A TAXONOMIC SURVEY OF THE NON-VASCULAR FLORA
OF THE UPPER BLUE RIVER

By

ELMER RAY BROWN

Bachelor of Science in Education
Southeastern State College
Durant, Oklahoma
1957

Master of Science
Oklahoma State University
Stillwater, Oklahoma
1959

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF EDUCATION
May, 1974

A TAXONOMIC SURVEY OF THE NON-VASCULAR FLORA OF THE UPPER BLUE RIVER

Thesis Approved:

Kenneth E. Wiggins
Thesis Adviser

John E. Thomas

L. Herbert Bruneau

Thomas D. Johnston

D. D. Durham
Dean of the Graduate College

PREFACE

The concept of developing a taxonomic survey and sampling the non-vascular flora of the Upper Blue River System grew out of an intense interest in teaching Phycology at East Central State College. Field trips into the survey area provided an added stimulus, and encouragement from students and colleagues prompted a serious consideration of the project, its development and value in contributing basic knowledge.

The objectives of the present study were to (1) make a thorough analysis of the non-vascular flora of the Upper Blue River System; (2) investigate the physico-chemical conditions of the ecology and distribution of the non-vascular aquatics; (3) note any relationships between the distribution of species and the habitats in which they were collected. A major portion of the study was conducted during the summer of 1965 through the summer of 1969. Sampling was initiated again in the summer of 1972 and terminated in the fall of 1973.

My sincere appreciation goes to Dr. Kenneth Wiggins for his personal assistance, his patience and his inspiration throughout this study.

The author is grateful for council and technical assistance provided by Dr. John Thomas, Dr. L. Herbert Bruneau, and Dr. Thomas D. Johnsten.

Further appreciation is expressed to Dr. Arthur Carroll, Oklahoma State University; Dr. James M. Cooper, Cameron State College; and

Dr. William F. Mahler, Southern Methodist University; for verification of species appearing in this study.

Finally, the author wishes to express thanks to his wife, Bettye, and our children. Their understanding and support made this endeavor possible.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

A taxonomic survey of non-vascular aquatic plants is essential to the knowledge of aquatic community structure. Periphyton, attached algae, are the most important primary producers in small, flowing streams. Periphyton have been analyzed in terms of standing crop (Blum, 1956), species composition (Round, 1964), productivity and species diversity (Wetzel, 1969; Kevern, Wilhm, and Van Dyne, 1966; Cooper, 1972).

The most widely used method for collecting periphyton samples that are suitable for stream use has been to place artificial substrata in a stream for an extended period of time. Castenholz (1961) submerged glass plates for two to four weeks at various depths. This technique provides a measure for organism accumulation resulting from initial colonization to the production of well established mats. The development of a more sophisticated periphyton sampler (Patrick, Hohn, and Wallace, 1954) called the Catherwood Diatometer made sampling quicker, more economical and less laborious. Hohn (1956) describes the diatometer as a continuous record method for indicating water quality. The diatometer, styrofoam floats, and submerged glass plates have been used in various studies on stream algae (Hohn, 1956; Hohn and Hellerman, 1963; Weber, 1966; and Weber and Raschke, 1966).

A review of the literature has failed to locate any published reports on species determination on the non-vascular flora of Blue River in Central Oklahoma. Hornuff (1957) included the Blue River in a survey of four Oklahoma streams with reference to production. Benthos was selected as an index of productivity, since these animals are considered to be near the center of the food chain and both prey upon plankton and are preyed upon by higher animals. Hornuff lists only the major forms of aquatic vegetation for the two study areas selected on the Blue River. Oxygen balance and productivity were the primary objectives of a study by Duffer (1965). This study compared physico-chemical conditions and community metabolism in stream reaches of differing geological formations. Chlorophyll a concentrations and oxygen exchange rates were determined and compared as a measurement of productivity. Eight genera of the principal primary producers and chlorophyll bearers were listed from this stream.

Early surveys of algae within the state were undertaken in 1929 by C. E. Taft. His early work was limited to specific groups and resulted in a series of published reports concerning these groups, i.e., the Desmids (1931, 1934, 1937); the Zygnemataceae (1937b); the Oedogoniacea (1935); and Vaucheria (1937b). Some additions to the algal flora of Oklahoma were reported by Taft in 1940.

Twenty-six new species and varieties were described from Oklahoma specimens by Transeau and Taft, 1934.

Malone (1944) studied the algae of the pond-stream system flowing through the campus of Catholic College, Guthrie, Oklahoma, and added 105 species and varieties to the known flora of Oklahoma. The Cyanophyceae, Chlorophyceae, and Euglenophyceae are represented by 36 species and the remaining 69 species were diatoms. All of her collections were from Logan County.

Crystal Lake, a 24 acre impoundment in Cleveland County, was studied by Leake (1945). Her taxonomic list included 118 species and varieties reportedly not previously known from the state.

A report on the genus Chara in Oklahoma by Ophel (1952) listed eight species and varieties occurring in the state.

Vinyard (1958) presented a compendium of the algal flora of Oklahoma exclusive of the diatoms. This report is based on his collections plus those of previous investigations. Vinyard does not list any specific collections from the Blue River. Cooper (1965) adds 3 species to the list of algal flora of Oklahoma and with his additions to that of Vinyard, lists the number of algae known from the state as 846 species.

The primary objective of this study is to survey the Upper Blue River watershed and to study the species composition of the reaches comprised in 116 kilometers.

CHAPTER II

DESCRIPTION OF STUDY AREA

General Description

The Blue River, a tributary of the Red River, is located in Pontotoc, Johnson and Bryan Counties in southeastern Oklahoma. The length of the channel approaches 225 km and the area of the drainage basin is approximately 2,000 square km. The gradient averages 1.1 m/km and ranges from 9.5 m/km in the headwaters to 0.4 m/km near the mouth. The average annual precipitation is 96.7 cm, with an average spring high of 13.3 cm and an average winter low of 5.3 cm (Hornuff, 1957).

