 14 coal is low in sulfur and ranges from 4 to 7 feet thick but 12 to 14 inches must be left when deep mining as protection from the soft roof. The sand filled channel above the roof in some areas has replaced the coal. The Anvil Rock Sandstone occurs normally between No. 12 and No. 14 coals, and it replaces the Providence Limestone in some areas. The sandstone often appears above No. 12, sometimes below it and other instances splits the seam. This phenomenon is ascribed to the usual variation in number and direction of the distributaries which built the alluvial fan or delta during the Pennsylvanian.

The Carbondale includes the major coal formations of Western Kentucky. No. 12 coal is low in sulphur, has a soft shale roof and reaches thicknesses of 6 feet in areas of

Hopkins and Webster Counties where it is often strip mined along with No. 11. Providence Limestone lies a few feet above No. 11 coal. It is a blue, argillaceous limestone and attains thicknesses of 568 feet in Webster County.

The No. 11 coal seam is one of the two extremely economical seams of Webster and Hopkins Counties and it is correlated with the No. 6 or Herrin seam of Illinois. No. 11 coal is less persistent than No. 9 but it often is thicker by an average 6 feet and often 7 feet. The thin areas of this coal are thought due to non-deposition as opposed to erosion (Hodgson, 1963). This seam contains two bands: the characteristic "blueband" which is the source of the ash content and a "sulfur band" 0.25 to 0.5 inch of marcasite (FeS_2), 9 to 16 inches beneath the top of the coal. No. 11 is mined in most counties of the Western Coalfield except those of the immediate border belt.

Coal No. 10 is reported not to be of workable thickness outside Union County. No. 9 coal, which is equivalent to No. 5 of Illinois is uniformly between 4.75 and 4.83 feet but is reported to be as much as 6.5 feet thick in areas of Hopkins County. A black shale above No. 9 coal forms the roof in underground mines but often contains siderite or pyrite concretions. No. 9 coal reportedly underlies 25,000 square miles of Midwest America.

No. 8 and 8B coals are local thin beds. The base of the Carbondale Formation is the Sebree Sandstone. This is a coarse sandstone, about 10 to 12 feet thick. Much of the sand is ferruginous with prominent ironstone plates and seams.

The Tradewater Formation of Western Kentucky is correlated with upper Pottsville of Illinois. The No. 7 coal of Union County, Kentucky is correlated with the DeKoven seam of Williamson County, Illinois. This seam occurs in Webster County beneath a layer of shale but is not of much commercial importance. The Davis or No. 6 coal attains an average 4 feet in thickness in Christian, Muhlenberg, Hopkins and Union Counties. The only other prominent coal of this formation is the Dawson Springs coal of southern Hopkins County where it is 40 to 54 inches thick. The coals are separated by thin shale, sandstone and limestone beds.

The Curlew Limestone is one of the more prominent beds of the formation. It consists of two beds, two feet thick, separated by 15 feet of shale. The limestone is blue- and argillaceous and in some areas it weathers to a porous chalky chert. Beneath this bed is the Curlew Sandstone, a massive, friable, strongly cross-bedded, cliff-forming sandstone known through much of western Kentucky and southern Illinois. The Aberdeen Sandstone, a massive, cliff-forming sandstone, reaches 50 feet of thickness in Butler County. The Finnie Sandstone beneath No. 3 coal is highly ferruginous and reaches a maximum thickness of 80 feet. The last bed of this formation is the Grindstaff Sandstone found in thin beds of Webster and Hopkins Counties. It is a fine-grained, light gray sandstone.

The basal formation of Pennsylvanian deposits in Webster and Hopkins Counties is the Caseyville. It is correlated with the Lick Creek Formation of southern

Illinois. This formation is a massive cliff-forming, cross-bedded, coarse-grained conglomeritic sandstone. Shale zones from a few feet to 50 feet thick occur in some areas. The depth of the formation varies from 200 to over 500 feet. The maximum thickness is attained in the pre-Pennsylvanian valley fills.

It is estimated (Hodgson, 1963) that over one-half billion tons of coal remain in a 410 square mile area beneath Hopkins, Crittenden, Webster, and Caldwell Counties. The reserves are within 6 coal seams found in 5 contiguous quadrangles of the above counties. Three-fourths of the reserves for this area are contained in the No. 9 and Dawson Springs coals. Over one-half of the total reserves (one-quarter billion tons) lie within the area of the Coiltown quadrangle. A significant portion of the area of this study lies within this quadrangle. (All of the preceding information is from McFarlan, 1943, unless otherwise noted.)

A HISTORY OF STRIP MINING

Strip mining began in the Illinois Basin when settlers from the east discovered natural outcroppings of coal along stream and river banks. They removed shallow overburden by hand, then later used draft animals to pull scrapers and remove the heavier loads.

Angle (1952) has compiled one of the few histories of mining in Williamson County. Most of the information recorded here is from his work Bloody Williamson. The history of mining in Williamson County, Illinois, began not with a strip mine but a deep mine opened by Laban Carter in 1869. By 1880, two additional mines were opened and 73,500 tons of coal were mined that year to rank Williamson County nineteenth in the state in coal production. The St. Louis and Big Muddy Coal Company founded by Samuel T. Brush introduced large scale mining to Williamson County. In 1890, the first year of operation for this mine, the entire county mined 200,000 tons of coal. Three years later Brush's mine alone brought out that amount making it the sixth largest mine in Illinois. Brush's operation continued to grow; 319,697 tons were mined in 1897 making his the largest in the state.

Union and management disputes have long been a part of the mining industry and Brush's mines were no exception. Due largely to such strife Brush's mines fell to sixth place in 1898, mining only 300,000 tons and to 39 th place the year after that when only 172,335 tons were mined.

The industry had a rebirth of sorts with the advent of strip mining to southern Illinois in 1913. The demands for coal since 1910 due to growing industry and technology and further promoted by wars, resulted in demands for and construction of more efficient equipment to extract coal.

The Southern Illinois Coal Company opened a strip mine in Williamson County in 1921. Although many improvements were made in the mechanics of strip mining, the coal market declined from 1923 to about 1939 and many small stripping operations were forced to close down.

Williamson County and all of Illinois suffered further because coal producers of Kentucky and West Virginia could undersell Illinois mines by hiring non-union laborers. Mines in Williamson County and others, hired only on a part time basis; began taking advantage of technical improvements which meant fewer miners, or closed down altogether. The crash of 1929 magnified the problems. Miners began working only one or two days a week, then not at all. They spent their savings, sold their cars, mortgaged their homes and reluctantly accepted local charity. By 1932, starvation threatened the county. Federal relief programs were initiated in 1933, and, in 1941, conditions were so bad that Williamson, Franklin, and Saline counties were the subject of a special WPA report: Seven Stranded Coal Towns: A Study of an American Depressed Area. The study concluded that three-fourths of the jobs that coal mining had supplied had disappeared and that no new opportunities were arising to fill the vacancies.

Between the years 1920 and 1946, the industry at large was more severely affected by the rise in labor costs, rise in unit cost of production, and increasing inelastic costs of transportation than other fuels industries. From 1922 to 1940 the industry was in a state of perpetual depression; competition was high, often there were too many operators, mines closed frequently and even more frequently miners were unemployed. However, between the years 1920 and 1946, the percent of tons of coal produced by strip mining in Illinois increased from 0.5% to 23.4%. This apparent anomaly is perhaps one of the most significant events in the history of strip mining. Strip mines were increasing in production while small underground mines were going out of business. Graham (1948) lists several reasons for this, the most important of which are that wages-per-ton costs are less, larger machinery saves labor costs, and greater recovery of coal through use of strip mining (Graham, 1948).

The outbreak of World War II and the inflationary conditions of many industries including the coal mining industry improved the situation in Williamson County to some degree but not as much as many had hoped. In Kentucky, the history of mining is much the same.

Strip mining was introduced to Kentucky in 1829 on the farm of William D. McLean near Paradise in Muhlenberg County. Other mines opened between 1830 and 1840 in Greenup, Perry, Pulaski and Union Counties. The first strip mine of commercial importance was started east of Madisonville in 1919.

The second was begun the following year near Providence in Webster County.

The development of larger equipment in the late 1920's gave strip mining a solution to the inflationary problems of the underground mines. Larger equipment meant fewer men could produce greater amounts of coal to satisfy the war-defense industry's demand for more coal no matter how difficult it was to obtain. A reflection of how these changes occur is the fact that in 1937 Kentucky was producing 180,000 tons of surface mined coal annually. Ten years and a World War later the amount had grown to 10.5 million tons annually (Anon, 1972). Improved earth moving equipment further enhanced the use of strip mining over deep mines.

The strip mining industry continued to grow with the production of larger equipment. Surface mining accounted for 67% of Western Kentucky's coal production by 1957 (Anon, 1972). This growth of strip mining has, however, had the continued effect of producing more coal but hiring fewer workers. According to data from the U.S. Bureau of Mines (1945-1964) quoted by Grubb and Ryder (1972) coal production in Hopkins County exceeded 10 million tons per year for all years from 1950 to 1964. During the same period the number of men hired by the mines in Hopkins County dropped from a high of 4,901 in 1950 to 1,849 in 1964. The total of men employed in strip mining represents 21% of the total, the other 79% worked in underground mines. The average amount of coal strip mined was 4.8 million tons or 40% of the average yearly total of 12.1 million tons, while 60% of the

The average strip mine production for the state of Kentucky in 1963 was 47.12 tons per man per shift while the average figure for underground mines was 17.03 tons per man per shift. During the same year, Muhlenberg County averaged 60.88 tons per man per shift and produced more coal than the total for the 18 coal producing counties of Indiana (Anon, 1972).

In 1966, 39% of the total coal produced in Kentucky, 36.4 million tons was surface mined. By 1970, surface mining accounted for 50% or 25.3 million tons. Huge machinery was still being produced. The largest shovel used in Kentucky in 1965 was a 115 cubic yard machine used at Paradise in Muhlenberg County (Anon, 1965).

Such large machinery often allows for greater strip-ping depth as well. The 1965 maximum depth of strippable coal was set at 150 feet. Anything deeper was considered economically unfeasible. But depth is not the only criteria of strip-ability of coal, topography and ease of disposal of the earth were also considered as well as quantity and quality of both coal and overburden. According to the Kentucky Geological Survey, most of the coal in western Kentucky is now under lease, including coal at depths of 1000 feet.

The initial question was "How did we allow 1.5 million acres of orphaned land to accumulate?" It happened not only in Williamson County, but in other counties and states as well, that strip mining became a feasible process at a most opportune time.

During the 1910 to early 1920's strip mining was introduced and a World War made it profitable. In southern Illinois this meant employment of miners who had lost jobs due to union-management disputes. From the middle 1920's through the 1930's, the Depression closed down most small businesses and mining operations and drastically reduced the operation of larger industries. Employment again was hard to come by for almost everyone including miners. Another war and greater demands for coal occurred in the 1940's. Huge earth moving equipment associated with the strip mines of today developed at the same time. Only since 1940 has mining developed into the large scale industry we know. After such hard times as were encountered in the beginning around 1920, the industry finally got moving in the late 1930's.

The young men in their 20's during the 1930's were lucky and happy to have work at that time. They worked hard to make strip mining a profitable industry, and they avoided looking back either to their past or to the trail their industry was leaving. Assuming these young men stayed with the company and were promoted regularly, they would now be in their mid-60's and high up in the company structure--high enough for the past several years, to influence company policy. Once they reached profit making status and started real industrial growth, these company policy makers and controllers could not and could not think in terms of anything but growth and profit. This is the mind-set of the

businessman. Add to this thinking, the body of a person who grew up in the lean years and it is no surprise that 1.5 million acres of land were strip mined before the idea of reclamation was ever voiced. Reclamation demands time, labor, machinery and money. Time, labor, machinery and money that these company policy makers and controllers would rather see stripping coal.

PALZO PROJECT

The two areas chosen for this study represent two different aspects of the problem of orphan strip mined land reclamation. The first of these areas is a 312 acre tract of land, 192 acres of which are in need of reclamation. The runoff from the tract is highly acidic with high concentrations of metal ions and sulfates and has ostensibly destroyed Sugar Creek at the north boundary. The tract, known as Palzo, is located in southeast Williamson County, Illinois. It was strip mined during the years 1959-1961 by the Stonefort Mining Company and left as unreclaimed orphan spoil. In 1966 the tract was purchased by the U.S. Forest Service and became part of the Shawnee National Forest.

The Illinois Sanitary Board in 1970 ordered reclamation of the area to stop pollution of Sugar Creek. Peabody Coal Company informed the Forest Service that shovels were used at Palzo to extract the coal rather than draglines. This meant that topsoil was mixed in with the spoil at the time of mining. When the tops of ridges would be leveled there would be no pockets of topsoil to spread over the area (Herman, 1974, unpublished M.Eng. thesis).

The method of reclamation chosen by the Forest Service was to incorporate digested sewage sludge, obtained from the Metropolitan Sanitary District of Greater Chicago, into the soil as a support medium for vegetational growth. This method was chosen rather than lime application because of more vigorous plant growth on test plots at Palzo where sludge

was applied.

The sewage sludge serves the multipurpose of providing nitrogen and phosphorus, a soil base, reducing the amount of runoff into Sugar Creek and reducing the amount of metal ions in that runoff. It also is a practical and useful means of disposal of the sludge.

The Forest Service began testing in November 1970 to determine rates of sludge application needed to attain the goals of plant growth and water pollution abatement. The treated waste was applied to the four plots at concentrations of 121, 71, 31, and 0 dry tons per acre. Each plot was seeded with K-31 tall fescue (Festuca arundinacea) and weeping lovegrass (Eragrostis curvula) at rates of 20 and 7 pounds per acre respectively. Complete ground cover was attained in two months on the 121 dry tons per acre plot with less growth on the other two and no growth on the control plot. The fescue began to wilt in late June when drought conditions prevailed but the lovegrass, a more drought resistant species remained viable. Root systems of both types of plants penetrated the earth only as deep as the level of sludge incorporation. Testing of the acid spoil beneath this area revealed that it had a pH of less than 3. Drainage from each of the four plots was collected and analyzed for chemical and bacterial characteristics. The results are given in Table III. (All of the above information, unless otherwise noted, is from the PALZO Environmental Impact Statement, 1972).

The acidic runoff at Palzo is a result of the oxidation of pyrites found in shale and coals. Upon contact with air and water, pyrite (FeS_2) is oxidized according to the equations:

Ferrous sulfate (FeSO_4) is further oxidized to ferric sulfate $\text{Fe}_2(\text{SO}_4)_3$.

This reaction proceeds further to form ferric hydroxide $\text{Fe}(\text{OH})_3$ or basic ferric sulfate $\text{Fe}(\text{OH})(\text{SO}_4)$.

(Hill, 1968)

This process is responsible for the contamination of Sugar Creek which in the region of Palzo is either orange $\text{Fe}(\text{OH})_3$ or mineral green $\text{Fe}(\text{SO}_4)_3$ in color. Table IV is a listing of the concentration values of various water quality parameters of the Palzo runoff and the proposed Illinois state standards as presented in the Palzo EIS (1972). There were several ponds on the tract which also had water quality comparable to the above. Figure 11 is a photograph of the drainage from one of these ponds near its outfall into Sugar Creek.

The high acidity and high sulfate concentration is probably due to the oxidation of framboidal pyrite. Caruccio (1974) determined that the coals from the lower sections of the Allegheny group "are overlain by strata indicative of marine or brackish paleoenvironments and are found to be rich in framboidal pyrite". His studies in the coalfields of

TABLE III. Percent Improvement in Metal Ion Concentrations
On the 121 Tons/Acre Plot (from Palzo EIS, 1972)

Parameter	Before Treatment <u>11/70</u>	After Treatment <u>5/71</u>	% Decrease
Aluminum	1120	120	89.3
Iron	3860	260	93.3
Manganese	64	10	84.4
Chromium	3.6	1.7	52.8
Copper	12.2	3.9	68.1
Zinc	31.8	19	40.3
Cadmium	1.44	0.95	34.1
Lead	0.32	0.21	34.4
Ammonia N	8.6	22.6	+262
Nitrate N	0.52	8.14	+152
Phosphorus	18.2	15.2	16.5
Calcium	79	525	+664
Sulfate	11000	3000	72.8
pH	2.45	5.93	
Bacteria	-	-	

TABLE IV. Ionic Concentration of Palzo Runoff and the
Proposed Illinois State Standards (from PALZO
EIS, 1972)

Parameter	Average Conc. <u>Palzo Runoff (mg/l)</u>	Proposed Ill. Standard (mg/l)
Iron	4000	0.5(dissolved) 2.0(total)
Aluminum	2000	-
Manganese	320	1.0
Magnesium	890	-
Copper	5.0	1.0
Zinc	20.0	1.0
Calcium	490	-
Chromium	2.00	0.30
Lead	0.25	0.10
Cadmium	0.81	0.15
Sulfate	23,700	-

FIGURE 11. Acid mine drainage entering Sugar Creek
as Palzo tract run-off

Pennsylvania revealed that though pyrite occurred in several forms--as euhedral crystals, coarse grained masses, coarse grained platy masses and framboidal pyrite--and sulfur is present in shales and coals in all the forms, only framboidal pyrite is correlated with the occasion of acid mine drainage. The DeKoven and Davis coal seams mined at Palzo are located stratigraphically at the top of the Spoon Formation which is correlated with the base of the Allegheny Formation. The high acidity and sulfate concentration of the Palzo runoff plus the stratigraphic location of the coal seams indicate the probable presence of framboidal pyrite in the shale and coals mined at Palzo.

Figure 12 is a diagrammatic representation of a geologic section at Palzo prepared from information in the Palzo EIS. Pyrite is present in the black shales that split the DeKoven coal seam and in the shales above the Davis coal.

After application of the sludge, the Forest Service plans to monitor chemical and biological characteristics of the test plot effluent and surface and subsurface drainage into Sugar Creek; biological characteristics in this instance are coliform bacterial counts.

The Forest Service planned chemical analysis of samples from Sugar Creek only immediately above and below Palzo. The author was granted permission by the Forest Service to perform analysis of water quality chemistry and diversity studies of benthic macro-invertebrate fauna of Sugar Creek before, during and after application of sludge. These analyses would then be used to further document the recovery of

FIGURE 12.

Geologic section at Palzo

GEOLOGICAL STRATA

CHARACTERISTICS

0 2 4 6 8 10 FT		GRANTSBURG AND WELLSTON SILT LOAM	LOESS DERIVED SOILS
	PALZO SANDSTONE	MEDIUM-GRAINED MASSIVE SANDSTONE
	DEKOVEN COAL
	BLACK SHALE	SHALE PARTING WITH ACID PRODUCING PYRITE
	DEKOVEN COAL
	UNDERCLAY AND SHALE	SHALE CONTAINS ACID PRODUCING PYRITE
	BLACK SHALE	BLACK CARBONACEOUS "SLATY" SHALE CONTAINS ACID PRODUCING PYRITE
	DAVIS COAL	

FIGURE 13.

Location of sampling stations on Sugar Creek

Sugar Creek and the restoration of Palzo. In order to assess the recovery and restoration, an idea of the normal chemical and biological characteristics of the stream was needed. Toward that goal, seven sampling stations were established along Sugar Creek. The locations of the sampling stations are shown in Figure 13.

Station 1 (Figure 14), is the sampling station farthest upstream from Palzo. The stream at this point is a shallow pool; leaves and mud form the stream bed substrate. The left side of the creek is a wooded area and the right side is a grassy field except for a 25 foot wide area of saplings and shrubs along the stream bank.

Station 2 (Figure 15) is a long riffle area with a base of bedrock and attached vegetation. The surrounding area is comprised of a wooded area on the right and grass fields 25 feet beyond the trees on the left.

Station 3 (Figure 16) is a pool with sand and silt substrate. Trees growing on a steep bank are the predominant vegetation of the right bank. Farm pasture and a few large trees are near the stream bank on the left.

Station 4 (Figure 17) is in a wooded area with steep limestone cliffs overgrown with mosses, ferns and small trees. The stream at this station is a three to four foot deep pool with a mud substrate. Stoney Branch, a smaller stream, empties into Sugar Creek between stations 4 and 5. Vegetation grows along the banks of Stoney Branch but it does receive runoff from gob piles and some strip mined areas.

FIGURE 14.

Facing upstream at station 1.
The pool area above the riffle in the center of
the photograph was the section sampled.

FIGURE 15.

Facing upstream at station 2.
The area in the foreground was the area sampled.

FIGURE 16.

Facing upstream at station 3.
The area sampled is in the immediate foreground.

FIGURE 17.

Looking across Sugar Creek at station 4.
The area sampled is slightly left of center in the photograph.
Stoney Branch is seen as it enters on
the opposite side of the stream.

FIGURE 18.

Looking upstream at station 5.
The area sampled is near the center of the picture.

FIGURE 19.

Station 6, facing upstream.
The area sampled is in the lower right of the photograph.

Station 5 (Figure 18) is a riffle with a slate, rubble and sand stream bed. The slate is washed into the creek from the gob piles during times of heavy rainfall. The surrounding characteristics are the same as those of Station 4.

Station 6 (Figure 19) is immediately upstream from Palzo in a woodland area with a mud and silt stream bed. This station is also a Forest Service sampling point.

Station 7 (Figure 20) is at the lower edge of the Palzo tract. Strip mines are the surrounding feature except for small area along the stream which were not mined and presently support small trees. The stream bed at this location is composed of fine silt and ferric hydroxide precipitate.

Reconnaissance trips of the study area were made in the summer and fall of 1972 to determine whether or not acid mine drainage was reaching Sugar Creek from additional sources. The first trip was made from station 5 to station 7. The second was made from station 5 upstream to station 3. No additional sources other than Stoney Branch between stations 4 and 5 were encountered. However, numerous log jams were encountered especially between stations 4 and 3. These log jams indicate a disturbed watershed. Excessive farming and timbering in the area have caused massive quantities of runoff to suddenly reach the creek during times of high flow. This sudden surge of water causes scouring of the stream banks and destruction of tree root foundations along the stream banks. The trees then fall

FIGURE 20.

Facing across Sugar Creek at station 7.
The area sampled is in the lower center of the photograph.

into the creek and either form log jams where they fall or are carried downstream to contribute further to established log jams. The stream is quite sinuous in this reach and it is probable that the log jams have become both cause and effect of the sinuosity. This also was the most picturesque area of the creek with moss and fern covered cliffs banking the stream on both sides.

Measurement of pH, conductivity, temperature and dissolved oxygen (DO) were performed in the field at the time of sampling. Analyses of hardness, iron, turbidity, sulfate, acidity and alkalinity were performed in the laboratory.

The measurement of pH was made with a Corning Model 610A pH meter for the October and December samplings and with an Orion Model 407 Specific Ion Meter at all times thereafter.

Conductivity was measured in $\mu\text{mhos/cm}$ with a Beckman Model RB3 SoluBridge conductivity meter.

A Yellow Springs Instrument Model 54 dissolved oxygen meter was used to measure dissolved oxygen in ppm and the accessory temperature probe was used to measure temperature in degrees Celsius.

Turbidity was measured in the laboratory with a Delta Scientific Corporation Photometric Analyzer which has a 2.5 cm light path. Results of the measurement are expressed in mg/L as SiO_2 .

Analyses of sulfate concentration were performed using Hach Chemical Co. Sulfa Ver III Powder Pillows of prepared

and pre-measured reagents. A standard concentration curve was prepared in our laboratory and measured photometrically with a Bausch and Lomb Spectronic 20 spectrophotometer.

Concentration of iron was determined by atomic absorption using a Bausch and Lomb atomic absorption spectrophotometer. Results of this analysis are expressed as ppm to a sensitivity of 0.11 ppm. Samples used for iron analysis were separate from other water samples and were preserved with 2 ml/250 ml of concentrated HCl or HNO₃.

Acidity and alkalinity were performed according to the procedures outlined in Standard Methods (1971) and endpoints were determined potentiometrically.

Alkalinity is expressed as mg/L CaCO₃ and determined as total alkalinity. The values listed in Tables V-XI were not corrected for the effect of CO₂. Acidity was expressed as mineral acidity when the pH of the solution was less than 4.5 and simply as total acidity of samples with a pH of 4.5 and higher.

Hardness, expressed as mg/L CaCO₃, was determined by use of Hach UniVer III Water Hardness Test Mixture and an EDTA titrating solution prepared and standardized in our laboratory.

Mean and standard error of the mean values for each parameter and each station are listed in Tables V through XI.

Values of pH for stations 1 through 5 follow the same pattern for all months sampled. The drop in pH at the time of sampling in March and May is thought to be the result of excess rainfall during these months. Herman (1974)

obtained rainfall data from monthly climatological data listings published by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) Environmental DATA service which lists 5.75 inches of rain in March, 7.33 inches in April, and 7.91 inches in May. These values are considerably higher than the 1.46 inches reported during the month of February.

Readings of pH taken at station 6 also follow the pattern noted above except for the October and March sample values. The pH listed for October is extremely low. Mr. Terry Lejcher of the U.S. Forest Service who was working on the Palzo restoration project, was present during the October sampling trip and assured the members of our group that such conditions did not exist a few days earlier. Further investigation revealed that a large strip pit of acid mine drainage had been drained into Sugar Creek a few hundred feet upstream from station 6. Such an occurrence, though tragic for the creek, did present a good opportunity to study the pattern of recovery of Sugar Creek from acid mine drainage in the area. The absence of water quality data at station 6 for the March sampling is due to inaccessibility during flood conditions.

The pH readings at station 7 show no correlation with the pattern exhibited at the other stations. During the periods of heavy rainfall in March, April, and May, the values did not change as they did at the other stations. All the runoff of the Palzo tract would flow past station 7 and it is thought that the effect of heavy rainfall would be

TABLES V - XI

SUGAR CREEK WATER QUALITY
PARAMETER UNITS

(H ⁺)	Moles/Liter
Turbidity	Milligrams/Liter as SiO ₂
Sulfate	Milligrams/Liter as SO ₄
Acidity	Milligrams/Liter as CaCO ₃
Alkalinity	Milligrams/Liter as CaCO ₃
Conductivity	Micromhos/centimeter
Iron	Parts per Million
Dissolved	
Oxygen	Parts per Million
Temperature	°Celsius
Hardness	Milligrams/Liter as CaCO ₃

TABLE V
WATER QUALITY AT STATION 1

	<u>(H⁺)</u>	<u>Turbidity</u>	<u>Sulfate</u>	<u>Acidity</u>
October	1.60 x 10 ⁻⁷	9 ± 1.00	167 ± 11.70	6 ± .55
December	3.66 x 10 ⁻⁷	1.3 ± .59	125 ± 3.43	6 ± .33
January	3.33 x 10 ⁻⁷	1.98 ± .09	145 ± 29.28	10.6 ± .36
February	2.63 x 10 ⁻⁷	3.0 ± .06	122 ± 8.22	
March	29.19 x 10 ⁻⁷		47.6 ± 4.67	8.4 ± 1.92
May	55.8 x 10 ⁻⁷		55.2 ± .41	12 ± .94
June	8.198 x 10 ⁻⁷	41.2 ± 2.61	45.8 ± 1.08	7.3 ± 1.58

	<u>Alkalinity</u>	<u>Iron</u>	<u>Conduc- tivity</u>	<u>D.O./ Temp.</u>	<u>Hardness</u>
October	75 ± 1.97		509 ± 4.93		
December	17 ± .55		297 ± 1.76		
January	24 ± 1.15	1.62	487 ± 8.33	13.8/0	
February		0.75	565 ± 6.67		
March	19.9 ± .23	1.25	109 ± 7.02	9.6/15	49 ± 0.67
May	24.6 ± 2.29		215 ± 2.56	10.2/16	89 ± 1.23
June	85.7 ± .94		250 ± 12.25		100 ± 0

TABLE VI
WATER QUALITY AT STATION 2

	<u>(H⁺)</u>	<u>Turbidity</u>	<u>Sulfate</u>	<u>Acidity</u>
October	1.76 x 10 ⁻⁷	7 ± .58	102 ± 12.18	6 ± .33
December	2.97 x 10 ⁻⁷	1 ± .24	131 ± 3.28	5 ± .47
January	3.39 x 10 ⁻⁷	2.2 ± .13	109 ± 3.60	10 ± .34
February	8.34 x 10 ⁻⁷	3.0 ± .13	134 ± 6.08	
March	40.07 x 10 ⁻⁷		33 ± 1.11	8.6 ± 1.15
May	54.18 x 10 ⁻⁷		55.8 ± 1.58	13 ± 1.15
June	5.23 x 10 ⁻⁷	12 ± .87	43.9 ± 2.18	7.8 ± .48

	<u>Alkalinity</u>	<u>Iron</u>	<u>Conduc- tivity</u>	<u>D.O./ Temp.</u>	<u>Hardness</u>
October	92 ± .58		346 ± 2.76		
December	19 ± .29		313 ± 13.76		
January	26 ± .33	1.85	479 ± 1.44	12/0	
February		0.85	571 ± 5.47		
March	19.2 ± .25	1.25	115 ± 2.12	9.6/15	49 ± 1.45
May	27.02 ± 1.02	0.65	215 ± 0	9.8/16	86 ± 1.80
June	66.5 ± 1.03	1.12	224 ± 6.40		94 ± 0.726

TABLE VII
WATER QUALITY AT STATION 3

	<u>(H⁺)</u>	<u>Turbidity</u>	<u>Sulfate</u>	<u>Acidity</u>
October	2.00 x 10 ⁻⁷	9.6 ± 1.32	109 ± 6.67	8 ± 1.28
December	2.91 x 10 ⁻⁷	1.8 ± .37	132 ± 4.69	5 ± .33
January	2.10 x 10 ⁻⁷	1.9 ± .21	115 ± 1.97	6.60 ± .24
February	1.30 x 10 ⁻⁷	2.9 ± .20	131 ± 13.38	
March	24.83 x 10 ⁻⁷		34 ± .55	8.1 ± .19
May	55.31 x 10 ⁻⁷		61. ± 3.81	12 ± 1.70
June	3.46 x 10 ⁻⁷	29 ± 7.50	48.2 ± 1.45	6.3 ± .69

	<u>Alkalinity</u>	<u>Iron</u>	<u>Conduc- tivity</u>	<u>D.O./ Temp.</u>	<u>Hardness</u>
October	107 ± .58		391 ± 12.11		
December	20 ± .55		318 ± 7.08		
January	27 ± 1.97	0.94	500 ± 2.36	12.6/1	
February		0.75	572 ± 1.67	10/17	
March	21.8 ± .41	2.0	116 ± 1.44	9.8/15	50 ± 0.94
May	26.1 ± .46	0.65	219 ± 1.44	10/15	91 ± 0.82
June	72.7 ± 1.07	0.85	240 ± 0		102 ± 0.94

TABLE VIII
WATER QUALITY AT STATION 4

	<u>(H⁺)</u>	<u>Turbidity</u>	<u>Sulfate</u>	<u>Acidity</u>
October	4.27 x 10 ⁻⁷	7.9 ± .36	153 ± 15.74	8 ± .87
December	2.68 x 10 ⁻⁷	2.9 ± .49	141 ± 2.64	5 ± .67
January	2.77 x 10 ⁻⁷	4.3 ± .32	119 ± 6.28	12.8 ± .20
February	1.9 x 10 ⁻⁷	5.8 ± .18	155 ± 12.27	
March	30.28 x 10 ⁻⁷		58 ± 1.63	11.2 ± .65
May	62.15 x 10 ⁻⁷		63 ± 3.74	14 ± 1.41
June	3.62 x 10 ⁻⁷	16 ± 6.82	43.4 ± 7.56	7.1 ± .58

	<u>Alkalinity</u>	<u>Iron</u>	<u>Conduc- tivity</u>	<u>D.O./ Temp.</u>	<u>Hardness</u>
October	32 ± 5.28		365 ± 25.28		
December	25 ± 1.25		348 ± 9.96		
January	38 ± .58	1.78	519 ± 3.63	14.2/0	
February		1.25	605 ± 4.08	14.5/8	
March	23.3 ± .11	3.45	125 ± 4.18	9.8/15	56 ± 0
May	33.2 ± .70	0.85	243 ± 1.67		97 ± 1.53
June	88.5 ± .76	0.65	258 ± 1.67		110 ± 1.45

TABLE IX
WATER QUALITY AT STATION 5

	<u>(H⁺)</u>	<u>Turbidity</u>	<u>Sulfate</u>	<u>Acidity</u>
October	53.08 x 10 ⁻⁷	12.7 ± 4.87	144 ± 8.89	8 ± 1.05
December	3.40 x 10 ⁻⁷	3.31 ± .69	142 ± 3.75	5.8 ± .55
January	3.00 x 10 ⁻⁷	4.6 ± .19	123 ± 4.99	14.8 ± 1.11
February	2.03 x 10 ⁻⁷	9 ± .43	160 ± 2.99	
March	51.05 x 10 ⁻⁷		64 ± 5.46	11.0 ± 1.42
May	57.97 x 10 ⁻⁷		61.07 ± .55	14 ± 1.54
June	3.83 x 10 ⁻⁷	62 ± 3.30	56.3 ± 1.47	9.7 ± 1.14

	<u>Alkalinity</u>	<u>Iron</u>	<u>Conduc- tivity</u>	<u>D.O./ Temp.</u>	<u>Hardness</u>
October	32 ± 3.45		339 ± 13.36		
December	24 ± 2.23		356 ± 8.35		
January	37 ± 1.00	2.32	530 ± 6.24	12.8/0	
February		1.12	606 ± 7.22	12.8/6	
March	22 ± 2.31	2.45	131 ± 2.76	9.8/15	56 ± 1.11
May	30.9 ± 2.69	0.85	240 ± 2.35		100 ± 0
June	73.6 ± 1.36	0.85	260 ± 0		115 ± 1.73

TABLE X
WATER QUALITY AT STATION 6

	<u>(H⁺)</u>	<u>Turbidity</u>	<u>Sulfate</u>	<u>Acidity</u>
October	8994.8 x 10 ⁻⁷	52 ± 23.8	3625 ± 1412	2275 ± 1037*
December	4.19 x 10 ⁻⁷	4.1 ± .36	152 ± 4.1	7 ± .33
January	4.60 x 10 ⁻⁷	3.5 ± .39	135 ± 2.5	23.2 ± .52
February	2.99 x 10 ⁻⁷	6.2 ± .22	162 ± 5.5	
March				
May	53.70 x 10 ⁻⁷		77.6 ± 4.5	17 ± 1.5
June	3.91 x 10 ⁻⁷	8 ± 1.3	62.06 ± 1.9	15.9 ± .51