Blue River originates as a small tributary stream in a tall grass prairie area near Roff, Pontotoc County, Oklahoma, where the residents refer to it as West Blue Creek. Numerous springs erupt into the stream as it flows southeastward and becomes a fifth order stream 7 km northwest of Connerville (Horton, 1965). A third order stream, East Blue Creek, joins West Blue Creek 3 km southeast of Connerville, a distance of 96 km from the origin of the stream. In this distance the elevation drops from 437 to 183 m. Blue River continues as a fifth order stream for 128 km to its confluence with the Red River at an elevation of 137 m.

Duffer (1965) describes a form factor of 0.12 and a compactness coefficient of 1.98. The form factor is the ratio of the average width to the axial length of the basin. The compactness coefficient is the ratio of basin perimeter to the circumference of a circle whose area is equal to that of the basin (Reid, 1961). Both of these values give some indication of the tendency toward flooding. A basin with a low form factor value or a high compactness coefficient value is less likely to receive intense rainfall simultaneously over its entire area than a basin of equal area having a high form factor value or a low compactness coefficient value.

Minor floods occur in the Blue River drainage basin about every four years, while they occur every other year in the more circular drainage basins. The Blue River drainage basin traverses tall grass prairie and post oak-black jack plant associations. The stream is located in the south central Oak-Hickory Savannah physiographic region as described by Bruner (1931). Primary land uses are cultivation and pasture.

Geological Structure Related to Study Area

The study area contains four geological formations outcropping primarily as limestone, granite and sand (Figure 1). The Arbuckles, a rock formation of Cambrian and Ordovician age, consists of limestones, dolomites, and some sandstones having an aggregate thickness of 1.980 m in some places. The limestones and sandstones in the upper part of the group are among the most productive aquifers in the state. The portion of the Blue River flowing through this formation contains numerous springs and the stream bottom contains eroded limestone boulders of various sizes. The soils from limestone and calcareous shales are dark colored, fine textured, slowly permeable and very productive.

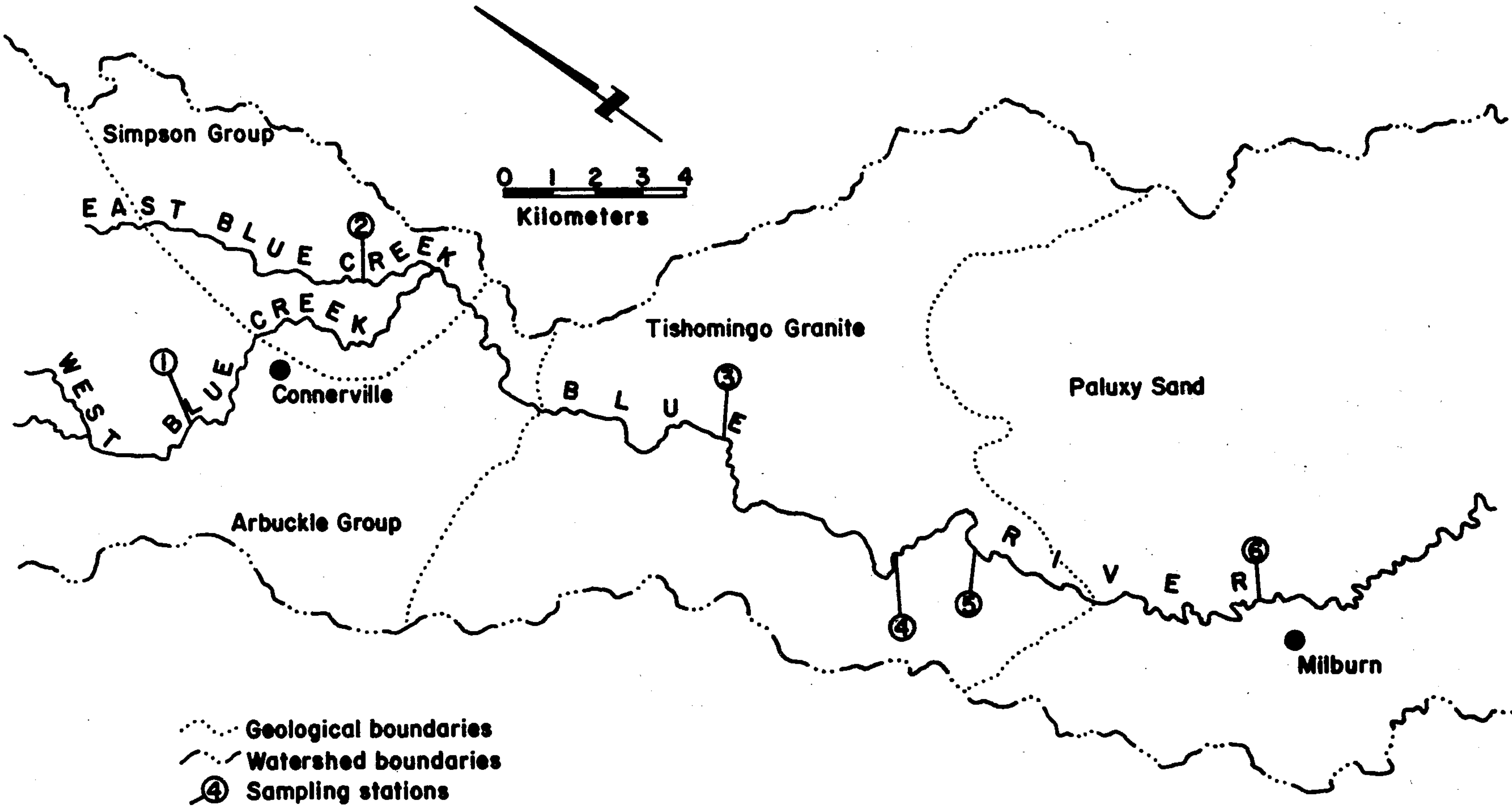

Figure 1. Map of Upper Blue River

The Simpson group, of Ordovician age, overlies the Arbuckle groups in a portion of the stream basin. This group has an average thickness of 460 m and consists of limestones, sandstones and shales. The stream bed in this area also contains eroded limestone. Limestones and sandstones of this formation contain many springs that flow into the stream.