	<u>Alkalinity</u>	<u>Iron</u>	<u>Conduc- tivity</u>	<u>D.O./ Temp.</u>	<u>Hardness</u>
October	3625 ± 1732**		3328 ± 967		
December	23 ± .29		370 ± 32		
January	32 ± .29	4.98	543 ± 5.15	12.8/0	
February		2.25	619 ± 1.4	13/7.5	
March					
May	26.1 ± 1.02	1.8	251 ± 4.3	10/15	109 ± 3.63
June	67.7 ± 9.2	1.25	298 ± 1.7		128 ± 3.27

*Mineral Acidity

**Total Acidity

TABLE XI
WATER QUALITY AT STATION 7

	<u>(H⁺)</u>	<u>Turbidity</u>	<u>Sulfate</u>	<u>Mineral Acidity</u>
October	12975 x 10 ⁻⁷	101 ± 27.92	11950 ± 1248	7825 ± 695
December	11258 x 10 ⁻⁷	44 ± 2.58	7125 ± 410.38	1875 ± 144.34
January	617.95 x 10 ⁻⁷	20 ± 1.78	450 ± 22.11	61.45 ± 9.96
February	2092 x 10 ⁻⁷	31 ± .47	595 ± 30.00	
March	674.9 x 10 ⁻⁷		125 ± 9.45	47.6 ± .97
May	2317 x 10 ⁻⁷		329.4 ± 97.34	115 ± 9.99
June	12215 x 10 ⁻⁷	59 ± 1.94	348 ± 8.61	

	<u>Total Acidity</u>	<u>Iron</u>	<u>Conduc- tivity</u>	<u>D.O./ Temp.</u>	<u>Hardness</u>
October	11050 ± 857		8055 ± 614		
December	3812 ± 139		1038 ± 49.30		
January	283.5 ± 9.96	64.17	983 ± 13.64	14.4/0	
February		49	1101 ± 11.15	12.4/7.5	
March	6.3 ± .41*	10.2	259 ± 1.44		97 ± 3.28
May	.276 ± 1.97	31.5	653 ± 6.87	10/15	578 ± 72.63
June	506 ± 4.62	66	1325 ± 55.28		383 ± 3.46

*Alkalinity

- FIGURE 21a Hydrogen ion concentration at stations
1-7 from October, 1972 to June, 1973
- FIGURE 21b pH at stations 1-7 from October, 1972
to June, 1973
- FIGURE 22 Turbidity at stations 1-7 from October,
1972 to June, 1973
- FIGURE 23 Sulfate concentrations at stations 1-7
from October, 1972 to June, 1973
- FIGURE 24 Acidity values at stations 1-7 from
October, 1972 to June, 1973
- FIGURE 25 Alkalinity measurements at stations 1-7
from October, 1972 to June, 1973
- FIGURE 26 Conductivity values at stations 1-7
from October, 1972 to June, 1973

Station 1 ○
Station 2 ●
Station 3 ×
Station 4 □
Station 5 ■
Station 6 △
Station 7 ▲

FIGURE 21a. Hydrogen ion concentration at stations 1-7
October, 1972 to June, 1973

FIGURE 21b. pH Values at Stations 1-7, October, 1972-
June, 1973

FIGURE 22. Turbidity at stations 1-7. October, 1972 to June, 1973

FIGURE 23. Sulfate concentrations at stations 1-7. October, 1972 to June, 1973

FIGURE 24. Acidity values at stations 1-7. October, 1972 to June, 1973

FIGURE 25. Alkalinity measurements at stations 1-7.
October, 1972 to June, 1973

FIGURE 26. Conductivity values at stations 1-7. October, 1972 to June, 1973

only to add more of the same runoff to Sugar Creek during those months.

A similarity of patterns is exhibited by turbidity readings at stations 1 through 5. A four to five-fold increase in turbidity for the month of June is coincident with and assumed to be the result of heavy rainfall during that and preceding months. Turbidity readings at station 6 are extremely high during October due to the inflow of acid mine drainage as previously noted. The turbidity values at station 7 were always high. These values are a result of combined turbidity and color due to the orange ferric hydroxide precipitate.

The sulfate concentration of natural waters is dependent upon the geologic assemblages of the watershed. The depositional environment of sedimentary rock in the Illinois Basin was conducive to the incorporation of much sulfate and sulfide oxidized to sulfate. At stations 1 through 5 during the samplings of October, December, January and February the sulfate values all remained equal to or greater than 100 mg/L concentrations. During the months of heavier rainfall, concentrations dropped to 60 mg/L or lower. This is a probable indication of the rapidity with which runoff flows into Sugar Creek. The top layers of soil are leached of sulfate gradually but it is removed quite rapidly. The amount of sulfate at station 6 during October is greater than that of December, January and February by more than an order of magnitude; however, at the next sampling, one month later, the sulfate concentration

at station 6 had returned to normal levels for Sugar Creek.

The sulfate concentration at station 7 was highest during October probably due to the extra effect of station 6, but it drops during succeeding months and is always higher than the other stations at the same time.

Acidity follows a consistent pattern among all stations except stations 6 and 7. Both total and mineral acidity were determined for the October sample at station 6 since the pH was less than 4.5 and mineral salts contribute to acidity in this range. Mineral acidity accounted for more than 50% of the total acidity for the October sample at station 6 and for the collections at station 7. The acidity values for station 7 are greater than for the other stations by two orders of magnitude.

Alkalinity is defined as the ability of a solution to accept hydrogen ions; carbonate and bicarbonate ions are the major contributors to alkalinity in natural waters. According to a USGS publication on characteristics of natural waters (Hem, 1970), most streams contain less than 200 mg/L of alkalinity. The alkalinity measurements at all areas of Sugar Creek not receiving acid mine drainage were below 110 mg/L; areas receiving acid mine drainage had reported alkalinity values of 0 mg/L since the pH of the solution was less than that of the alkalinity endpoint.

Public Health Standards for drinking water of 1962 (Hem, 1970) lists concentrations of iron greater than 0.3 mg/L as reason for the rejection of a water supply. Maxwell

and Devaul (1962) stated that soluble iron concentrations of greater than 1 or 2 ppm in surface waters "usually indicates acid wastes from mine drainage or other sources". The data presented in this paper concur with that statement. The values of soluble iron for samples taken at stations 1, 2, and 3 were always greater than 0.3 mg/L and below 2 ppm concentrations except at station 3 in the March flood period. Station 4 also exhibited values below 2 ppm except in March. The soluble iron concentrations at station 5, below Stoney Branch exceeded 2 ppm on January and March. Station 6 shows a gradual decline in iron concentrations after the strip pit was drained into Sugar Creek. Soluble iron concentrations at station 7 were continually high.

Measurements of conductivity for the first five stations and station 6, except in October, were similar in pattern. Conductivity at station 7 dropped to within the range of the other stations only during March and the time of high flow but later reattained the exceedingly high values typical of this station. Conductivity values during October and December at the first six stations, except October at station 6, are those of "normal" flow in Sugar Creek. The slightly higher readings of January and February at these stations are thought to be a reflection of conditions at a lower flow. During these winter months the ground is frozen most of the time and only a small amount of this surface runoff reaches the stream, thus the stream waters become more concentrated. These conditions are reversed during and after spring floods. The data for March, May, and June are

the lowest of the values for conductivity.

Dissolved oxygen measurements at all stations and at all times measured were below saturation but above the range of concern for this parameter. The measurements at station 7 cannot be considered highly accurate since salinity, which is known to influence this measurement was not taken into consideration.

Values listed for water hardness although expressed as mg/L CaCO_3 reflect the presence of iron and the probable presence of other heavy metals which were not measured. The hardness values at all stations were lowest in March but increased during succeeding months. Station 7, as expected, had hardness concentrations as much as five times greater than those reported at other stations.

DIVERSITY OF BENTHIC MACRO-INVERTEBRATE FAUNA IN SUGAR CREEK

Diversity indices are mathematical descriptions of biological community structure. Recently these indices have served as the conversational meeting ground between biologists, who long ago first recognized the concept of diversity in the form of species lists, and engineers who are more appreciative of quantitation. The literature of the subject of diversity indices is extensive, but the more significant contributions are reviewed in an article by Cairns (1973). Each index is an attempt to present the most effective mathematical way of stating that a greater variety of organisms, though probably a fewer number of each kind, signifies a healthy stream situation, whereas a large number of only a few different kinds of organisms indicates stress.

The diversity of the benthic macro-invertebrate fauna of Sugar Creek was included in the analyses at stations 1 through 6 to establish background data for this stream. As restoration of Palzo proceeded and the quality of the runoff was improved, the diversity measurements would show how the biological recolonization was progressing in that area. For this analysis organisms were identified to the taxonomic level of family and subsequently a family diversity value was computed for each sampling.

Five, one-quart samples of the top two to four inches of substrate were collected at each station and kept in a cooler until returned to the lab where they were stored in the refrigerator. Each sample was washed through 10 and 28

mesh wire sieves. The debris and organisms retained by the sieves were emptied into a 24 x 24 inch white enamel pan and carefully examined for benthic invertebrates. The organisms were collected from each sample and preserved in 75% ethyl alcohol. Later, the organisms were identified to the taxonomic level of family. The results of that identification are listed in Appendix A.

Family diversity was computed according to the mathematical formula used by Wilhm and Dorris (1968):

$$d = 1/N [\log_2 N! - \sum_{i=1}^s \log_2 N_i!]$$

where:

d = diversity per individual

n_i = number of individuals of the i-th species in the sample

n = total number of individuals in the population.

s = number of species

Diversity values were computed both for each sample and as a composite of the five samples taken at each station. The composite values for each station are listed in Table XII and a graphical plot of family diversity versus time is shown in Figure 27.

The diversity at station 2 as shown in Figure 27 is greater than for all other stations at all times sampled. Since station 2 is a riffle station, a high diversity would be expected.

Stations 1,3,4, and 5 show similar diversity in October and the following June. The general pattern of

TABLE XII
FAMILY DIVERSITY FOR SUGAR CREEK

	1	2	3	4	5	6	7
October	1.09	3.05	1.1	0.794	1.19	0.5	-
December	1.8	2.71	1.97	0.922	1.344	0.720	-
January	2.49	3.07	2.02	0.876	1.10	0.482	-
February	2.14	2.84	1.75	0.395	1.64	0.864	1.471
May	1.48	3.5	1.82	0.503	0.710	0.363	-
June	0.506	2.01	0.686	0.532	0.528	0.602	1.15

FIGURE 27.

Family diversity $[H = \frac{1}{N}(\log_2 N! - \sum \log_2 n_i!)]$
at Stations 1-7, October, 1972-June, 1973

- Station 1
- Station 2
- x Station 3
- Station 4
- Station 5
- △ Station 6
- ▲ Station 7

FIGURE 27. Family diversity $[H' = 1 / (\log_2 N! - \sum \log_2 n_i!)]$ at Stations 1-7, October, 1972-June, 1973

diversity at these stations during the intervening months is an increase in diversity until February when diversity values decrease, especially from May through June. This pattern is expected since during the winter months many insects reach the last instar stage or attain an increased larval size prior to emergence in the spring. This increase in size causes the organisms to be retained by the sieves and thus become part of the diversity calculations. Stoneflies (Plecoptera), for example, were recorded only during the winter months. The families collected during the June sampling are for the most part permanent inhabitants of the stream (Tubificidae, Mollusca, Dryopidae and Elmidae), inhabitants which spend the greater part of their life cycle in the stream and a shorter period as emerged adults (Sialidae) have lengthy life cycles (Gomphidae), or simply failed to emerge with the rest of their population (Ephemeridae and Baetidae).

The diversity values for station 6 present a unique observation for this stream. In October, a strip pit was drained into the creek about 100 feet upstream. This event destroyed the biota down stream from that point, thus the low diversity at that time. The diversity values fluctuate during the following months but by June this value is within the range of the cluster values for stations 1, 3, 4, and 5.

The results of diversity measurements for station 7 show the flaws of this analytical method. In October and January, station 7 had zero diversity. Three individuals in two families were collected in December when diversity rose

to 0.528. In February seven organisms in 5 families gave a diversity of 1.47 which is higher than the diversity for stations 4 and 6 at the same time. No organisms were collected during May. While the diversity at all other stations dropped in June, the diversity measured at Station 7 rose, the effect of twelve individuals in three families. The formula used to measure diversity in this study is inadequate when small numbers of individuals are sampled, as shown by the values obtained for station 7 in December. The families collected during February when the diversity value was the highest for that station, are not all typical pioneer species as shown by the recolonization of station 6. Although they were collected from Sugar Creek, those organisms are not thought to have actually begun to inhabit the area around station 7, but to have washed downstream from healthier areas. This situation exemplifies the danger of using diversity measurements alone. Knowledge of the niches and habitats of the families must accompany a diversity value if accurate information is to be obtained.

Several diversity indices appear in the literature which are based on information theory in addition to the one of Wilhm and Dorris discussed above. It was thought that possibly one of these indices might better describe the diversity of benthic invertebrate macro-fauna, especially at station 7. The indices used are (1) Cairn's Sequential Comparison Index which is:

$$\frac{\text{Number of Runs}}{\text{Number of Organisms}} \times \text{Number of different kinds of organisms}$$

where:

Runs = the number of times in a random sequential arrangement of the organisms, that one organism is different from the previous one.

(2) Simpson's Diversity Index:

$$\sum_{i=1}^n \pi^2$$

where:

π = the proportion of the i th species in the sample.

(3) Patten's Redundancy Calculation:

$$R = \frac{H_{\max} - H}{H_{\max} - H_{\min}}$$

where:

$$H = k(\log N! - \sum_{i=1}^s \log n_i!)$$

$$H_{\max} = k [\log N! - s \log (N/s)!]$$

$$H_{\min} = k \{ \log N! - \log [N - (s-1)]! \}$$

(4) Menhinick's Index:

$$D = S/\sqrt{N}$$

where:

S = number of species (in this study S = number of families)

N = total number of individuals in the sample.

(5) Margalef's Index:

$$D = s-1/\log_e N$$

where:

S and N are the same as above.

The positive and negative attributes of these indices have been variously discussed by Wilhm and Dorris (1966), Gaufin and Tarzwell (1952, 1956), Patten (1963), Archibald (1971), Brillouin (1960), Chutter (1972), and Pielou (1966).

A time-share BASIC computer program was composed to calculate the above indices from the information supplied. This information consists of a numerical listing of families and the number of individuals per family. A print-out of this program is included in Appendix B. The results of the analysis are listed in Table XIII and graphs of Family Diversity, Margalef's, Menhinick's and 1-Simpson's Indices for each station are included in Figures 28-34. For the sake of simplicity calculations of redundancy were reduced to $R = H_{\max} - H/H_{\max}$. $H_{\min}$ was taken to equal 0.

An analysis of these indices shows a positive correlation between Margalef's Index and Family Diversity, between 1-Simpson's Index and Family Diversity, between Cairn's SCI and Family Diversity, and between Redundancy and Simpson's Index. Any of these indices will generally give diversity information similar to that attained by Family Diversity analysis except Menhinick's Index. However, at several specific points, discrepancies did occur.

At Station 1 from October to December diversity is shown to increase using the Family Diversity Index, but to decrease using Margalef's Index, even though there is overall close correlation between the two indices. A closer correlation is observed at station 2 between these two indices. Menhinick's Index generally shows little correlation with any of the other indices except at specific points.

Family Diversity and 1-Simpson's Index show discrepancies at stations 1, 2, and 3. Generally, however, 1-Simpson's Index appears to mirror the trends of Family Diversity

TABLE XIII

ALL DIVERSITIES FOR SUGAR CREEK

	<u>Sta- tion</u>	<u>Total Fami- lies</u>	<u>Total Organ- isms</u>	<u>Runs</u>	<u>SCI</u>	<u>SCI DI</u>	<u>Simp- son's</u>	<u>l- Simp- son's</u>	<u>Diver- sity</u>	<u>Redun- dancy</u>	<u>Men- hin- ick's</u>	<u>Mar- galef</u>
October	1	11	453	182	.364	4.00	.650	.350	1.09	.853	.517	1.64
	2	25	319	419	.838	20.9	.150	.850	3.05	.558	1.40	4.16
	3	14	516	197	.394	5.51	.633	.367	1.10	.855	.616	2.08
	4	4	221	136	.272	1.08	.698	.302	.794	.875	.269	.556
	5	5	122	272	.544	2.72	.510	.490	1.19	.785	.453	.833
	6	2	4	229	.458	0.91	.625	.375	.5	.564	1	.721
	7	-	-	-	-	-	-	-	-	-	-	-
68 December	1	9	324	524	.648	5.83	.358	.642	1.80	.740	.5	1.38
	2	18	341	388	.776	13.9	.214	.786	2.71	.612	.975	2.92
	3	14	294	309	.618	8.65	.387	.613	1.97	.709	.816	2.29
	4	5	200	213	.426	2.13	.589	.411	.922	.852	.354	.755
	5	4	59	264	.528	2.11	.440	.560	1.34	.702	.521	.736
	6	5	192	134	.268	1.34	.729	.270	.720	.883	.361	.761
	7	2	3	253	.506	1.01	.556	.444	.528	.387	1.15	.910
January	1	17	148	384	.768	13.0	.231	.769	2.49	.571	1.40	3.20
	2	16	73	429	.858	13.7	.113	.887	3.07	.362	1.87	3.50
	3	10	46	354	.708	7.08	.308	.692	2.02	.516	1.47	2.35
	4	6	121	177	.354	2.12	.685	.315	.876	.841	.545	1.04
	5	3	14	290	.58	1.74	.429	.571	1.10	.575	.802	.758
	6	5	147	75	.15	.75	.46	.154	.482	.917	.412	.802
	7	1	1	1	.002	1	0	0	1	-	-	-

TABLE XIII (continued)

	<u>Sta- tion</u>	<u>Total Fami- lies</u>	<u>Total Organ- isms</u>	<u>Runs</u>	<u>SCI</u>	<u>SCI DI</u>	<u>Simp- son's</u>	<u>1- Simp- son's</u>	<u>Diver- sity</u>	<u>Redun- dancy</u>	<u>Men- hin- ick's</u>	<u>Mar- galef</u>
February	1	16	187	353	.706	11.2	.281	.719	2.14	.651	1.17	2.86
	2	15	82	420	.84	12.6	.173	.827	2.84	.428	1.66	3.18
	3	10	361	333	.666	6.66	.353	.647	1.74	.753	.526	1.53
	4	9	528	50	.1	.9	.891	.110	.395	.948	.392	1.28
	5	10	71	315	.63	6.3	.372	.628	1.64	.657	1.19	2.11
	6	7	157	148	.296	2.07	.685	.315	.864	.853	.559	1.19
	7	5	7	372	.744	3.72	.225	.776	1.47	.163	1.89	2.06
May	1	8	137	256	.512	4.09	.483	.516	1.48	.740	.683	1.42
	2	20	195	462	.924	18.4	.094	.906	3.5	.435	1.43	3.60
	3	8	52	351	.702	5.61	.313	.687	1.82	.580	1.11	1.77
	4	4	345	79	.158	.632	.816	.183	.503	.928	.215	.513
	5	5	26	122	.244	1.22	.722	.278	.710	.791	.981	1.23
	6	7	504	44	.088	.616	.904	.096	.363	.952	.312	.964
	7	-	-	-	-	-	-	-	-	-	-	-
June	1	6	126	88	.176	1.05	.836	.163	.506	.909	.535	1.03
	2	9	21	385	.77	6.93	.225	.776	2.01	.354	1.96	2.62
	3	3	9	200	.4	1.2	.629	.370	.686	.666	1	.910
	4	10	563	70	.14	1.4	.864	.136	.532	.931	.422	1.42
	5	2	3	239	.478	.956	.556	.444	.528	.387	1.15	.910
	6	9	336	99	.198	1.78	.831	.169	.602	.914	.491	1.38
	7	3	12	306	.612	1.83	.389	.611	1.15	.523	.866	.805

FIGURES 28.-34.