Tishomingo granite and other igneous rocks crop out in the lower part of the Arbuckles as an igneous basement rock. It is a pinkish granite, coarse-grained and consists of microline, plagioclase, quartz and biolite. Soils in the granitic area are light colored and medium to coarse textured. The deep granitic soils have heavy clay subsoils which are slowly or very slowly permeable. These soils are moderately productive (U.S.D.A., 1961).

The Paluxy sand belongs to the Trinity group of Cretaceous formations. In southern Oklahoma this formation consists of 120-215 m of conglomerate, fine sand, and clay. This formation slants toward the Gulf of Mexico at a slope of about 13 m/km. The Paluxy sand is overlain by Goodland limestone, a nearly pure limestone formation 6 to 9 m in thickness. Water enters the sand formation in its outcrop and percolates down the slope. Artesian pressure is created since the water is confined by the overlying limestone. The soils of the Paluxy sand area are light colored, medium to coarse textured and permeable. They are moderately productive. Soils developed from Goodland limestone and the Washita group are very dark, fine textured and slowly permeable. A high percentage of these soils are used for cultivated crops, and when properly managed, are very productive.

Descriptions of Sampling Stations

Six sampling stations were selected for study on the Upper Blue River watershed area. The length of the river encompassed by the study is 48 km, beginning about 80 km from the source (Figure 1). The area selected was characterized by continuous flow as contrasted to the intermittent flow of the headwaters, and it did not receive municipal sewage effluents as was characteristic farther downstream.

Station 1 on West Blue Creek is characterized by an average width of 18.5 m and depth of 0.4 m. Discharge increases in this area because of accrual from the many springs of the limestone formation. The channel bed is composed of eroded limestone frequently forming surface waterfalls and natural dam-like scarps. Station 2 on East Blue Creek has an average width of 16.0 m and a depth of 0.31 m. Discharge in this area was not as great as station 1 due to the more level topography and reduction of springs. Station 3 on Blue River was selected below the confluence of East and West Blue Creeks and is characterized by an average width of 18.7 m and an average depth of 0.31 m. Eroded limestone, sand and riffles characterized the channel bed. The channel bed in station 4 is composed of a series of exposed granite scarps separated by deeper pools where sediment has been deposited. Riffles and low falls are characteristic of the exposed granite areas. This formation has an average stream width of 17.0 m and depth of 0.52 m. Station 5 is also in a granite outcrop. The confluence of Sandy Creek enters the Blue River and a width of 17.1 m and average depth of 0.41 m form the channel. The stream bed is composed of smaller stones and sand. Approximately 4 km above this station the Oklahoma Department of

Wildlife Conservation purchased land for public recreation and now maintains about 5 km of the Blue River. Station 6 is in the fringe of the granitic outcrop and Paluxy sand. Discharge decreases as a result of seepage into the Paluxy sand formation. The decrease in discharge, associated with seepage, was accompanied by a decrease in channel. An average width of 10.8 m and a depth of 0.27 m was characteristic of this station.

CHAPTER III

METHODS

Sampling Times

This study was based on collections made in two separate segments. The major portion of the collections were made from August 1965 through July of 1969. Sampling was initiated again in June of 1972 and terminated in September of 1973.

Initially, weekly visits to the study areas were made to collect samples and data. Following the summer of 1965, samples and data were collected bimonthly.

Physico-Chemical

Measurements of temperature, pH, alkalinity, conductivity, and turbidity were made at each station during each sampling time. Water temperature was determined with a mercury centigrade thermometer. Hydrogen-ion concentration, expressed as pH, was measured with a Hellige Comparator. Conductivity was determined with an Industrial Instruments Conductivity Bridge during early phases of the study and later measurements were determined in the field by a Beckman EV6 Environmeter. Turbidity samples were collected and returned to the laboratory where measurements were determined by a Hellige turbidimeter. Samples were collected periodically for alkalinity determination, phenolphthalein and methyl orange alkalinity were measured by titration with 0.02N sulfuric acid (A.P.H.A., 1960).

Biological

Extensive hand collections were obtained from the available natural habitats within each sampling area. Samples were scraped from benthic materials, boulders and sunken logs. Attached periphyton were squeezed from plumes of *Myriophyllum* when abundant in the habitat. Dense mats of algae were seasonally abundant in pool areas and near shorelines. Samples were easily removed and preserved for future study. Thick clusters of bryophytes and aquatic mosses were collected from the falls areas near stations 1, 2 and 3. Dense mats of vegetation in these areas provide a continual release of pseudoplankton. Plankton samples were collected at each station by pouring liter samples through a standard 40 mesh nylon plankton net. The samples were then removed from the net and preserved in a suitable preservative. Specimens collected from the field were separated and placed in receptacles with enough water to cover them and transported to the laboratory. Fresh materials were examined microscopically for sexual and asexual reproductive structures which would permit species determinations. Duplicate samples were preserved in a preservative equal to the volume of the specimens. This preservative is composed of six parts water, three parts 95% alcohol, and one part commercial formalin. Five cc of glycerin is added to each 100 cc of the preservative producing a medium which protects the specimen against total loss should the preservative evaporate (Prescott, 1954).

In addition to the preserved materials, semi-permanent slides were made for selected specimens. These slides were prepared using glycerin gelly as a mounting medium and sealed with canada balsam.

The diatom collections from the sampling stations were secured from both artificially introduced and natural substrates in the stream. The diatometer, artificial substrate, used in this study is an instrument constructed chiefly of plexiglass. Diatometers have been employed successfully as samplers by Patrick (1954); Patrick, Hohn and Wallace (1954); Hohn and Hellerman (1963); and Weber (1966).