Graphic representation of four diversity indices
at Stations 1-7, October, 1972-June, 1973

- + Margalef's Index
- Family Diversity Index
- ⊙ Menhinick's Index
- 1-Simpson's Index

FIGURE 28. Graphic representation of four diversity indices at Station 1, October, 1972-June, 1973

FIGURE 29. Graphic representation of four diversity indices at Station 2, October, 1972-June, 1973

FIGURE 30. Graphic representation of four diversity indices at Station 3, October, 1972-June, 1973

FIGURE 31. Graphic representation of four diversity indices at Station 4, October, 1972-June, 1973

FIGURE 32. Graphic representation of four diversity indices at Station 5, October, 1972-June, 1973

FIGURE 33. Graphic representation of four diversity indices at Station 6, October, 1972-June, 1973

FIGURE 34. Graphic representation of four diversity indices at Station 7, October, 1972-June, 1973

but with smaller index values. At station 4 from May to June Family Diversity shows a slight increase while 1-Simpson's Index shows a decrease. At station 5 while 1-Simpson's Index shows an increase in diversity from October to December, Margalef's Index registers a decrease. However, from May to June, Family Diversity and Margalef's Index drop when 1-Simpson's Index increases. At station 6, Margalef's Index shows fewer fluctuations than Family Diversity and a gradual increase in diversity throughout the sampling period which is the expected trend. Under such circumstances Margalef's Index may be preferred over the other indices. The other indices at station 6 show various responses and Menhinick's Index show the highest diversity in October when most of the fauna had been obliterated. Cairn's SCI is closely correlated with Family Diversity when measurements were low but discrepancies occur when diversity is high. The results at station 7 were much the same for all indices.

With the exception of Menhinick's Index, all of the above indices are thought to be equally useful as a measurement of stream quality. Margalef's Index possibly is a superior measurement of recovery after stress but further study of this possibility is recommended. The situation at station 7 shows that diversity indices alone can produce misleading results. Knowledge of the particular habits and habitats of the families cannot be ignored; indeed, one could not conclude whether or not an index was useful without reference to the organisms involved.

The restoration of Palzo has been a learning experience for all concerned. Regrettably restoration was not completed before termination of this study. When Palzo was first visited by the author in February of 1972, it was a corrugated terrain and barren of all vegetation except on the 4 test plots. This condition had remained the same since Palzo was strip mined in 1959. Since that visit, progress has been made toward reclamation, but it has been slow, due to unforeseen complications.

A gauge to measure discharge of Sugar Creek was installed by the Forest Service at the down stream end of the Palzo tract - station 7. This meter was never put into operation since according to the hydrologist for the Shawnee National Forest, log jams and later silting in or disappearance of these jams causes severe fluctuations in discharge from time to time and a rating curve was thus impossible to establish.

Progress reports, circulated by the Forest Service since May 1974, cite problems of wet weather causing delay in construction of pipelines, leaks in storage lagoons, labor support disagreements with contractors, and adverse winter weather as some of the events which have delayed sludge application. The legal problems, economic problems, sociological problems, and technical problems are different but they must be solved whether recently mined land or orphan mined land is being reclaimed.

Although no final conclusions can be drawn as to the efficiency of using sludge to reclaim the orphan

strip mines at Palzo, this study has provided some valuable information. The introduction of acid mine drainage at Station 6 in October 1972 provided information concerning the progression of families of organisms as recolonization proceeds.

This event also demonstrated that chemical and physical parameters will indicate recovery long before biological indices confirm it. Once recovery is begun downstream at Station 7, it is expected to follow a pattern similar to that shown at Station 6.

One of the principal deterrents to recolonization by benthic fauna at Station 7 is thought to be the presence of ferric hydroxide precipitate and absence of a favorable substrate. For this reason it is anticipated that results of Palzo reclamation on the fauna of Sugar Creek at Station 7 may not be noticeable until after a voluminous wash-out occurs, such as during the floods of March. Although velocity measurements are lacking, visual observations showed that the velocity of Sugar Creek is extremely slow in the pool at Station 7. Ferric hydroxide precipitate and acid mine drainage will endure here for a considerable length of time in the absence of high flow.

CLEAR CREEK SWAMP

The second of the areas of orphan strip-mined land included in this study is the Clear Creek Swamp in Hopkins and Webster counties, Kentucky. Though not mined, most of the swamp is an effect of poor farming in the early years and poor strip mine practices on what are now acres of orphan spoil. It probably will never be reclaimed.

Clear Creek empties into the Tradewater River which in turn empties into the Dam 50 pool of the Ohio River. A better understanding of why Clear Creek will not be reclaimed is attained if one begins at the Ohio River and works back upstream. The elevation of the Ohio at the mouth of the Tradewater River is 320 feet above mean sea level. Upon completion of the high-head dam at Smithland, this elevation will be increased to 324 feet. The mouth of Clear Creek is 35 miles up the Tradewater and 333 feet above mean sea level. Thus the Tradewater drops 13 feet - soon to become 9 feet - over a distance of 35 miles or about 0.26 feet per mile (Grubb and Ryder, 1972). During periods of heavy rainfall, tributaries emptying into the Tradewater are backed up for a considerable time and distance.

Clear Creek, one of the tributaries which also has a shallow gradient, drops 35 feet from its headwaters to the mouth on the Tradewater, or at a rate of 1.8 feet per mile (Spencer, 1974). A consulting geologist for the 1961 Legislative Research Commission has noted that the Clear

Creek valley dropped from two to four feet during the years 1907-1961 (Quimby, 1961). Although Clear Creek has never had a steep gradient, the 1909 Earlington Quadrangle map shows it to have had a well-defined channel. This low gradient of Clear Creek was its eventual doom, for today, it is a 8,400 acre, acid mine drainage swamp (Grubb and Ryder, 1972).

According to a 1969 study of the Clear Creek Watershed (Watershed Work Plan, 1969), the condition of the Clear Creek Swamp is the result of both poor soil conservation techniques in farming and strip-mining in the upper basin. Although poor farming methods have caused increased erosion and later filling of stream channels, the deleterious effect on the swamp today is from acid mine drainage.

Coal mining has been a major economic resource of the area since the early 1900's and is no less of a factor today. Approximately 12,350 acres of the Clear Creek Watershed (9.8%) have been strip mined. In 1969, coal mining was reported to employ approximately 25% of the area's workforce (Watershed Work Plan, 1969). Total coal production in Hopkins County alone according to the U. S. Bureau of Mines (1945-1964) exceed 10 million tons per year for all years from 1950-1964; strip-mining accounted for 40% of the total.

A study by Shawler (unpublished M. Eng. thesis, 1974) shows that the water quality of Clear Creek is better at its mouth than in the upper reaches. Grubb and Ryder (1974) noted that the discharge at the mouth of Clear Creek during times of low flow were less than that near the source. They attributed the loss in flow to evapo-transpiration in the swamp and partially to temporary storage. It was concluded in Grubb and Ryder's study that the chemical constituents of the mine waters are being concentrated or stored in the swamp. Shawler's work indicates that the chemical constituents are not now being concentrated as much as they are being stored, deposited, or diluted.

The 1969 Clear Creek Watershed study lists sedimentation, erosion, and floodwaters as the major problems in the Clear Creek Swamp and estimates damages caused by such phenomena at \$409,335 annually based on a 1969 economy. The U. S. Army Corps of Engineers (Louisville District) consider draining the swamp and/or channelization of stream beds in the area of Clear Creek and the Tradewater to be economically unfeasible. This is a problem of orphaned strip mined and deep mined areas that will not and probably cannot be reclaimed. The area of mined land is too extensive. No estimates were found of how far the swamp may extend in the future.

This area has been a study area for students at the University of Louisville since 1969. Its history, and vary-

FIGURE 35.

Outline map of the Clear Creek Swamp and
Weirs Marsh system. Numbers are those
of the respective sampling points.

ing degrees of water quality lend themselves to several experimental situations. The studies center around one man's solution to the unreclaimable Clear Creek. Mr. Fred Steedly has a 600 acre farm which borders on Weirs Marsh near its confluence with Clear Creek (Figure 35). He constructed a levee in 1962 to keep the swamp from invading the bottomland of his farm. It is approximately 15 feet high and one and one half miles long. During the heavy winter and spring rains a freshwater lake forms inside the levee. An auger pump and two check valves were installed to reduce the lake to a 25 foot wide ditch along the inside edge. Windwaves and muskrats cause erosion of the levee which must be periodically repaired. Without the levee an approximate 40 acre field and a 10 acre hardwood forest, one of the last remaining stands in Hopkins and Webster counties, would be innundated.

The Weirs Marsh and levee ditch both have supported tremendous fish, reptile, amphibian and bird populations; however, the water outside the levee in the Weirs Marsh is not of the same good quality as that which collects inside the levee. Neichter (unpublished M. Eng. thesis, 1973) made a water quality survey of the levee ditch and Weirs Marsh, as well as other points along Clear Creek. His collecting stations are shown in Figure 35 and the data of that study is presented in Tables XIV-XIX. This data documents the previous statement that the backing up of Clear

TABLES XIV - XIX

CLEAR CREEK WATER QUALITY
PARAMETER UNITS

pH	Units
Temperature	°Celsius
Conductivity	Micromhos/centimeter
Hardness	Milligrams/Liter as CaCO_3
Alkalinity	Milligrams/Liter as CaCO_3
Acidity	Milligrams/Liter as CaCO_3
Sulfate	Milligrams/Liter as $\text{SO}_4^{=}$
Iron	Parts per million
Dissolved Oxygen	Parts per million

TABLE XIV

WATER QUALITY DATA - November 7, 1971

Station	1	2	3	4	5	6	7	8	9	10	11
pH	-	-	7.85	7.6	-	-	-	8.0	7.5	2.8	-
Temperature	-	-	20.0	14.0	-	-	-	25.0	13.9	20.0	-
Conductivity	-	-	310	620	-	-	-	1275	1300	1900	-
Hardness	-	-	290	520	-	-	-	1700	1470	2340	-
Alkalinity	-	-	49	100	-	-	-	105	128	0	-
Acidity	-	-	0	0	-	-	-	0	0	128	-
Sulfate	-	-	72	145	-	-	-	650	550	1100	-
Iron	-	-	0.10	0.06	-	-	-	0.06	0.35	16.94	-
D.O.	-	-	9.1	4.6	-	-	-	9.1	9.5	10.2	-

TABLE XV

WATER QUALITY DATA - January 16, 1972

Station	1	2	3	4	5	6	7	8	9	10	11
pH	-	-	-	6.5	-	-	-	7.9	6.5	3.3	-
Temperature	-	-	-	0	-	-	-	0	0	0	-
Conductivity	-	-	-	-	-	-	-	-	-	-	-
Hardness	-	-	-	965	-	-	-	993	968	587	-
Alkalinity	-	-	-	184	-	-	-	232	88	0	-
Acidity	-	-	-	34	-	-	-	16	27	77	-
Sulfate	-	-	-	730	-	-	-	580	890	480	-
Iron	-	-	-	0.25	-	-	-	0.05	0.20	3.00	-
D.O.	-	-	-	-	-	-	-	-	-	-	-

TABLE XVI

WATER QUALITY DATA - February 5, 1972

Station	1	2	3	4	5	6	7	8	9	10	11
pH	6.1	6.3	6.75	3.8	6.0	4.05	6.05	6.5	5.6	3.4	-
Temperature	2	2.0	2.0	4.0	3.0	2.0	0.5	2.0	2.0	2.0	-
Conductivity	350	560	350	950	400	975	1150	2100	1500	1125	-
Hardness	140	180	140	400	120	400	580	960	640	460	-
Alkalinity	70	95	90	0	92	0	86	1224	228	0	-
Acidity	2.5	4.0	1.7	480	1.3	15.0	4.0	36.0	6.4	56.0	-
Sulfate	97	175	101	390	82	328	505	925	690	495	-
Iron	0.20	0.25	0.25	2.0	0.05	0.9	0.2	0.05	0.25	2.2	-
D.O.	14.8	12.3	15.2	13.1	8.2	14.8	14.3	12.6	7.6	11.2	-

TABLE XVII

WATER QUALITY DATA - February 25, 1972

Station	1	2	3	4	5	6	7	8	9	10	11
pH	6.3	6.1	6.5	6.6	8.5	6.3	-	-	-	4.2	-
Temperature	6.1	6.3	6.8	6.0	6.7	6.8	-	-	10.0	9.0	-
Conductivity	265	340	180	690	220	540	-	-	470	465	-
Hardness	100	1300	600	260	700	210	-	-	133	215	-
Alkalinity	5	19.8	5	11	5	14	-	-	10	0	-
Acidity	4	4	4	3	6	7	-	-	7	17	-
Sulfate	62	90	24	160	30	167	-	-	92	162	-
Iron	0.5	2.5	3.5	1.5	2.0	2.0	-	-	3.0	1.25	-
D.O.	11.6	12.2	13.1	12.6	13.9	12.5	-	-	12.5	12.0	-

TABLE XVIII

WATER QUALITY DATA - March 24, 1972

Station	1	2	3	4	5	6	7	8	9	10	11
pH	7.0	6.65	6.6	6.65	7.2	7.05	-	-	6.8	3.2	6.75
Temperature	9.5	9.5	8.0	10.0	8.0	9.5	-	-	9.5	8.0	4.0
Conductivity	420	900	260	600	250	850	-	-	900	900	280
Hardness	90	318	70	322	54	306	-	-	244	66	80
Alkalinity	21	52	18	57	18	59	-	-	54	0	25
Acidity	32	25	27	19	18	25	-	-	34	140	25
Sulfate	46.6	248	30	100	30	100	-	-	140	120	26.6
Iron	1.25	1.0	0.5	0.3	0.5	0.3	-	-	0.5	1.5	0.5
D.O.	9.6	9.6	8.8	10.0	10.6	11.2	-	-	9.0	12.0	10.0

TABLE XIX

WATER QUALITY DATA - April 23, 1972

Station	1	2	3	4	5	6	7	8	9	10	11
pH	7.0	7.2	7.2	7.2	7.4	7.35	-	-	6.55	3.6	6.5
Temperature	21.0	20.0	18.0	19.0	18.5	19.5	-	-	14.0	18.0	14.0
Conductivity	320	360	250	400	235	395	-	-	395	875	300
Hardness	96	110	76	120	68	114	-	-	112	162	94
Alkalinity	-	-	-	-	-	-	-	-	-	-	-
Acidity	-	-	-	-	-	-	-	-	-	-	-
Sulfate	-	-	-	-	-	-	-	-	-	-	-
Iron	-	-	-	-	-	-	-	-	-	-	-
D.O.	10.4	10.0	8.4	10	12.0	10.4	-	-	13.0	11.4	8.7

Creek is polluting Weirs Marsh. Station 4 is the point nearest the confluence of Clear Creek and Weirs Marsh. In November and December the water quality of Station 4 was good. However, on February 5 its water quality was almost as poor as that of Station 10 further upstream on Clear Creek. Station 9 further upstream on Weirs Creek also shows a decrease in water quality on that date though not as great as that of Station 4. It also was on February 5 when Weirs Creek was reported to have been running backward. Water quality at both stations returned to near normal by February 23 and remained so through April of that year.

The biological quality of the area has also been the subject of several studies. Jageman (unpublished M. Eng. thesis, 1972) studied the bottom fauna of the levee ditch and the Weirs Marsh in the area of Station 6 (Figure 35). The results of his study of Chironomidae show a greater frequency of pollution tolerant chironomids in the levee ditch.

The Clear Creek-Weirs Marsh system has improved and developed some interesting ecosystems during recent times. Twenty years ago Hopkins County suffered from an infestation by the salt marsh mosquito (Aedes sollicitans) especially in areas around the Clear Creek swamp. This mosquito is commonly found in estuaries along the Gulf and Atlantic coasts. The female mosquito does not lay her eggs in or on the water but in the grass near the water's edge. Here the eggs dry

and mature until flood waters reach them. Within a few minutes from the time water contacts the eggs, they hatch. During hot summer months the entire life cycle from egg through larva, pupa and adult can take as little as 5 days (Stokes, 1967).

The first record of this mosquito in western Kentucky was at Fort Knox in 1953. In 1955 the State Department of Health carried out an emergency mosquito control program and aeriaily sprayed 15,000 acres in and around Hopkins County. It is theorized that the eggs of Aedes sollicitans were brought in by migrating waterfowl which are abundant in this area. The eggs fell into the water, hatched and the population grew at an almost exponential rate. An idea of the magnitude of the problem is presented in a study by Stokes (1967). According to this study, the Clear Creek watershed has approximately 15,000 acres of land which would meet the habitat requirements of Aedes sollicitans. He reports that 20,000 eggs have been found in 1 square foot of such habitat. If one assumes a less rigorous figure of 1,000 mature adults emerging from this square foot area, the results are 2.6136×10^{12} mosquitoes in the Clear Creek Swamp for a yearly mosquito production estimate of 1.3068×10^{13} mosquitoes. Stokes reported an annual cost from this infestation to be \$4,107,900 (1969 dollars). Weirs Marsh is assumed to have made a significant contribution to the extent of mosquito breeding areas based on the

TABLE XX
WATER QUALITY PARAMETERS OF CLEAR CREEK WATERSHED

	<u>Lower Swamp</u>	<u>Weirs Marsh</u>	<u>Upper Swamp</u>
pH	4.5 - 3.0	5.6 - 7.5	4.2 - 2.9
Acidity ppm	115 - 180	0 - 10	17 - 217
Sulfate ppm	950 - 1200	550 - 925	162 - 1145
Iron ppm	2 - 17	1.0	1 - 19
Conductivity	950 - 2600	1300 - 2100	465 - 3500

TABLE XXI

DIVERSITY OF BENTHIC MACRO-INVERTEBRATE
FAUNAL POPULATIONS IN THE CLEAR CREEK WATERSHED

<u>Family</u>	<u>Lower Swamp</u>	<u>Weirs Marsh</u>	<u>Upper Swamp</u>
Asellidae		41	
Astacidae		10	
Belostomatidae		4	
Chironomidae	24	5	290
*Coenagrionidae		2	
*Corixidae	17	3	34
Culicidae		1	
Cyrenidae		12	
*Dytiscidae adults	140	15	6
*Dytiscidae larvae	26	29	
Ephemeridae		1	
Gammaridae		58	
Gerridae	2		
*Gyrinidae	14	1	
*Haliplidae adults	1	4	
*Haliplidae larvae	5	3	
Heleidae	2		7
*Hydrophilidae adults	1	2	3
*Hydrophilidae larvae			1
Lepidoptera		1	
*Lestidae		6	
*Libellulidae		4	
Lumbricidae	2	1	
Physidae		10	
*Sialidae			34
Tabanidae		1	1
Total	234	213	376
Family Diversity	1.67	3.07	1.10

*Known or suspected to be predators of Culicidae (mosquitoes).

TABLE XXII
DISSOLVED OXYGEN PROFILES IN WEIRS MARSH,
SPRING AND SUMMER 1974

<u>Season</u>	<u>Condition</u>	<u>Temper- ature</u>	<u>D.O.-6 inches below surface</u>	<u>D.O. on bottom of marsh</u>
Early May:	top of <u>Chara</u> beds 3 inches below surface	17°C	15.3	9.7
Late May:	<u>Chara</u> beds reaching to surface	22°C	9.3	5.8
Early June:	water level dropping below top of <u>Chara</u> beds	22°C	11.2	3.2
Late June:	water level droppking further, active decay of <u>Chara</u>	23°C	1.0	0

fact that Clear Creek does reduce the quality of water in that area during spring floods. It is then probably that the number of mosquitoes calculated for Clear Creek in the Stokes report is low.

The immediate solution to this problem was extensive and heavy aerial spraying of DDT in the area of the Clear Creek swamp during the years 1956 to 1960. Since that time spraying was continued but less intensively than before. In recent years the mosquito problem has become only a minor one. Although spraying definitely reduced the mosquito population, observations and collection of other macro-invertebrates which now inhabit parts of Clear Creek and Weirs Marsh point to a possible biological control of the mosquito population.

During the spring and summer of 1974, collections were made in three areas: in the lower Clear Creek swamp near Station 12, in Weirs Marsh near Station 4, and in the upper swamp near Station 11 (Figure 35). Water quality parameters representing average values for the area are given in Table XX. A list of the families of macro-invertebrate benthic fauna collected at these stations and the Family Diversity calculations are given in Table XXI.

Of the families listed as known or suspected predators of Culicidae, 83% are either in the order Coleoptera (beetles) or Odonata (damselflies and dragonflies). The beetles in both the adult and larval stages feed on both

mosquito larvae and pupae. Hinman (1934) reported that under laboratory conditions, a single beetle (Dytiscidae: Dytiscus sp.) devoured 434 mosquito larvae in two days. The Odonata prey upon mosquito larvae and pupae in the water and later as adults they feed on adult mosquitoes. While the nymphal stages of the Odonata tabulated in Table XXI are not numerous, the harder-to-capture adults are present by the thousands and are a constant aestival phenomenon in this area.

In addition to these predator-prey relationships which apparently are helping suppress the number of mosquitoes in the area, certain plant associations are thought to be having the same effect. Unlike the Palzo project which has the hope that reclamation will stop the acidic runoff and subsequent destruction of Sugar Creek, the Clear Creek swamp has no such hope. The Palzo project is costing in excess of \$2,000,000 to reclaim 192 acres. The problems in the Clear Creek swamp cost \$4,500,000 for mosquito control and \$409,335 for annual upkeep and maintenance of roads, fences, etc. based on a 1969 economy, but residents of Hopkins County still have the 10,000 acre swamp and it's still growing.

The problem could have been worse by the amount of acreage strip mined since 1966 in Kentucky and 1963 in Illinois. In these years the respective states passed stringent reclamation laws and Kentucky included provision for the reclamation of orphaned land.

RECLAMATION LAWS OF KENTUCKY AND ILLINOIS

The first reclamation legislation in Kentucky was introduced in 1948. It was never acted upon by the legislature. A second law was proposed in 1950 but it was amended to the point of being ineffective. In 1952, a third attempt was made to introduce strip mine legislation but special interest groups saw to it that the bill was not passed (Journal of the Senate, 1954).

The first strip mine law was passed in 1954. It was introduced on January 21 by Senator Moloney of Fayette County, as Senate Bill 45 (SB45), "An Act relating to strip mining and the conservation and reclamation of natural resources affected thereby." Nine days previous to that Lawrence W. Wetherby, then governor of Kentucky addressed the General Assembly meeting in joint session and called for approval of this bill. He cited the "effective but reasonable" strip mine bill which was to be introduced at this session and urged that it be passed for the dignity of the entire commonwealth.

On January 28, 1954, S.B. 45 was passed by the senate by a vote of 22-14 and became Kentucky Revised Statute (KRS) 350. The law was amended and strengthened by the legislature in 1956, 1960, 1962, 1964 and 1966. The amendments of 1966 included section 350.152:

"Acquisition of land by commonwealth for reclamation purposes (1) The commonwealth, acting by and through its department of natural resources, shall have the power to acquire, either by negotiation or by exercise of the power of eminent domain, land which has been affect or disturbed by strip or auger mining, which consists of orphan banks or unreclaimed spoil piles, and which in its present state is hazardous or otherwise detrimental to the health and safety of the citizens of the commonwealth and for the restoration of which federal funds have been made available."

This was the first legislative acknowledgement of the problem of orphan strip mines. Legislation was now in existence in Kentucky which permitted the restoration of the lands which had been strip mined and abandoned since the mid-1800's, provided federal funds were available.

In 1972, House Bill 3 (HB3) gave the thereby created Department of Environmental Protection and Natural Resources the "authority, power, and duty to. . . provide for the control, and regulation of strip mining and reclamation in a manner to accomplish the purpose of KRS 350." This bill later became KRS 224.

The federal government once again addressed itself to the problem of reclamation with the 1974 Federal Strip Mine Bill. This bill was vetoed by President Ford. The 1975 Federal Strip Mine Bill was in the House Interior Committee as of February 26, 1975 where provisions for the reclamation of orphan land were being defended against administrative attempts to eliminate or weaken them. Representative Sam Steiger (R-Ariz) proposed the elimination of a land reclamation fund from the bill. The proposal was rejected along

with a companion proposal to move the responsibility of reclamation from the Interior Department to the Department of Agriculture. A defender of the original version, Representative Morris Udall (D-Ariz) stated that such changes would eliminate the reclamation program. The funding of the program is proposed to come from a reclamation fee of 35 cents-per-ton for strip mine coal and 10 cents a ton for deep mined coal. The federal administration proposed in 1974 a 10 cents per ton fee for both types based on the premise that the greater fee would "produce more money than needed for orphan land reclamation (Courier Journal, February 26, 1975).

The Illinois strip mine laws are found in the Illinois Revised Statutes (IRS) Chapter 93, Sections 180.1 to 180.15 in that chapter were known as the Surface-Mined Land Reclamation Act enacted in 1961. It was amended in 1963 and 1967. This act was repealed when IRS 93 sections 201-216, the Surface-Mined Land Conservation and Reclamation Act became effective September 17, 1971.

The Kentucky law and Illinois law though they differ in certain respects, require similar degrees of reclamation. The Illinois law however is not controlled by the Department of Environmental Protection and Natural Resources as it is in Kentucky but is still under the jurisdiction of the Department of Mines and Minerals. The Illinois law also does not have a section devoted to reclamation of orphan land.

How the coal companies dealt with the added costs of reclamation was the subject of a 1967 study by Brooks (1967). In western Kentucky, these costs are met in two ways. In the short run the cost was absorbed by the company. In the long run the costs of reclamation are accounted for by lowering the unit cost of production. The latter is accomplished by employing technological advances and expanding production to increase efficiency. Larger companies then can better afford the cost of reclamation since they can produce more coal. Brooks concluded that increased costs of reclamation reduced output and employment in the short run but in house technological changes restored them in the long run.

His study, however, was not addressed to orphan mines. "Conditions existing after mining is completed are generally accepted much like a sunk investment cost and reclamation plans proceed from that point." (Brooks, p. 68)

This may be the route taken by coal companies throughout the nation. In the proceedings of "Hearings before the Subcommittee on Mines and Mining" in the House of Representatives, 92nd Congress, 1971, Russell Train, Chairman of the Council on Environmental Quality cited the Kentucky statute (KRS 350) as a good state statute. Kentucky's reclamation law was held up as a model for federal legislation. The 1975 federal strip mine bill which passed both the House and Senate and was awaiting presidential

action as of March 31, 1975 has an added clause that the Kentucky statute lacks, a 10-25¢ per ton deep mined coal and a 35¢ per ton strip mine coal fee. These funds are to be used for the reclamation of orphan land.

DISCUSSION AND CONCLUSIONS

This study has had as its objective an interdisciplinary look at the problem of reclamation of orphan strip mines. It was found that each of the aspects of geology, history, water quality chemistry, aquatic biology, economics and law have orphan characteristics of their own which contribute to the whole problem of reclamation of the orphan land.

The stratigraphy of formations overlying the coal have been destroyed in the process of strip mining creating an orphan geology. Such action has resulted in secondary effects on the chemistry, hydrology, and biology. Acid mine drainage which results from the oxidation of pyrite formed under the anaerobic conditions of Paleozoic swamps is one of, if not, the major problem associated with strip mines. The amount of acid mine drainage runoff from the strip mines varies in amount and location. Carruccio (1974) correlated the presence of framboidal pyrite with the occurrence of acid mine drainage and thus presented a method to predict the occurrence of the problem in future mining endeavors. The problem of orphan mines still remains as non-point source runoff of acid mine drainage.

Once the runoff reaches a receiving stream, it affects the stream's chemistry in all parameters measured in this study. The further oxidation of pyrite leads to the formation of ferric hydroxide precipitate. This with

the precipitation of clay and soil from the freshwater runoff causes excess siltation in streams and the formation of acid mine drainage swamps and bogs.

This change in water quality chemistry of streams and their sediments affects the biota of the stream. When the incidence of acid mine drainage is most severe macro-invertebrate faunal populations are non-existent. This was the case of Sugar Creek in Williamson County, Illinois below the Palzo strip mines. Here the stream sediment was a gelatinous ferric hydroxide precipitate. This coupled with extremely acidic water, excluded a biota for the stream. Under less stringent conditions, when forest, field or farm runoff is present with acid mine drainage, a special type of ecosystem develops as in parts of the Clear Creek Swamp. Clear Creek is a serious problem, however. An 8,400 acre swamp with an unstable future will also have an unstable ecosystem which may result in the recurrence of such problems as the salt marsh mosquito infestation of 20 years ago.

In addition to the geologic history, the archeological history was also destroyed by the process of strip mining. At Palzo two Indian artifacts, an arrowhead and a scraper, were found in the spoil. This is a possible indication of previous Indian occupation. In western Kentucky the Parrish site was destroyed by strip mining. This site was of particular historical interest because it is thought to have been an intermediate culture between that of the Paleo-

and Archaic Indian cultures.

The more current history of the people who live in surrounding areas is a reflection of both orphan and recent strip mines. Initially underground mining employed many men at the turn of the century. A World War's need for coal brought about strip mining on a larger scale. In the early years before strip mining became so highly mechanized, it also created many jobs. First in Illinois and later in Kentucky, labor management disputes began and smaller mines were forced to close. The Depression of the 1930's further slowed production in all mines and forced several more to close. The demands of a second World War's need for coal brought forth the gigantic machinery like that of today. As mentioned earlier, we allowed 1.5 million acres to be strip mined and abandoned because strip mining became feasible at a most opportune time. The larger, more efficient, machinery required fewer man-hours. The people of many coal mining communities witnessed draglines destroy both their farms and towns, as well as many job opportunities. Of the farms still in existence, many were returned to the farmers in an almost sterile condition. "It just don't seem to grow things like it used to." (Barnhill, 1972)

Kentucky passed its first law to regulate the degree of reclamation of strip mines in 1954. The first stringent law and the first to have a section addressed to the problem of orphan land reclamation was passed in 1966. Illinois has

a similar law first passed in 1961, but it not addressed to the orphan mine problem. The economics of reclamation of 40,000 acres of land and 4,000 acres of water in western Kentucky (Anon, 1972) and 7,000 acres in Williamson County (Cunningham, 1975) is prohibitive. A nation with a 60 billion dollar national debt cannot afford another 3 to 25 billion dollar cost for orphan land reclamation.

Kentucky received \$500,000 for this purpose from the federal government in 1974. Job Corps labor was used to regrade some of this land near Madisonville, Kentucky (Michael Vaughn, Reclamation Officer, Madisonville, Kentucky. Personal communication, 1974). When these funds become available, the decision must be made as to how they are to be spent. Based on experience from this study, the following suggestions are made: (1) Any area not producing acid mine drainage or producing amounts which can be neutralized by the receiving stream should not be disturbed; (2) Any area with a viable ecosystem should not be disturbed. To begin reclamation in these areas will often result in the exposure of more pyrite to oxidation and the production of acid mine drainage. (3) Areas to be reclaimed should include those with the most severe acid mine drainage problems. (4) Reclamation of such areas should include fertilizing and reseeding as soon after regrading as possible, preferably the same season. Some of the regraded areas of Palzo became severely eroded due to complications in the schedule of

sludge delivery; thus application of sludge and seeding were postponed until after further regrading. It is further suggested that the above standards be observed if federal 10 and 35¢ per ton fee for coal mined funds become available. That then is the status of orphaned land today, most of it still orphaned.

This dissertation was also conceived as an educational outline. The information contained herein is an interdisciplinary look at the problem of orphan strip mines which could be used as a starting point for future studies in the seven areas previously mentioned, or as a beginning for continuance of interdisciplinary studies in this area. The latter possibility would apply to the education of reclamation officers and engineers dealing with the problem of strip mined land reclamation.

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VITA

The author, Clara Ann Leuthart, is the daughter of Earl Anthony and Lois (Hosick) Leuthart. She was born February 1, 1946 in Louisville, Kentucky.

Her elementary education was obtained at Christ the King Grade School, Louisville, Kentucky, and secondary education at Loretto High School, Louisville, Kentucky, where she was graduated in 1964.

In September, 1964 she entered Catherine Spalding College with a Mother Rose Meagher Scholarship, and in May, 1968, received the degree of Bachelor of Science with a major in biology.

From September, 1968 until May, 1969 she taught biology, chemistry, general science and health at St. Catherine High School, New Haven, Kentucky.

In September, 1969 she was awarded a teaching assistantship in the Department of Biology at the University of Louisville. During the summer of 1970 she was a technician on an NIH study of sulphur metabolism in Salmonella typhimurium. In September, 1970 she was awarded an NSF traineeship for one year. In August, 1971 she was graduated with the degree of Master of Science.