The diatometer consists of a styrofoam float approximately 12 x 16 x 2 inches, supporting a central plexiglass cradle holding 1 x 3 inch glass microscope slides. The slides are placed with the long axis parallel to the length of the diatometer. The slides tend to collect periphyton mats more readily in this position and not so much silt. Diatometers were constructed and placed at each sampling station. Each diatometer was loaded with slides and firmly anchored to a forty-two pound concrete block sunken near the center of the stream. The diatometers are held in the stream current by the addition of a small V-shaped shield fastened to the bow. This attachment allows the diatometer to behave like a small child's toy boat with the bow continually pointed upstream.

Slides were removed from the sampler after exposures of one week; later exposures of two weeks were found to be sufficient. The periphyton was removed by scraping the slides with a razor blade. The collection from each slide was placed in a vial, labeled, and preserved by addition of preservative.

Laboratory Preparations

To make a detailed evaluation of diatom species, the diatom must be "cleaned". A technique employed by Hohn and Hellerman (1963) is satisfactory for this treatment. All organic material is removed from the samples and only the frustules of the diatoms and other siliceous materials remain. To "clean" the diatoms, scraped material is allowed to settle and preservative decanted. Fifty millimeters of concentrated nitric acid and 0.5 g of potassium dichromate were added to a beaker with the scrapings and the mixture boiled gently under a hood for 20 minutes. The "cleaned" material was allowed to cool and settle. The nitric acid-potassium dichromate mixture was then decanted and distilled water added until the mixture tested neutral with litmus paper. Acid free materials are stored in vials for an extended period of time if necessary. This treatment does not change the markings on the siliceous cell walls and leaves the two valves, as well as a group of cells, attached to one another.

Microscope slides were prepared by a modification of methods employed by Hohn and Hellerman (1963); Williams (1964); and Weber (1966). The vial containing the desired sample was thoroughly shaken and a 1 cc aliquot of the material withdrawn with a pipette. The 1 cc aliquot was then placed on a No. 1, 18 mm square coverslip and allowed to dry on a slide warmer tray at a very low, uniform heat. Once moisture had been eliminated from the sample Hyrax mounting medium with a refractive index of 1.65 was placed on the coverslip inverted onto a cleaned microscope slide. The mount was allowed to dry and the slide permanently labeled. The process was repeated for each sample for each collection.

The determination of the various taxa were carried out by the use of available monographic treatments whenever possible. Handbooks and manuals concerning the algae were used for taxa on which monographs were not available.

CHAPTER IV

RESULTS AND DISCUSSION

Physico-Chemical Conditions

The recorded range of temperature exhibited considerable seasonal fluctuation with a maximum of 31°C in July and a minimum of 7°C in February (Table I).

TABLE I

TEMPERATURE RANGE AT SAMPLING STATIONS (°C)

	Stations					
Season*	1	2	3	4	5	6
Spring	12-21	9-18	8-23	8-23	10-24	10-26
Summer	20-23	25-27	26-29	27-29	27-29	28-31
Fall	16-19	16-24	17-24	17-24	17-27	17-29
Winter	10-14	7-11	7-12	7-12	7-12	8-11

*Spring: March-May
Summer: June-August
Fall: September-November
Winter: December-February

The widest range of temperature values were recorded in the spring when temperature ranges of 10°C-26°C were recorded for station 6. There is less seasonal spread in temperature at each station and the stream becomes progressively warmer from station 1 through station 6. Lower temperatures were recorded for all stations during the winter. The headwaters of this stream system are relatively cool in the summertime due to the influence of many springs. Warming by the air, the sun and conduction from the ground is relatively slow. This warming continues downstream at an increasing rate until the ambient temperature is attained and the water then flows on influenced mainly by the weather and the daily cycle.

In the winter the reverse may apply in spring-fed streams which start relatively warm and become cooler. Minckley (1963) found temperatures of Doe Run, a spring stream in Meade County, Kentucky, gradually became warmer downstream in the summer, while the temperature at the source remained warmer during the winter. This emphasizes the biologically important fact that a stream which is cool in the summer because it is spring-fed is warmer in the winter than streams fed by run-off. Organisms capable of inhabiting the headwaters are influenced to a rather uniform type community due to the minor fluctuations in temperatures. Greater temperature fluctuations downstream may influence other types of communities with greater temperature tolerances.

No collections were made or physical and chemical measurements recorded while ice cover or flooding was present.

Differences in turbidity range among the stations were more varied as one progressed downstream during the summer. Stations 5 and 6 exhibit a range of 10-19 ppm and 12-19 ppm during the summer (Table II). The stream channel at stations 5 and 6 is largely composed of a coarse sandy strata covered with a fine textured sand. During the spring and early summer, rains increase the stream flow and the eroding sand bars increase turbidity.

TABLE II

TURBIDITY RANGE (PPM PER LITER) AT SAMPLING STATIONS

	Stations					
Season	1	2	3	4	5	6
Spring	4-5	4-5	4-6	4-7	5-9	5-9
Summer	5-6	5-8	5-8	7-14	10-19	12-19
Fall	4-4	4-4	4-6	4-6	4-9	4-9
Winter	4-4	4-4	4-4	4-5	4-6	4-6

Specific conductance and alkalinity measurements were recorded for each of the stations (Table III).

Specific conductance and bicarbonate alkalinity decreased downstream while total carbonate increased downstream. Duffer (1965) reported this physico-chemical condition in the Blue River and attributes the decrease in conductivity to bicarbonate conversion to monocarbonate.

Hynes (1970) and Reid (1961) discuss the delicate role of chemical buffering systems of streams. Calcium carbonate, which is a common constituent of many rocks, is almost insoluable in water, but it dissolves fairly readily, as bicarbonate, in carbonic acid, and it neutralizes the soil water where it occurs. Calcium bicarbonate in solution is a good buffer-system and thus resists changes in pH, but it remains in solution only in the presence of a certain amount of free carbon dioxide, the so-called equilibrium CO_2. Therefore, any process which removes carbon dioxide, photosynthesis or loss to the air, tends to cause precipitation of calcium carbonate from solution, especially where bicarbonate is abundant.

Spring water in limestone regions is often rich in calcium bicarbonate where it emerges to the surface. As it flows along it looses carbon dioxide and after some distance this loss becomes loss of equilibrium CO_2 and deposition of calcium carbonate occurs. In the Blue River system bicarbonate is relatively high at stations 1 and 2 (Table III). The presence of numerous springs at these stations provide equilibrium CO_2 and permit maintenance of constant quantities of bicarbonate in solution.

TABLE III

CONDUCTANCE AND ALKALINITY RANGE

Stations	Specific Conductance Micromhos/cm	Alkalinity HCO_3^-	$CO_3^{=}$
1	525-530	300-313	6-8
2	525-530	310-313	7-8
3	485-525	287-290	10-12
4	385-400	245-265	25-29
5	385-395	244-250	24-27
6	385-395	244-246	24-25

Hynes (1970) and Hutchinson (1957) indicate many phanerograms of hard water are capable of direct use of bicarbonate ions. Large populations of aquatic mosses and liverworts are represented in the floral composition of stations 1 and 2 and an abundance of mosses are found at station 3. Perhaps the biological processes acting to influence chemical shifts in the water in these reaches are in part responsible for an increased carbonate alkalinity downstream. Neel (1951) studied the physical and chemical features of headwaters of limestone streams in Clark County, Kentucky. This study indicated the periphyton of riffles to depend upon bicarbonate as their chief source of CO_2, frequently removing large quantities and altering the pH as well.

The pH ranges among the sampling stations on the Blue River were consistently alkaline. A lower range of 7.4-7.9 was recorded for station 1 where numerous springs flow from the limestone outcropping. A higher pH range of 8.3-8.6 was recorded downstream at station 6 which exhibits an intermittent stream flow in a sandy outcropping (Table IV). This increase in pH is related to the bicarbonate-carbonate shift.

TABLE IV

pH RANGE AT SAMPLING STATIONS

	Stations					
Season	1	2	3	4	5	6
Spring	7.4-7.6	7.8-8.0	7.9-8.0	8.2-8.3	8.3-8.3	8.3-8.4
Summer	7.6-7.8	7.6-7.7	7.7-8.0	8.0-8.4	8.2-8.4	8.2-8.6
Fall	7.4-7.9	7.8-8.0	7.8-7.9	8.2-8.4	8.1-8.4	8.2-8.4
Winter	7.4-7.7	8.0-8.1	7.7-8.0	8.3-8.3	8.3-8.4	8.3-8.4

Duffer (1965) discusses the physical properties associated with calcium carbonate solubility. Due to the low solubility product of calcium carbonate, 0.48×10^{-8}, this substance generally precipitates from a calcareous water when the pH is raised beyond 8.3 to permit existence of appreciable carbonate ions (Hutchinson, 1957). However, metastable conditions may exist where there is apparent supersaturation with calcium carbonate. Steidtmann (1935) has suggested that colloidal calcium salts accounted for the apparent supersaturation of a travertine-deposition water. The downstream increase in carbonate alkalinity may be attributed to excess calcium carbonate in a relatively stable colloidal form. The bicarbonate to monocarbonate shift produces a pH shift toward an increased alkalinity.

Community Structure of Non-Vascular Aquatics

A total of 50 taxa were collected from sampling stations (Table V). The Bacillariophyceae accounted for 20 taxa, Myxophyceae 4, Desmidaceae 4, and Cladophoraceae 3. The composition of representative families compare favorably with other studies. Maloney (1944) reported finding 29 genera of the Bacillariophyceae in a study on the seasonal algal flora on the pond-stream system flowing through the campus of Catholic College, Guthrie, Oklahoma. Whitford and Schumacher (1963), studying communities of algae in North Carolina streams, found the Bacillariophyceae to be important in most communities with Chlorophyceae second in importance.

Station 1 is characterized by a channel bed of eroded limestone frequently surfacing to form waterfalls and natural dam-like scarps.

Pools are in evidence below the dams and where formations form pockets. Numerous springs provide a source of continuous flow.

TABLE V

TABULAR VIEW OF FAMILIES

Family	Genera	Species, Varieties and Forms
Chlamydomonaceae	1	1
Volvocaceae	2	2
Tetrasporaceae	1	1
Chaetophoraceae	2	2
Oedogoniaceae	1	1
Cladophoraceae	3	3
Hydrodictyaceae	1	1
Scenedesmaceae	1	1
Zygenmataceae	1	2
Desmidaceae	4	4
Characeae	1	1
Ceratiaceae	1	1
Vaucheriaceae	1	1
Bacillariophyceae	15	20
Euglenophyceae	1	1
Myxophyceae	4	4
Rhodophyceae	1	1
Ricciaceae	1	1
Hypnaceae	1	1
Fissidentaceae	1	1
Totals	44	50

Diplonese smithii var. pumila (Grun.) Hust. was collected from all sampling stations and appears as a dominant in samples throughout the study period. This species occurred abundantly in the samples of stations 1, 2 and 3. The dominant macroflora was composed of the Bryophytes Riccia fluitans L., Hygroamblystegium fluvatile (Hedw.) Loeske var. ovatum Grout., and Fissidens fontanus (B. Pyl.) Steud. (formerly F. julianus). These species were in evidence throughout the eroded limestone and granite outcroppings and frequently formed dense mats on the natural dam-like scarps. Species of Spirogyra and the Desmids, Closterium lanceolatum Kuetz., Pleurotaenium maximum (Reinsch) Lund., Euastrum verrucosum Ehr. and Cosmarium granatum Breb. become entangled within these bryophyte clumps and may be collected by squeezing the samples into a collecting vial. Chlamydomonas sp., Volvox sp., and Scenedesmus sp. may be collected by a similar method or by washing the bryophyte clumps from the springs that flow continuously in the limestone area.