In September, 1972, she began study in the Interdisciplinary Program of the Graduate School at the University of Louisville toward the degree of Doctor of Philosophy. She was awarded a teaching assistantship in September of 1972 and a research assistantship in July, 1973. Projects in which she participated as a laboratory and field analyst include the Environmental Impact Analysis of the Cannelton, Newburgh, and Uniontown Dams, and the 201 Water Quality and Management Planning Study of the Louisville SMSA. As a part of these studies she obtained national certification (YMCA) as a scuba diver in May, 1974.

APPENDIX A
BENTHIC MACRO-INVERTEBRATE DATA FOR
SUGAR CREEK, ILLINOIS

Station 1
October 28, 1972

	1	2	3	4	5	0
Agriionidae						
Annicolidae	2					
Amphizoidae						
Ancyclidae						
Annelida						
Asellidae						
Astacidae						
Paetidae				1		1
Chironomidae	21	223	25	87	5	361
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae	1			1		2
Empidae						
Ephemeridae				1		1
Gammaridae						
Glossiphoniidae						
Gomphidae						
Haliplidae						
Heleidae		2		2	1	5
Heptageniidae			1			1
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae	3					3
Planorbidae						
Psychodidae						
Psychonidae					2	2

	1	2	3	4	5	0
Pyrallidae						
Rhyacophilidae						
Sialidae	1		1	2		4
Simuliidae						
Smynturidae						
Sphaonidae	11	9	1	1	2	24
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae						
Tubificidae	5	33	2	4	5	49
Total Families	7	4	5	8	5	11
Total Organisms	44	268	30	99	15	453
Runs	342	150	154	129	365	182
SCI	4.788	1.20	1.54	2.064	3.65	4.004
Simpson's	0.311	0.715	0.702	0.776	0.262	0.650
1-Simpson's	0.689	0.285	0.298	0.224	0.738	0.350
Diversity	1.81	0.774	0.768	0.703	1.63	1.09
Redundancy	0.56	0.884	0.786	0.866	0.393	0.853
Menhinick's	1.06	0.244	0.913	0.804	1.29	0.517
Margalef's	1.59	0.537	1.18	1.52	1.48	1.64

Station 2
October 28, 1972

	1	2	3	4	5	0
Agrionidae	1					
Amnicolidae						
Amphizoidae						
Ancyridae			1			1
Annelida						
Asellidae						
Astacidae						
Baetidae	1	9	35		31	76
Chironomidae	7	9	11	1	31	69
Chloroperlidae						
Chordodidae	1					1
Coenagrionidae		2		1		3
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae	5	1	11		2	19
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae			2	1	1	4
Haliplidae						
Heleidae		1				1
Heptageniidae	2		1			3
Hydrachnidae					3	3
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae	6					6
Hydroptilidae						
Leptoceridae						
Libellulidae		2				2
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae	1					1
Perlidae						
Perlodidae		1				1
Phryganeidae						
Physidae	4	25	4	4	3	40
Planorbidae					1	1
Psychodidae						
Psychomyiidae		1				1

	1	2	3	4	5	0
Pyrilidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smytnuridae						
Sphaenidae	10	7	15	9	2	43
Stratiomyidae			1			1
Succineidae	1	1			2	4
Tabanidae	2					2
Tipulidae	27			1		28
Tubificidae		5		2		7
Total Families	13	12	10	7	10	25
Total Organisms	43	64	82	19	77	319
Runs	436	378	379	380	341	419
SCI	11.336	9.072	7.58	5.32	6.82	20.95
Simpson's	0.131	0.213	0.255	0.291	0.330	0.150
1-Simpson's	0.869	0.787	0.745	0.709	0.670	0.850
Diversity	2.73	2.41	2.17	1.72	1.85	3.05
Redundancy	0.331	0.479	0.563	0.424	0.621	0.558
Menhinick's	1.98	1.5	1.10	1.61	1.14	1.40
Margalef's	3.19	2.64	2.04	2.04	2.07	4.16

Station 3
October 28, 1972

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae					1	1
Annelida						
Asellidae						
Astacidae					1	1
Baetidae					3	3
Chironomidae	5	103	151	97	46	402
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae	2		1		1	4
Empidae						
Ephemeridae	1		1	1		3
Gammaridae						
Glossiphoniidae						
Gomphidae						
Haliplidae						
Heleidae	1	1		3	1	6
Heptageniidae						
Hydrachnidae			1			1
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae	1				1	2
Planorbidae					1	1
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyrallidae						
Rhyacophilidae						
Sialidae					2	2
Simuliidae						
Smythuridae						
Sphaenidae	2	1	3	1		7
Stratiomyidae						
Succineidae						
Tabanidae	1					1
Tipulidae						
Tubificidae	38	17	4	11	12	82
Total Families	8	4	6	5	10	14
Total Organisms	51	122	161	113	69	516
Runs	204	131	65	138	271	197
SCI	3.264	1.048	0.78	1.38	5.42	5.516
Simpson's	0.569	0.732	0.881	0.747	0.479	0.633
1-Simpson's	0.431	0.268	0.119	0.253	0.521	0.367
Diversity	1.22	0.666	0.408	0.705	1.48	1.10
Redundancy	0.716	0.880	0.931	0.870	0.687	0.855
Menhinick's	1.12	0.362	0.473	0.470	1.20	0.616
Margalef's	1.78	0.624	0.984	0.846	2.13	2.08

Station 4
October 28, 1972

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyelidae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae	18	2	3		7	30
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae		3	3		2	8
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae	1					1
Gammaridae						
Glossiphoniidae						
Gomphidae						
Halipidae						
Heleidae						
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyrallidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smythuriidae						
Sphaeriidae						
Stratiomyidae						
Succinidae						
Tabanidae						
Tipulidae						
Tubificidae	110	10	20		42	182
Total Families	3	3	3	0	3	4
Total Organisms	129	15	26	0	51	221
Runs	104	235	202		143	136
SCI	0.624	1.41	1.21		0.858	1.09
Simpson's	0.747	0.502	0.618		0.699	0.698
1-Simpson's	0.253	0.498	0.382		0.301	0.302
Diversity	0.610	0.992	0.851		0.719	0.794
Redundancy	0.891	0.630	0.750		0.833	0.875
Menhinick's	0.264	0.775	0.588		0.420	0.269
Margalef's	0.412	0.739	0.614		0.509	0.556

Station 5
October 28, 1972

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae	8	6	1	12	4	31
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae				8		8
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Halipidae						
Helidae						
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae					1	1
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyrallidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smynthuridae						
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae						
Tubificidae	28		24	2	27	81
Total Families	2	1	2	3	4	5
Total Organisms	36	6	25	22	33	122
Runs	176	1	46	278	164	272
SCI	0.704	0.002	0.184	1.668	1.31	2.72
Simpson's	0.654	1	0.923	0.439	0.686	0.510
1-Simpson's	0.346	0	0.077	0.562	0.314	0.49
Diversity	0.690	0	0.186	1.13	0.757	1.19
Redundancy	0.820	1	0.945	0.645	0.796	0.785
Menhinick's	0.333	0.408	0.4	0.64	0.696	0.453
Margalef's	0.279	0	0.311	0.647	0.858	0.833

Station 6
October 28, 1972

	1	2	3	4	5	0
Aggrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae						
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidac						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Halipidae						
Helicidae						
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae					1	1
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
<u>Pyrallidae</u>						
<u>Rhyacophilidae</u>						
<u>Sialidae</u>					3	3
<u>Simuliidae</u>						
<u>Smythuridae</u>						
<u>Sphaenidae</u>						
<u>Stratiomyidae</u>						
<u>Succineidae</u>						
<u>Tabanidae</u>						
<u>Tipulidae</u>						
<u>Tubificidae</u>						
Total Families	0	0	0	0	2	2
Total Organisms	0	0	0	0	4	4
Runs					229	229
SCI					0.916	0.916
Simpson's					0.625	0.625
1-Simpson's					0.375	0.375
Diversity					0.5	0.5
Redundancy					0.564	0.564
Menhinick's					1	1
Margalef's					0.721	0.721

Station 7
October 28, 1972

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae						
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Haliplidae						
Heleidae						
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
<u>Pyrallidae</u>						
<u>Rhyacophilidae</u>						
<u>Sialidae</u>						
<u>Simuliidae</u>						
<u>Smythuridae</u>						
<u>Sphaenidae</u>						
<u>Stratiomyidae</u>						
<u>Succineidae</u>						
<u>Tabanidae</u>						
<u>Tipulidae</u>						
<u>Tubificidae</u>						
<u>Total Families</u>	0	0	0	0	0	0
<u>Total Organisms</u>	0	0	0	0	0	0
<u>Runs</u>						
<u>SCI</u>						
<u>Simpson's</u>						
<u>1-Simpson's</u>						
<u>Diversity</u>						
<u>Redundancy</u>						
<u>Menhinick's</u>						
<u>Margalef's</u>						

Station 1
December 2, 1972

	1	2	3	4	5	0
Agriionidae						
Amnicolidae						
Amphizoidae						
Ancyclidae						
Annelida						
Asellidae						
Astacidae						
Baetidae		3		6	1	10
Chironomidae	13	65	12	6	45	141
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae	5				1	6
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Haliplidae						
Heleidae	5	4		4	2	15
Heptageniidae						
Hydrachnidae		1				1
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae			13			13
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae	1				3	4
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyrallidae						
Rhyacophilidae						
Sialidae	1				2	3
Simuliidae						
Smynthuridae						
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae						
Tubificidae	71	30	6	9	15	131
Total Families	6	5	3	4	7	9
Total Organisms	96	103	31	25	69	324
Runs	217	277	303	371	269	524
SCI	2.60	2.77	1.82	2.97	3.77	5.83
Simpson's	0.571	0.486	0.363	0.270	0.477	0.358
1-Simpson's	0.429	0.514	0.637	0.730	0.523	0.642
Diversity	1.18	1.241	1.35	1.666	1.380	1.80
Redundancy	0.773	0.765	0.629	0.502	0.708	0.740
Menhinick's	0.612	0.493	0.539	0.8	0.843	0.5
Margalef's	1.095	0.863	0.582	0.932	1.42	1.38

Station 2
December 2, 1972

	1	2	3	4	5	6
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae	1	1	2	1	1	6
Astacidae						
Baetidae	1		8		13	22
Chironomidae						
Chloroperlidae	12	2	7	4	24	49
Chordodidae						
Coenagrionidae	1		1		1	3
Culicidae	1					1
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae	1	3		7	18	29
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae					1	1
Halipidae						
Heleidae	1		1	1	5	8
Heptageniidae				1		1
Hydrachnidae	1		2		1	4
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae				3		3
Hydroptilidae						
Leptoceridae			1	1	1	3
Libellulidae						
Lumbricidae	1			1	2	4
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae	2	2	6	2	1	13
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae	1				1	2

	1	2	3	4	5	0
Pyrallidae						
Rhyacophilidae		1	2			3
Sialidae						
Simuliidae						
Smythuridae						
Sphaenidae	56	2	13	9	53	133
Stratiomyidae						
Succinidae						
Tabanidae						
Tipulidae						
Tubificidae	29	1	4	4	18	56
Total Families	13	6	12	11	14	18
Total Organisms	108	9	50	34	140	341
Runs	314	407	420	427	390	388
SCI	8.16	4.88	10.08	9.39	10.92	13.97
Simpson's	0.354	0.185	0.143	0.156	0.216	0.214
1-Simpson's	0.646	0.815	0.857	0.844	0.784	0.786
Diversity	1.83	1.719	2.69	2.48	2.47	2.71
Redundancy	0.659	0.162	0.373	0.341	0.569	0.612
Menhinick's	1.25	2.00	1.70	1.89	1.18	0.975
Margalef's	2.56	2.28	2.81	2.84	2.63	2.92

Station 3
December 2, 1972

	1	2	3	4	5	• 0
Agriionidae						
Amnicolidae						
Amphizoidae						
Ancyclidae				2	3	5
Annelida						
Asellidae						
Astacidae						
Baetidae	1				1	2
Chironomidae	6	6	31	25	106	174
Chloroperlidae						
Chordodidae						
Coenagrionidae					2	2
Culicidae						
Diptera						
Dolchopodidae						
Dryopidae						
Dytiscidae						
Elmidae		1			1	2
Empidae						
Ephemeridae	5	2	7			14
Gammaridae						
Glossiphoniidae						
Gomphidae						
Halipidae						
Heleidae	1	5	6	1	3	16
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae		1				1
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae		1			1	2
Planorbidae		1				1
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyralidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smythuridae						
Sphaenidae		2	3	1		6
Stratiomyidae						
Succineidae						
Tabanidae		1				1
Tipulidae	22					22
Tubificidae	3	2	2	2	37	46
Total Families	6	10	5	5	8	14
Total Organisms	38	22	49	31	154	294
Runs	285	426	284	187	236	309
SCI	3.42	8.52	2.84	1.87	3.776	8.65
Simpson's	0.385	0.161	0.441	0.661	0.533	0.387
1-Simpson's	0.615	0.839	0.559	0.339	0.467	0.613
Diversity	1.57	2.30	1.44	0.870	1.22	1.97
Redundancy	0.599	0.277	0.662	0.761	0.792	0.709
Menhinick's	0.973	2.13	0.714	0.898	0.645	0.816
Margalef's	1.37	2.91	1.03	1.16	1.39	2.29

Station 4
December 2, 1972

	1	2	3	4	5	0
Agriionidae						
Amnicolidae						
Amphizoidae						
Ancylidae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae	6	9	2	28	8	53
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae	1					1
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae					1	1
Elmidae						
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Haliplidae						
Heleidae						
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyrallidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smythidae						
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae					1	1
Tubificidae	13	4	65	16	46	144
Total Families	3	2	2	2	4	5
Total Organisms	20	13	67	44	56	200
Runs	236	214	17	257	139	213
SCI	1.42	0.856	0.068	1.03	1.11	2.13
Simpson's	0.515	0.574	0.942	0.537	0.696	0.589
1-Simpson's	0.485	0.426	0.058	0.463	0.304	0.411
Diversity	0.952	0.730	0.166	0.877	0.742	0.922
Redundancy	0.688	0.709	0.965	0.786	0.833	0.852
Menhinick's	0.671	0.555	0.244	0.302	0.535	0.354
Margalef's	0.668	0.390	0.238	0.264	0.745	0.755

Station 5
December 2, 1972

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae	4	6			3	13
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Halipidae						
Heleidae						
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae	2	5			1	8
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyralidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smythuridae						
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae				2		2
Tipulidae						
Tubificidae	25	9	2			36
Total Families	3	3	1	1	2	4
Total Organisms	31	20	2	2	4	59
Runs	184	314	1	1	186	264
SCI	1.10	1.88	0.002	0.002	0.744	2.11
Simpson's	0.671	0.355	1	1	0.625	0.440
1-Simpson's	0.329	0.645	0	0	0.375	0.560
Diversity	0.755	1.31	0	0	0.5	1.344
Redundancy	0.792	0.571	1	1	0.564	0.702
Menhinick's	0.539	0.671	0.707	0.707	1	0.521
Margalef's	0.582	0.668	0	0	0.721	0.736

Station 6
December 2, 1972

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae						
Astacidae						
Baetidae		1				1
Chironomidae	6		12	3	4	25
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae			2			2
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Halplidae						
Heleidae			1		1	2
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyralidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smythuridae						
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae	1					1
Tipulidae						
Tubificidae	24	19	59	10	50	162
Total Families	3	2	4	2	3	5
Total Organisms	31	20	74	13	55	192
Runs	164	43	179	180	83	134
SCI	0.984	0.172	1.43	0.72	0.50	1.34
Simpson's	0.638	0.905	0.663	0.645	0.832	0.729
1-Simpson's	0.362	0.095	0.337	0.355	0.168	0.271
Diversity	0.779	0.216	0.826	0.628	0.437	0.720
Redundancy	0.786	0.929	0.829	0.749	0.901	0.883
Menhinick's	0.539	0.447	0.465	0.555	0.405	0.361
Margalef's	0.582	0.334	0.697	0.390	0.499	0.761

Station 7
December 2, 1972

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae						
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Halipidae						
Heleidae						
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyrilidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smythridae						
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae	1					1
Tipulidae						
Tubificidae						
Hemipterans	2					2
Total Families	2					2
Total Organisms	3					3
Runs	253					253
SCI	1.01					1.01
Simpson's	0.556					0.556
1-Simpson's	0.444					0.444
Diversity	0.528					0.528
Redundancy	0.387					0.387
Menhinick's	1.15					1.15
Margalef's	0.910					0.910

Station 1
January 14, 1973

	1	2	3	4	5	0
Agriionidae						
Amnicolidae						
Amphizoidae						
Ancylidae						
Annelida						
Asellidae				1	3	4
Astacidae						
Baetidae		1			2	3
Chironomidae		2	3	12	11	28
Chloroperlidae						
Chordodidae			1			1
Coenagrionidae						
Culicidae			1			1
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae			1			1
Empidae						
Ephemeridae						
Gammaridae					1	1
Glossiphoniidae						
Gomphidae			1			1
Haliplidae						
Heleidae	1					1
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae	4	1	9	5	5	24
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae	1			1	1	3
Planorbidae				1	2	3
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyrallidae						
Rhyacophilidae						
Sialidae					2	2
Simuliidae						
Smythuriidae						
Sphaenidae	3	1	2	29	24	59
Stratiomyidae						
Succinidae						
Tabanidae		2				2
Tipulidae	2		7		4	13
Tubificidae		1				1
Total Families	5	6	8	6	10	17
Total Organisms	11	8	25	49	55	148
Runs	373	409	378	300	388	384
SCI	3.73	4.91	6.05	3.6	7.76	13.06
Simpson's	0.256	0.188	0.235	0.422	0.252	0.231
1-Simpson's	0.744	0.813	0.765	0.578	0.748	0.769
Diversity	1.55	1.66	1.97	1.43	2.21	2.49
Redundancy	0.324	0.131	0.411	0.664	0.500	0.571
Menhinick's	1.51	2.12	1.60	0.857	1.35	1.40
Margalef's	1.67	2.40	2.17	1.28	2.25	3.20