The genus Batrachospermum was collected several times from small flowing cold springs and once from the stream channel below a low falls. These specimens were never fruiting which made them impossible to identify to species.

Station 2 is characterized by a level topography, eroded limestone and surfacing springs. The macroflora was composed of the Bryophytes Hygroamblystegium fluvatile (Hedw.) Loeske var. ovatum Grout and Fissidens fontanus (B. Pyl.) Steud. formerly F. julianus. The algal species Chaetophora elegans (Roth) C. A. Agardh, and Drapranaldia plumosa (Vaucher) C. A. Agardh were collected in the springs of this area.

Station 3 is located below the confluence of West Blue Creek. The stream bed is eroded limestone with riffle areas and pools below. Plankton samples collected from the pool areas generally would yield some species of Bacillariophyceae and pseudoplankton that was washing downstream from some substrate above. The samples collected and scraped from the diatometers were more satisfactory than those obtained by other methods.

Station 4 is composed of a series of exposed granite scarps and boulders that are separated by deeper pools where sediment has been deposited. Spirogyra ellipsora Transeau, Pithopora oedogonia (Mont.) Wittrock, and an Oedogonium species that was not in reproductive stages of development were collected from these pools.

Riffles and low falls are also characteristic of the exposed granite. A falls area often will cover the entire width of the stream. Vaucheria orthocarpa Reinsch forms small cushion-like mats on the under side of these falls. However, the most striking member of the algal flora in this area is Cladophora glomerata (L.) Kuetz. This species forms a vivid dark green plume that may sway freely back and forth in the swift water that courses below the falls. Rhizoclonium crassipellitum West and West is abundant in these riffle areas and frequently forms a wiry entwined mat that becomes the habitat of numerous aquatic insects and their larvae.

Station 5 is also in a granite outcrop but here the stream bed is composed of smaller stones and sand. This station also is a natural low water crossing and is used by cattle to gain access to the bottom land pastures that lie on the other side. During the course of this study Hydrodictyon reticulatum (L.) Lagerheim was collected from the downstream side of this crossing on numerous occasions. During the summers of 1965 and 1966 this species developed an enormous bloom and covered the surface and exposed stream bed for approximately 100 yards. The appearance of this species is probably related to the reduction of stream flow in the late summer and the proximity to well-fertilized bottom land pastures. Domestic animals also used this area for watering purposes. The species has not been collected from any other station and has not been collected since August of 1967. The scouring action produced from increased stream flow and cross fencing the pasture to eliminate domestic animals from this area may have influenced changes in the physical and chemical properties of this habitat. Members of the Myxophyceae, Oscillatoria limnosa (Roth) Agarth, Anabaena circinalis Rabenhorst, Lyngbya latissima Prescott and Nostoc linka (Roth) Bornet and Thuret have been collected from pools formed in the late summers.

Station 6 is on the fringe of the Paluxy sand and discharge decreases as a result of seepage into the sand formation. Not as many forms of attached algae were collected from this station.

Chara contraria Keutz. was collected from sand bars in this area and several non-fruiting members of the Characeae were collected from stations 5 and 6. It was not possible to identify these specimens on purely vegetative structures.

The Blue River, a hard-water stream, occurs as a spring fed and surface drainage stream in a region of soluable basic geologic formations. The headwaters are rich in soluable bicarbonates and exhibit a lush flora of periphyton and bryophytes. Macroinvertebrates are abundant in these reaches. A combination of buffering systems involving carbon dioxide loss and bicarbonate shifts to carbonate serves to shift the pH value toward the basic range of the scale. The increase in pH value is accompanied by a marked rise in total alkalinity and species composition becomes less diverse downstream. The combination of high carbonate concentrations and altering carbon dioxide content of limestone streams apparently constitutes a highly favorable environment for plants and animals. Reid (1961) contends hard-water streams support a varied and abundant association of organisms. Most unpolluted major streams exhibit a pH value on the alkaline side of neutrality, and tend toward uniformity of composition.

Taxonomic List

The genera and species identified as members of the aquatic flora of the upper Blue River watershed are presented in a taxonomic list. The reference following each family is the authority used in determining the taxa in that group. Genera are designated in the taxonomic list where insufficient evidence was present to determine the species. It is felt that a genera should be reported in order to provide a reference index for future research.

CHLOROPHYTA

CHLAMYDOMONACEAE (Smith, 1950)

Chamydomonas *sp*.

VOLVOCACEAE (Smith, 1950)

Eudorina *elegans* Ehr.

Volvox *sp*.

TETRASPORACEAE (Prescott, 1962)

Tetraspora *cylindrica* (Wahl.) C. A. Agardh

CHAETOPHORACEAE (Prescott, 1962)

Chaetophora elegans (Roth) C. A. Agardh

Drapranaldia plumosa (Vaucher) C. A. Agardh

OEDOGONIACEAE (Taft, 1935)

Oedogonium sp.

CLADOPHORACEAE (Prescott, 1962)

Cladophora glomerata (L.) Kuetzing

Pithopora oedogonia (Mont.) Wittrock

Rhizoclonium crassipellitum West and West

HYDRODICTYACEAE (Prescott, 1962)

Hydrodictyon reticulatum (L.) Lagerheim

SCENEDESMACEAE (Prescott, 1962)

Scenedesmus sp.

ZYGNEMATACEAE (Transeau, 1951)

Spirogyra crassa Kutzing

Spirogyra ellipsora Transeau

DESMIDIACEAE (Taft, 1931, 1934, 1937)

Closterium lanceolatum Kuetz.

Pleurotaenium maximum (Reinsch) Lund.

Euastrum verrucosum Ehr.

Cosmarium granatum Breb.

CHARACEAE (Ophel, 1952)

Chara contraria Kuetz.

PYRROPHYTA

CERATIACEAE (Prescott, 1962)

Ceratium hirundinella (Muell.) Dujardin

CHRYSOPHYTA

VAUCHERIACEAE (Prescott, 1962)

Vaucheria orthocarpa Reinsch

BACILLAROPHYCEAE (Patrick and Reimer, 1966)

Diplonese smithii var. pumila (Grun.) Hust.

Diatoma vulgare var. brevis Grun.

Synedra ulna (Nitzche) Ehr.

Synedra pulchella var. pulchella (Ralfs) Kuetz.

Gomphonema olivaceum (Lyngb.) Kuetz.

Epithemia turgida Ehr.

Epithemia sorex Kuetz.

Cymbella cistula (Hempr.) Kirchn.

Cymbella affinis Kuetz.

Navicula canalis var. Canalis Patr.

Navicula peregrima (Ehr.) Kutz.

Navicula cryptocephala Kutz.

Cymatopleura solea (Breb.) Wm. Smith

Surirella ovalis Breb.

Surirella striatula Trupin

Gomphonema constrictum Ehr.

Fragularia brevistrata Grun.

Gyrosigma kutzingii Grun.

Melosira sp.

Eunotia pectinalis Kuetz.

EUGLENOPHYTA

EUGLENOPHYCEAE (Prescott, 1962)

Euglena sp.

CYANOPHYTA

MYXOPHYCEAE (Prescott, 1962)

Oscillatoria limnosa (Roth) Agardh

Nostoc lineka (Roth) Bornet and Thuret

Anabaena circinalis Rabenhorst

Lyngbya latissima Prescott

RHODOPHYTA

RHODOPHYCEAE (Prescott, 1962)

Batrachospermum sp.

BRYOPHYTA

FISSIDENTACEAE (Grout., 1928-1940)

Fissidens fontanus (B. Pyl.) Steud. (formerly *F. julianus*)

HYPNACEAE (Grout., 1928-1940, Crum, 1965)

Hygroamblystegium fluvatile (Hedw.) Loeske var. *ovatum* Grout

RICCIACEAE (Conard, 1956)

Riccia fluitans L.

CHAPTER V

SUMMARY

1. The objectives of the study were a taxonomic survey of the non-vascular flora, to investigate the physico-chemical conditions affecting the ecology and distribution of the non-vascular aquatics and to note any relationships between the distribution of species and the habitats in which they were collected. The Upper Blue River, a central Oklahoma clear water stream, was studied from late summer 1965 to the fall of 1973.

2. Six study areas were established among geological formations of limestone, granite and sand.

3. Bimonthly samples were collected from each study area until the summer of 1969. Sampling was initiated again in June of 1972 and terminated in September of 1973.

4. Artificial substrata were used to sample the periphyton community. Diatometers with exposed 1 x 3 inch glass slides were attached to sunken concrete blocks at each station. Slides were removed at bimonthly intervals and processed for microscopic examination.

5. Temperatures were influenced by springs in the headwaters where higher temperatures were recorded in the winter and lower temperatures in the summer. The recorded range of temperatures was narrow within each sampling area but varied from 7°C in February to a maximum of 31°C in July within the 116 kilometers of the study site. Differences in

turbidity range among the stations were more varied as one progressed downstream during the summer. Turbidity remained relatively stable during the winter. Specific conductance decreased downstream as a result of bicarbonate conversion to carbonate.

6. The pH ranges among the sampling stations were consistently alkaline. A lower range of pH, 7.4-7.9, was recorded for station 1 where numerous springs flow from limestone outcropping. A higher pH range of 8.3-8.6 was recorded downstream at station 6 which exhibits an intermittent stream flow in a sandy outcropping. Bicarbonate alkalinity decreases and carbonate alkalinity increases downstream. A combination of buffering systems involving carbon dioxide loss and bicarbonate shifts to carbonate serves to change the pH values toward a more alkaline range in the lower reaches.

7. Forty-seven taxa of algae and three taxa of bryophytes were identified from the Upper Blue River. Diatoms dominated the flora at all stations. Diplonese smithii var. pumila (Grun.) Hust. was collected from all sampling stations and appears as a dominant in samples throughout the study period. Dense mats of the bryophytes, Riccia fluitans L., Hygroamblystegium fluvatile (Hedw.) Loeske var. ovatum Grout. and Fissidens fontanus (B. Pyl.) Steud. (formerly F. Julianus) were abundant in the riffle and falls areas of stations 1, 2 and 3. Perhaps these bryophyte populations are capable of direct use of bicarbonate ions and act to influence chemical shifts which in part are responsible for an increased carbonate alkalinity downstream.

A SELECTED BIBLIOGRAPHY

American Public Health Association. 1960. Standard methods for the examination of water and waste water. 11th ed. Amer. Public Health Assoc. New York. 626 p.

Blum, J. L. 1956. The ecology of river algae. Bot. Rev. 22:291-340.

Bruner, W. E. 1931. The vegetation of Oklahoma. Eco. Monogr. 1:99-188.

Castenholtz, R. W. 1961. An evaluation of a submerged glass method of estimating production of attached algae. Verh. Internat. Verein. Limnol. 14:155-159.

Cooper, J. M. 1962. Some algae of Lake Carl Blackwell, Oklahoma, exclusive of diatoms. Master's thesis. Okla. State Univ. 26 p.

Cooper, M. C. 1972. Spatial and temporal variation in productivity, species diversity, and pigment diversity of periphyton in a stream receiving domestic and oil refinery effluents. Ph.D. thesis. Okla. State Univ. 54 p.

Crum, H., W. C. Steere, and L. E. Anderson. 1956. A list of the mosses of North America. Bryologist. 68:377-432.

Duffer, W. R., and Troy C. Dorris. 1966. Primary productivity in a southern Great Plains stream. Limnol. Oceanog., 11, No. 2, 143-151.