Station 2
January 14, 1973

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae	4				3	7
Astacidae						
Baetidae		2			2	4
Chironomidae	5	3		1	1	10
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae		1			3	4
Empidae						
Ephemeridae						
Gammaridae	1				2	3
Glossiphoniidae					1	1
Gomphidae						
Halipidae						
Heleidae	1				1	2
Heptageniidae						
Hydrachnidae		1				1
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae			1	2	1	4
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda			2			
Nemouridae	2	3		2	6	13
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae			1			1
Psychomyiidae						

	1	2	3	4	5	0
Pyrilidae	1					1
Rhyacophilidae	1				1	2
Sialidae						
Simuliidae						
Smythuridae						
Sphaenidae	3	1				4
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae						
Tubificidae	2	3		2	7	14
Total Families	9	7	3	4	11	16
Total Organisms	20	14	4	7	28	73
Runs	415	419	225	363	437	429
SCI	7.47	5.87	1.65	2.90	9.61	13.72
Simpson's	0.155	0.173	0.375	0.265	1.48	0.113
1-Simpson's	0.845	0.827	0.625	0.735	0.852	0.887
Diversity	2.25	1.97	0.896	1.33	2.46	3.07
Redundancy	0.263	0.241	0.218	0.244	0.296	0.362
Menhinick's	2.01	1.87	1.50	1.51	2.08	1.87
Margalef's	2.67	2.27	1.44	1.54	3.00	3.50

Station 3
January 14, 1973

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae				1		1
Annelida						
Asellidae	1					1
Astacidae						
Baetidae				3		3
Chironomidae						
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae			1			1
Gammaridae	1			1		2
Glossiphoniidae						
Gomphidae						
Halipidae						
Heleidae	2		1	1	1	5
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae				5		5
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae	1					1
Planorbidae	2		1			3
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyralidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smyntauridae						
Sphaenidae						
Stratiomyidae						
Succinoidea						
Tabanidae						
Tipulidae						
Tubificidae	5			17	2	24
Total Families	6	0	3	6	2	10
Total Organisms	12	0	3	28	3	46
Runs	387		341	292	225	354
SCI	4.64		2.05	3.50	0.9	7.08
Simpson's	0.25		0.333	0.416	0.556	0.308
1-Simpson's	0.75		0.667	0.584	0.444	0.692
Diversity	1.66		0.862	1.43	0.528	2.02
Redundancy	0.309		0	0.59	0.387	0.516
Merhinick's	1.73		1.73	1.13	1.15	1.47
Margalef's	2.01		1.82	1.50	0.910	2.35

Station 4
January 14, 1973

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae						
Astacidae						
Baetidae		/				/
Chironomidae		//	/		2	14
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae			/			/
Gammaridae						
Glossiphoniidae						
Gomphidae						
Halipidae						
Heleidae						
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millinidae						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyidae						

	1	2	3	4	5	0
Pyralidae						
Rhyacophilidae						
Sialidae	3				2	5
Simuliidae						
Smythuriidae						
Sphaenidae	1					1
Stratiomyidae						
Succinellidae						
Tabanidae						
Tipulidae						
Tubificidae	65	6	17		11	99
Total Families	3	3	3	0	3	6
Total Organisms	69	18	19	0	15	121
Runs	47	268	103		249	177
SCI	0.282	1.61	0.618		1.49	2.12
Simpson's	0.890	0.488	0.806		0.573	0.685
1-Simpson's	0.110	0.512	0.194		0.427	0.315
Diversity	0.315	0.987	0.443		0.867	0.876
Redundancy	0.933	0.662	0.852		0.677	0.841
Menhinick's	0.361	0.707	0.688		0.775	0.545
Margalef's	0.472	0.692	0.679		0.739	1.04

Station 5
January 14, 1973

	1	2	3	4	5	0
Agriionidae						
Amnicolidae						
Amphizoidae						
Ancyclidae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae					4	4
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryonidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Haliplidae						
Heleidae						
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae			1		1	2
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	6
Pyralidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smythuridae						
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae						
Tubificidae	1				7	8
Total Families	1	0	1	0	3	3
Total Organisms	1	0	1	0	12	14
Runs	1		1		267	290
SCI	0.002		0.002		1.60	1.74
Simpson's	1		1		0.458	0.429
1-Simpson's	0		0		0.542	0.571
Diversity	0		0		0.996	1.10
Redundancy	1.7×10^{38}		1.7×10^{38}		0.586	0.575
Menhinick's	1		1		0.866	0.802
Margalef's	0		0		0.805	0.758

Station 6
January 14, 1973

	1	2	3	4	5	0
Agriionidae						
Amnicolidae						
Amphizoidae						
Ancyelidae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae	2		4		1	7
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Halipidae						
Heleidae						
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae	1					1
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyrallidae						
Rhyacophilidae						
Sialidae					1	1
Simuliidae						
Smytnauridae						
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae						
Timulidae	1		1	1		3
Tubificidae	128	2	2		3	135
Total Families	4	1	3	1	3	5
Total Organisms	132	2	7	1	5	147
Runs	21	1	278	1	323	75
SCI	0.168	0.002	1.668	0.002	1.938	0.75
Simpson's	0.941	1	0.428	1	0.44	0.46
1-Simpson's	0.059	0	0.571	0	0.56	0.154
Diversity	0.205	0	0.959	0	0.864	0.482
Redundancy	0.964	1	0.454	1.7×10^{38}	0.374	0.917
Menhinick's	0.348	0.707	1.13	1	1.34	0.412
Margalef's	0.614	0	1.03	0	1.24	0.802

Station 7
January 14, 1973

	1	2	3	4	5	0
Agriionidae						
Amnicolidae						
Amphizoidae						
Ancyclidae						
Annelida						
Asellidae						
Astacidae						
Bactidae						
Chironomidae						
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolchipodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Haliplidae						
Heleidae						
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomiidae						

	1	2	3	4	5	0
Pyralidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smythuridae						
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae					/	/
Tubificidae						
Total Families	0	0	0	0	/	/
Total Organisms	0	0	0	0	/	/
Runs					/	/
SCI					0.002	0.002
Simpson's					/	/
1-Simpson's					0	0
Diversity					0	0
Redundancy					1.7×10^{38}	1.7×10^{38}
Menhinick's					/	/
Margalef's					0	0

Station 1
February 23, 1973

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoridae						
Anovelidae						
Annelida						
Asellidae						
Astacidae					1	1
Bactidae					2	2
Chironomidae	10		5	14	13	42
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae	1			1	1	3
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae	1					1
Haliplidae						
Heleidae				2	1	3
Heptageniidae						
Hydrachnidae						
Hydraenidae					1	1
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae		1			4	5
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae					1	1
Planorbidae					1	1
Psychodidae						
Psychomyiidae					1	1

	1	2	3	4	5	0
Pyralidae						
Rhyacophilidae					1	1
Sialidae						
Simuliidae						
Smythuriidae						
Sphaenidae	7	2	6	28	1	44
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae	1				1	2
Tubificidae	34	1	7	35	1	78
Total Families	7	3	3	5	14	16
Total Organisms	55	4	18	80	30	187
Runs	267	292	321	340	383	353
SCI	3.74	1.75	1.93	3.4	10.72	11.29
Simpson's	0.433	0.375	0.340	0.345	0.222	0.281
1-Simpson's	0.567	0.625	0.660	0.655	0.778	0.719
Diversity	1.477	0.896	1.323	1.58	2.32	2.14
Redundancy	0.666	0.218	0.547	0.679	0.354	0.651
Menhinick's	0.944	1.5	0.707	0.559	2.56	1.170
Margalef's	1.50	1.44	0.692	0.913	3.82	2.87

Station 2
February 23, 1973

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae						
Astacidae						
Beetidae						
Chironomidae	1		19	9	1	30
Chloroperlidae			3			3
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae	1		3			4
Empidae			2		1	3
Ephemeridae						
Gammaridae		1		1	2	4
Glossiphoniidae						
Gomphidae						
Haliplidae						
Helodidae	6					6
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae				1	1	2
Hydroptilidae						
Leptoceridae			4	1		5
Libellulidae						
Lumbricidae				1		1
Lymnaeidae						
Millipede						
Muscidae		1				1
Nematoda						
Nemouridae		1	4	2	2	9
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae			1			1

	1	2	3	4	5	6
Pyrilidae			3	1	2	6
Rhyacophilidae						
Sialidae						
Simuliidae						
Smythuridae						
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae	2		1			3
Tubificidae	2		2			4
Total Families	5	3	10	7	6	15
Total Organisms	12	3	42	16	9	82
Runs	319	324	382	320	414	420
SCI	3.19	1.94	7.64	4.48	4.97	12.6
Simpson's	0.319	0.333	0.244	0.352	0.185	0.173
1-Simpson's	0.681	0.667	0.756	0.648	0.815	0.827
Diversity	1.445	0.862	2.24	1.55	1.7	2.84
Redundancy	0.398	0	0.445	0.440	0.162	0.428
Menhinick's	1.44	1.73	1.54	1.75	2	1.66
Margalef's	1.61	1.82	2.41	2.16	2.28	3.18

Station 3
February 23, 1973

	1	2	3	4	5	0
Agriionidae						
Amnicolidae						
Amphizoidae						
Ancyclidae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae	14	4	126	7	5	156
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolchopodidae						
Dryopidae						
Dytiscidae						
Elmidae	6		1			7
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Haliplidae						
Heleidae						
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydrotillidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae			1			1
Millipede						
Muscidae						
Nematoda						
Nemouridae	1			3		4
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae			1	1		2
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyrilidae						
Rhyacophilidae						
Sialidae	2					2
Simuliidae						
Smynthuridae						
Sphaonidae	1		35	8		44
Stratiomyidae						
Succineidae						
Tabanidae	1					1
Tipulidae	2		1	1		4
Tubificidae	68	3	37		32	140
Total Families	8	2	7	5	2	10
Total Organisms	95	7	202	20	37	361
Runs	241	255	300	333	130	333
SCI	386	1.02	4.2	3.33	0.52	6.66
Simpson's	0.539	0.510	0.453	0.31	0.766	0.353
1-Simpson's	0.461	0.490	0.547	0.69	0.234	0.647
Diversity	1.3	0.733	1.40	1.545	0.506	1.745
Redundancy	0.749	0.583	0.776	0.494	0.869	0.753
Menhinick's	0.821	0.756	0.493	1.12	0.329	0.526
Margalef's	1.54	0.514	1.13	1.34	0.277	1.53

Station 4
February 23, 1973

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae						
Astacidae						
Baetidae					1	1
Chironomidae	1	3	1	6	8	19
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae	1			1		2
Empidae						
Ephemeridae					1	1
Gammaridae					2	2
Glossiphoniidae						
Gomphidae						
Haliplidae						
Heleidae				2	1	3
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae					1	1
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyralidae						
Rhyacophilidae						
Sialidae					1	1
Simuliidae						
Smythuriidae						
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae						
Tubificidae	235	97	25	69	72	498
Total Families	3	2	2	4	8	9
Total Organisms	237	100	26	78	87	528
Runs	11	41	55	105	145	50
SCI	0.066	0.164	0.22	0.84	2.32	0.9
Simpson's	0.983	0.942	0.926	0.789	0.695	0.891
1-Simpson's	0.017	0.058	0.074	0.211	0.305	0.110
Diversity	0.066	0.173	0.181	0.582	0.902	0.395
Redundancy	0.990	0.967	0.947	0.881	0.821	0.948
Menhinick's	0.195	0.2	0.392	0.453	0.858	0.392
Margalef's	0.366	0.217	0.307	0.689	1.57	1.28

Station 5
February 23, 1973

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae	1					1
Astacidae						
Baetidae	1					1
Chironomidae	28	2				30
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Halipidae						
Heleidae	1					1
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae	1					1
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae	1				1	2
Nematoda						
Nemouridae		2				2
Onophronidae						
Perlidae						
Perlodidae		1				1
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyralidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smythuridae						
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae	1					1
Tubificidae	31					31
Total Families	8	3	0	0	1	10
Total Organisms	65	5	0	0	1	71
Runs	323	303			1	315
SCI	5.17	1.82			0.002	6.3
Simpson's	0.414	0.36			1	0.372
1-Simpson's	0.586	0.64			0	0.628
Diversity	1.41	0.981			0	1.64
Redundancy	0.698	0.290			1.7×10^{38}	0.657
Menhinick's	0.992	1.34			1	1.19
Margalef's	1.67	1.24			0	2.11

Station 6
February 23, 1973

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyelidae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae	9	4	1	4	4	22
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae		1			1	2
Dryopidae						
Dytiscidae						
Elmidae					1	1
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae					1	1
Gomphidae						
Halipidae						
Heleidae	2					2
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae		1				1

	1	2	3	4	5	0
Pyralidae					1	1
Rhyacophilidae						
Sialidae						
Simuliidae						
Smythuriidae						
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae						
Tubificidae	41	29	30	19	9	128
Total Families	3	4	2	2	6	7
Total Organisms	46	35	31	23	17	157
Runs	111	157	11	159	315	148
SCI	0.666	1.26	0.044	6.36	3.78	2.07
Simpson's	0.801	0.701	0.938	0.713	0.349	0.685
1-Simpson's	0.199	0.299	0.062	0.287	0.651	0.315
Diversity	0.515	0.730	0.160	0.571	1.49	0.864
Redundancy	0.876	0.808	0.956	0.824	0.477	0.853
Menhinick's	0.442	0.676	0.359	0.417	1.46	0.559
Margalef's	0.522	0.844	0.291	0.319	1.76	1.19

Station 7
February 23, 1973

	1	2	3	4	5	0
Acerionidae						
Amnicolidae						
Amphizoidae						
Ancyelidae						
Annelida						
Asellidae						
Astacidae						
Baetidae				1	1	2
Chironomidae		2				2
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Haliplidae						
Heleidae		1				1
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae				1		1
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyrilidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smythuridae				1		1
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae						
Tubificidae						
Total Families	0	2	0	3	1	5
Total Organisms	0	3	0	3	1	7
Runs		140		320	1	372
SCI		0.56		1.92	0.002	3.72
Simpson's		0.556		0.333	1	0.225
1-Simpson's		0.444		0.667	0	0.776
Diversity		0.528		0.862	0	1.471
Redundancy		0.387		0	1.7×10^{38}	0.163
Menhinick's		1.15		1.732	1	1.89
Margalef's		0.910		1.82	0	2.06

Station 1
May 2, 1973

	1	2	3	4	5	0
Agriionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae	1	5	3	3	3	15
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera.						
Dolichopodidae						
Dryopidae						
Dytiscidae					1	1
Elmidae	1					1
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Halipidae						
Heleidae	2		2			4
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae				1	1	2
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae	1	1	1			3
Psychodidae						
Psychomyidae						

	1	2	3	4	5	0
Pyrallidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smynthuridae						
Sphaenidae	3	3	4	3	6	19
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae						
Tubificidae	10	9	65	8		92
Total Families	6	4	5	4	4	8
Total Organisms	18	18	75	15	11	137
Runs	311	336	111	334	307	256
SCI	3.73	2.69	1.11	2.67	2.46	4.10
Simpson's	0.358	0.358	0.756	0.369	0.388	0.483
1-Simpson's	0.642	0.642	0.244	0.631	0.612	0.516
Diversity	1.51	1.36	0.710	1.32	1.20	1.48
Redundancy	0.483	0.533	0.854	0.509	0.478	0.740
Menhinick's	1.41	0.943	0.577	1.03	1.21	0.683
Margalef's	1.73	1.04	0.926	1.11	1.25	1.42

Station 2
May 2, 1973

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida		1				1
Asellidae	6	1		6		13
Astacidae						
Baetidae	1	8	1		7	17
Chironomidae	9	1	1		2	13
Chloroperlidae						
Chordodidae						
Cocnagrionidae		1				1
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae	1	3			6	10
Dytiscidae						
Elmidae	2	5	2	6		15
Empidae						
Ephemeridae						
Gammaridae	11			1	1	13
Glossiphoniidae						
Gomphidae					1	1
Haliplidae						
Heleidae	2	3	1	2	1	9
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae			35	1	1	37
Leptoceridae						
Libellulidae						
Lumbricidae	1	2			1	4
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae				9		9
Perlodidae	1					1
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyralidae						
Rhyacophilidae				5		5
Sialidae						
Simuliidae			8	5		13
Smythuridae						
Sphaenidae		1			1	2
Stratiomyidae						
Succineidae						
Tabanidae		1		1	1	3
Tipulidae		1			1	2
Tubificidae	4	9	2		11	26
Total Families	10	13	7	9	12	20
Total Organisms	37	37	50	36	34	195
Runs	395	442	229	424	400	462
SCI	7.9	11.49	3.21	7.63	9.6	18.48
Simpson's	0.192	0.145	0.52	0.162	0.189	0.094
1-Simpson's	0.808	0.855	0.48	0.838	0.811	0.906
Diversity	2.28	2.61	1.28	2.38	2.35	3.5
Redundancy	4.10	0.327	0.701	0.378	0.376	0.435
Menhinick's	1.64	2.14	0.990	1.5	2.06	1.43
Margalef's	2.49	3.32	1.53	2.23	3.12	3.6

Station 3
May 2, 1973

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyelidae						
Annelida						
Asellidae	1					1
Astacidae						
Baetidae					1	1
Chironomidae	1	3			1	5
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae			1			1
Empidae						
Ephemeridae						
Gammaridae	1					1
Glossiphoniidae						
Gomphidae						
Haliplidae						
Heleidae	2			1	1	4
Heptageniidae						
Hydrachnidae						
Hydracnidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	6
Pyralidae						
Rhyacornilidae						
Sialidae						
Simuliidae						
Smythuridae						
Sphaenidae	1	3	10	10		24
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae						
Tubificidae	1		5	9		15
Total Families	6	2	3	3	3	8
Total Organisms	7	6	16	20	3	52
Runs	393	264	269	264	326	351
SCI	4.72	1.06	1.61	1.58	1.96	5.62
Simpson's	0.184	0.5	0.492	0.455	0.333	0.313
1-Simpson's	0.816	0.5	0.508	0.545	0.667	0.687
Diversity	1.61	0.720	0.972	1.04	0.862	1.82
Redundancy	0.081	0.545	0.648	0.659	0	0.580
Menhinick's	2.27	0.816	0.75	0.671	1.73	1.11
Margalef's	2.57	0.558	0.721	0.668	1.82	1.77

Station 4
May 2, 1973

	1	2	3	4	5	0
Agriionidae						
Amnicolidae						
Amphizoidae						
Ancyelidae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae			1			1
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae					2	2
Gammaridae						
Glossiphoniidae						
Gomphidae						
Haliplidae						
Heleidae		17	5	6	4	32
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyrallidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smythuridae						
Sphaenidae		1				1
Stratiomyidae						
Succinidae						
Tabanidae		1	1		1	3
Tipulidae						
Tubificidae		67	89	71	83	310
Total Families	0	4	4	2	4	4
Total Organisms	0	86	96	77	90	345
Runs		178	72	96	68	79
SCI		1.42	0.576	0.384	0.544	0.632
Simpson's		0.646	0.867	0.856	0.853	0.816
1-Simpson's		0.354	0.138	0.144	0.147	0.183
Diversity		0.822	0.405	0.361	0.439	0.503
Redundancy		0.837	0.922	0.926	0.914	0.928
Menhinick's		0.431	0.408	0.228	0.422	0.215
Margalef's		0.673	0.657	0.230	0.667	0.513

Station 5
May 2, 1973

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyclidae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae						
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Haliplidae						
Heleidae						
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyrilidae						
Rhyacophilidae						
Sialidae		1				1
Simuliidae						
Smythuridae						
Sphaenidae			1			1
Stratiomyidae						
Succineidae						
Tabanidae		1				1
Tipulidae		1				1
Tubificidae		16	2	4		22
Total Families	0	4	2	1	0	5
Total Organisms	0	19	3	4	0	26
Runs		136	246	1		122
SCI		1.08	0.984	0.002		1.22
Simpson's		0.717	0.556	1		0.722
1-Simpson's		0.283	0.444	0		0.278
Diversity		0.658	0.528	0		0.710
Redundancy		0.780	0.387	1.7×10^{38}		0.791
Menhinick's		0.918	1.15	1		0.981
Margalef's		1.02	0.910	0		1.23

Station 6
May 2, 1973

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae		1		1		2
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera			1			1
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Haliplidae						
Heleidae		4	3	1	2	10
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede	1					1
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyralidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smynthuridae						
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae		3	5			8
Tipulidae		3				3
Tubificidae	56	63	287	72	101	479
Total Families	2	5	4	3	2	7
Total Organisms	57	74	296	74	103	504
Runs	17	135	21	33	23	44
SCI	0.068	1.35	0.168	0.198	0.092	0.616
Simpson's	0.966	0.731	0.941	0.947	0.962	0.904
1-Simpson's	0.034	0.269	0.059	0.053	0.038	0.096
Diversity	0.102	0.776	0.217	0.168	0.120	0.363
Redundancy	0.978	0.839	0.968	0.965	0.977	0.952
Menhinick's	0.265	0.581	0.232	0.349	0.197	0.312
Margalef's	0.247	0.929	0.527	0.465	0.216	0.964

Station 7
May 2, 1973

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae						
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Halplidae						
Heleidae						
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
<u>Pyrilidae</u>						
<u>Rhyacophilidae</u>						
<u>Sialidae</u>						
<u>Simuliidae</u>						
<u>Smythuridae</u>						
<u>Sphaenidae</u>						
<u>Stratiomyidae</u>						
<u>Succineidae</u>						
<u>Tabanidae</u>						
<u>Tipulidae</u>						
<u>Tubificidae</u>						
<u>Total Families</u>	0	0	0	0	0	0
<u>Total Organisms</u>	0	0	0	0	0	0
<u>Runs</u>						
<u>SCI</u>						
<u>Simpson's</u>						
<u>1-Simpson's</u>						
<u>Diversity</u>						
<u>Redundancy</u>						
<u>Menhinick's</u>						
<u>Margalef's</u>						

Station 1
June 2, 1973

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae					1	1
Astacidae						
Baetidae						
Chironomidae	1					1
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae				1		1
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Haliplidae						
Heleidae						
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	6
Pyrallidae						
Rhyacophilidae		1				1
Sialidae						
Simuliidae						
Smythuriidae						
Sphaenidae	2	4		1		7
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae						
Tubificidae	56	18	3	15	23	115
Total Families	3	3	1	3	2	6
Total Organisms	59	23	3	17	24	126
Runs	46	165	1	121	33	88
SCI	0.276	0.99	0.002	0.726	0.132	1.056
Simpson's	0.902	0.645	1	0.785	0.920	0.836
1-Simpson's	0.097	0.355	0	0.215	0.079	0.163
Diversity	0.281	0.755	0	0.476	0.191	0.506
Redundancy	0.938	0.767	1	0.833	0.942	0.909
Menhinick's	0.391	0.626	0.577	0.728	0.408	0.535
Margalef's	0.490	0.638	0	0.706	0.315	1.034

Station 2
June 2, 1973

	1	2	3	4	5	6
Agriionidae						
Amnicolidae						
Amphizoidae						
Ancyclidae						
Annelida						
Asellidae			8			8
Astacidae						
Baetidae						
Chironomidae					1	1
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae						
Gammaridae				1		1
Glossiphoniidae						
Gomphidae						
Haliplidae						
Heleidae						
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae				2		2
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae					1	1
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychoniidae						

	1	2	3	4	5	0
Pyrallidae						
Rhyacophilidae				1		1
Sialidae						
Simuliidae						
Smythuriidae						
Sphaenidae			1			1
Stratiomyidae						
Succineidae						
Tabanidae					1	1
Tipulidae						
Tubificidae	3				2	5
Total Families	1	0	2	3	4	9
Total Organisms	3	0	9	4	5	21
Runs	1		59	285	345	385
SCI	0.002		0.236	1.21	2.76	6.93
Simpson's	1		0.802	0.375	0.28	0.225
1-Simpson's	0		0.197	0.625	0.72	0.776
Diversity	0		0.352	0.896	1.18	2.01
Redundancy	1		0.828	0.218	0.145	0.354
Menhinick's	0.577		0.667	1.5	1.789	1.96
Margalef's	0		0.455	1.44	1.864	2.63

Station 3
June 2, 1973

	1	2	3	4	5	0
Agriionidae						
Amnicolidae						
Amphizoidae						
Ancyclidae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae	/					/
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolchopodidae						
Dryopidae						
Dytiscidae						
Elmidae			/			/
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Halipilidae						
Heleidae						
Heptageneidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomiidae						

	1	2	3	4	5	0
Pyralidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smythuridae						
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae						
Tubificidae	1	5	1			7
Total Families	2	1	2	0	0	3
Total Organisms	2	5	2	0	0	9
Runs	231	1	234			200
SCI	0.924	0.002	0.936			1.2
Simpson's	0.5	1	0.5			0.629
1-Simpson's	0.5	0	0.5			0.371
Diversity	0.5	0	0.5			0.686
Redundancy	0	1	0			0.666
Menhinick's	1.41	0.447	1.414			1
Margalef's	1.44	0	1.44			0.910

Station 4
June 2, 1973

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae	4					4
Astacidae						
Baetidae	4					4
Chironomidae	8			4		12
Chloreperlidae						
Chorodidae						
Cocnagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae	5					5
Empidae						
Ephemeridae				1		1
Gammaridae	5					5
Glossiphoniidae	1					1
Gomphidae						
Halipidae						
Heleidae	4			3		7
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae			1			1
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyrallidae						
Rhyacophilidae						
Sialidae	3					3
Simuliidae						
Smythuridae						
Sphaenidae						
Stratiomyidae						
Succinoidea						
Tabanidae						
Tipulidae						
Tubificidae	28		102	61	332	523
Total Families	9	0	2	4	1	11
Total Organisms	62	0	103	69	332	563
Runs	369		1	112	1	70
SCI	6.64		0.04	0.896	0.002	1.4
Simpson's	0.249		0.981	0.787	1	0.864
1-Simpson's	0.751		0.019	0.213	0	0.136
Diversity	2.26		0.065	0.596	0	0.532
Redundancy	0.505		0.988	0.874	1	0.931
Menhinick's	1.14		0.197	0.482	0.054	0.422
Margalef's	1.94		0.216	0.709	0	1.42

Station 5
June 2, 1973

	1	2	3	4	5	0
Agrionidae						
Amnicolidae						
Amphizoidae						
Ancyridae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae						
Chloroperlidae						
Chordodidae						
Cocnaerionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Haliplidae						
Heleidae						
Heptageniidae						
Hydrachnidae			/			/
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyrilidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smythuridae						
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae						
Tubificidae		2				2
Total Families	0	1	1	0	0	2
Total Organisms	0	2	1	0	0	3
Runs		1	1			239
SCI		0.002	0.002			0.956
Simpson's		1	1			0.556
1-Simpson's		0	0			0.444
Diversity		0	0			0.528
Redundancy		1.70×10^{38}	1.7×10^{36}			0.387
Menhinick's		1	1			1.15
Margalef's		0	0			0.910

Station 6
June 2, 1973

	1	2	3	4	5	0
Acrionidae						
Amnicolidae						
Ampuizoidae						
Ancyelidae						
Annelida						
Asellidae						
Astaciidae			1			1
Bactidae						
Chironomidae	1	2	2		2	7
Chloroceridae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera	2					2
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae		2				2
Gammaridae						
Glossiphoniidae						
Gomphidae				1		1
Halipidae						
Heleidae		2	1	1		4
Heptageniidae						
Hydrachnidae						
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychomyiidae						

	1	2	3	4	5	0
Pyralidae						
Rhyacophilidae						
Sialidae	1	3	4		4	12
Simuliidae						
Smytnauridae						
Sphaeridae						
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae		1				1
Tubificidae	62	126	65	45	8	306
Total Families	4	6	5	3	3	9
Total Organisms	66	136	73	47	14	336
Runs	61	70	113	49	245	99
SCI	0.488	0.84	1.13	0.294	1.47	1.78
Simpson's	0.884	0.860	0.797	0.917	0.429	0.831
1-Simpson's	0.116	0.140	0.203	0.082	0.571	0.169
Diversity	0.349	0.476	0.594	0.236	1.10	0.602
Redundancy	0.925	0.916	0.876	0.944	0.575	0.914
Menhinick's	0.492	0.514	0.585	0.438	0.802	0.491
Margalef's	0.716	1.02	0.932	0.519	0.756	1.38

Station 7
June 2, 1973

	1	2	3	4	5	0
Agriionidae						
Amnicolidae						
Amphizoidae						
Ancylidae						
Annelida						
Asellidae						
Astacidae						
Baetidae						
Chironomidae	1			4	1	6
Chloroperlidae						
Chordodidae						
Coenagrionidae						
Culicidae						
Diptera						
Dolichopodidae						
Dryopidae						
Dytiscidae						
Elmidae						
Empidae						
Ephemeridae						
Gammaridae						
Glossiphoniidae						
Gomphidae						
Halipidae						
Heleidae						
Heptageniidae						
Hydrachnidae	4					4
Hydraenidae						
Hydrometridae						
Hydrophilidae						
Hydropsychidae						
Hydroptilidae						
Leptoceridae						
Libellulidae						
Lumbricidae						
Lymnaeidae						
Millipede						
Muscidae						
Nematoda						
Nemouridae						
Onophronidae						
Perlidae						
Perlodidae						
Phryganeidae						
Physidae						
Planorbidae						
Psychodidae						
Psychonidae						

	1	2	3	4	5	0
Pyralidae						
Rhyacophilidae						
Sialidae						
Simuliidae						
Smythuridae						
Sphaenidae						
Stratiomyidae						
Succineidae						
Tabanidae						
Tipulidae						
Tubificidae		2				2
Total Families	2	1	0	1	1	3
Total Organisms	5	2	0	4	1	12
Runs	164	1		1	1	306
SCI	0.656	0.002		0.002	0.002	1.84
Simpson's	0.68	1		1	1	0.389
1-Simpson's	0.32	0		0	0	0.611
Diversity	0.464	0		0	0	1.15
Redundancy	0.664	1		1	1.7×10^{38}	0.523
Menhinick's	0.894	0.707		0.5	1	0.866
Margalef's	0.621	0		0	0	0.805

APPENDIX B
TIME SHARE BASIC COMPUTER PROGRAM
TO CALCULATE DIVERSITY

DVR 2

10 DIM N(100),M(100)

20 MAT N=ZER

21 PRINT "STATION NUMBER?",

22 INPUT Q8

23 PRINT "SAMPLE NUMBER?",

24 INPUT Q1

25 PRINT "GIVE DATE NUMERICALLY AS MONTH, DAY, YEAR"

26 INPUT Q2,Q3,Q4

27 REM Q2=MONTH, Q3=DAY, Q4=YEAR

30 PRINT "HOW MANY TAXA"

40 INPUT F1

41 PRINT "INPUT FAMILY NO. AND NO. OF INDIVIDUALS SEPARATED BY COMMA"

42 PRINT "TERMINATE WITH 0,0"

50 INPUT F,N

60 IF F=0 THEN 90

70 N(F)=N

80 GOTO 50

90 GOSUB 100


```
91 GOSUB 500
92 GOSUB 900
94 GOTO 9999
100 REM SUBROUTINE TO CALCULATE SEQUENTIAL COMPARISON INDEX
101 REM AND SIMPSONS INDEX
110 T=0
120 FOR F=1 TO F1
130 T=T+N[F]
140 M[F]=T
150 NEXT F
160 H=Y=0
170 FOR F=1 TO F1
180 H=H+N[F]
190 NEXT F
195 PRINT "TOTAL TAXA" F1
196 PRINT "TOTAL NUMBER" H
200 REM SIMPSONS INDEX
210 FOR F=1 TO F1
```

```

220  Y=Y+(N[F]/H)^2
230  NEXT F
235  PRINT
240  PRINT "HOW MANY RANDOM SELECTORS"
250  INPUT I1
260  N3=0
270  L=0
280  FOR I=1 TO I1
290  R=INT(T*RND(0)+.5)
300  IF R=0 THEN 290
310  FOR F=1 TO F1
320  IF M[F]<R THEN 370
330  IF F=L THEN 350
340  N3=N3+1
350  L=F
360  GOTO 380
370  NEXT F
380  NEXT I

```

390 PRINT "NUMBER OF RUNS IS "N3

400 PRINT "SCI VALUE IS"N3/I1

410 PRINT "SIMPSONS INDEX IS "Y

420 PRINT "1-SIMPSONS INDEX IS"1-Y

430 RETURN

500 REM SUBROUTINE TO CALCULATE DIVERSITY INDEX AND REDUNDANCY

510 N=0

520 FOR P=1 TO F1

530 N=N+N[P]

540 NEXT P

560 REM CALCULATES TRUE DIVERSITY PER INDIVIDUAL

570 Q=0

580 FOR J=1 TO F1

590 M=N[J]

600 GOSUB 800

610 Q=Q+Z

620 NEXT J

630 M=N

```

640 GOSUB 800
650 D0=(Z-Q)/N
660 REM CALCULATES THEORETICAL MAXIMUM DIVERSITY
670 M=N
680 GOSUB 800
690 D9=Z/M
700 REM CALCULATES REDUNDANCY IN PERMUTATION DIVERSITY
710 R=(D9-D0)/D9
720 PRINT "DIVERSITY" D0
730 PRINT "REDUNDANCY", R
740 RETURN
800 REM SUBROUTINE TO CALCULATE LOGM! (BASE 2)
810 Z=0
820 FOR I=2 TO M
830 Z=Z+LOG(I)
840 NEXT I
850 Z=Z/LOG(2)
860 RETURN

```

900 REM SUBROUTINE TO CALCULATE MEHNINICKS INDEX AND MARGALEFS

901 REM INDEX

910 $M1 = F1 / (N)^{.5}$

920 PRINT "MEHNINICKS INDEX IS" M1

930 $M2 = (F1 - 1) / \text{LOG}(N)$

940 PRINT "MARGALEFS INDEX IS" M2

950 GOTO 30

9999 END