Forest, H. S. 1954. Handbook of algae. University of Tennessee Press. Knoxville.

FWPCA. 1966. A guide to the common diatoms at water pollution surveillance system stations. U. S. Dept. of Interior., Cincinnati, Ohio.

Grout, A. J. 1903. Mosses with a handlens and microscope. A. J. Grout Pub., New York City.

Grout, A. J. 1928-1940. Moss flora of North America, north of Mexico. 3 vols. A. J. Grout Pub., New York City.

HEW, 1959. Algae in water supplies. Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.

HEW, 1961. Plankton population dynamics. Dept. Health, Education and Welfare. National Water Quality Network. Supplements, Washington, D.C.

Hohn, M. H. 1956. The diatometer - a continuous record method for indicating water quality. Presented at Stream Pollution and Waste Disposal Conference. Wichita, Kansas. Pub. Western Petroleum Refiners Association. 9 p.

Hohn, M. H. and J. Hellerman. 1963. The taxonomy and structure of diatom populations from three eastern North American rivers using three sampling methods. Trans. Amer. Micro. Coc. 82:250-329.

Hornuff, L. E. 1957. A survey of four Oklahoma streams with reference to production. Oklahoma Fish Res. Lab. Rept. No. 62. 22 p.

Horton, R. E. 1945. Erosional development of streams and their drainage basins. Geol. Amer. Bull. 56:275-370.

Hutchinson, G. E. 1957. A treatice on limnology. Vol. I. Geography, physics, and chemistry. Wiley, New York. 1015 p.

Hynes, H. B. N. The ecology of running waters. Univ. of Toronto Press. Toronto. 555 p.

Kevern, N. R., J. L. Wilhm, and G. M. Van Dyne. 1966. Use of artificial substrata to estimate the productivity of periphyton. Limnol. and Oceanog. 11:499-502.

Leake, D. V. 1939. Preliminary notes on the production of motile cells in <u>Basicladia crassa</u> Hoffman and Tilden. Proc. Oklahoma Acad. Sci. 19:109-110.

Leake, D. V. 1945. The algae of Crystal Lake, Cleveland County, Oklahoma. Amer. Midland Nat. 34:750-768.

Maloney, M. (Sister) 1944. Seasonal algal flora on the campus of Catholic College, Guthrie, Oklahoma. Proc. Okla. Acad. Sci. 24:42-48.

Minckley, W. L. 1963. The ecology of a spring stream, Doe Run, Meade County, Kentucky. Wildl. Monogr. No. 11. Louisville, Kentucky. 124 p.

Miser, H. D. 1954. Geologic map of Oklahoma. U. S. Geol. Surv.

Ophel, I. L. 1952. The genus <u>Chara</u> in Oklahoma. Proc. Okla. Acad. Sci. 33:179-183.

Patrick, R. 1948. Factors affecting the distribution of diatoms. The Botanical Review. 14(8):473-524.

Patrick, R. and C. W. Reimer. 1966. The diatoms of the United States. Vol. I., Academy of Natural Sciences, Philadelphia, Penn.

Prescott, G. W. 1954. How to know the fresh-water algae. Wm. C. Brown Company, Dubuque, Iowa.

Prescott, G. W. 1962. Algae of the western Great Lakes area. Wm. C. Brown Company, Dubuque, Iowa.

Reid, G. K. 1961. Ecology of inland waters and estuaries. Reinhold, New York City. 375 p.

Round, R. E. 1964. The ecology of benthic algae. In D. F. Jackson (ed.), Algae and Man. Plenum Press. New York City.

Smith, G. M. 1950. The fresh-water algae of the United States. 2nd ed. McGraw Hill, New York City.

Smith, G. M. 1951. Manual of phycology. Chronica Botanica Company. Waltham, Mass.

Taft, C. E. 1931. Desmids of Oklahoma. Publs. Univ. of Okla. Biol. Surv. 3(3):277-321.

Taft, C. E. 1934. Desmids of Oklahoma II. Trans. Amer. Micros. Soc. 53(2):95-321.

Taft, C. E. 1935. The Oedogoniaceae of Oklahoma including new species and varieties. Bull. Torr. Bot. Club. 64:281-290.

Taft, C. E. 1937. Desmids of Oklahoma III. Trans. Amer. Micros. Soc. 56(4):397-404.

Taft, C. E. 1937B. A new species of <u>Vaucheria</u>. Bull. Torr. Bot. Club. 64:557.

Taft, C. E. 1940. Additions to the algae of Oklahoma. Proc. Okla. Acad. Sci. 20:49-54.

Taft, C. E. 1949. New, rare, or otherwise interesting algae. Trans. Amer. Micros. Soc. 68(3):208-216.

Tiffany, L. H. 1937. The Oedogoniales in North America. North Amer. Flora. 11:1-102.

Transeau, E. N. et al. 1934. New species of Zygnemataceae. Trans. Amer. Micros. Soc. 53(3):208-230.

Transeau, E. N. 1951. The Zygnemataceae. Ohio State Univ. Press. Columbus.

Vinyard, Wm. C. 1955. Epizoophytic algae from mollusks, turtles and fish in Oklahoma. Proc. Okla. Acad. Sci. 34:63-65.

Vinyard, Wm. C. 1958. The algae of Oklahoma (exclusive of diatoms). Unpublished Ph.D. dissertation. Michigan State University.

Weber, C. I. 1966. Methods of collecting and analysis of plankton and periphyton samples in the water pollution surveillance system. Water Pollution Surveillance System Applications and Development Report No. 19, F.W.P.C.A. 22 p.

Wetzel, R. G. 1969. Primary production rates from changes in biomass-periphyton. In R. A. Vollenweider (ed.), A Manual on Methods for Measuring Primary Production in Aquatic Environments. Handbook No. 12. International Biological Programme. 7 Maryleborne Road, London, N.W. 1. 213 p.

Whitford, L. A. and G. J. Schumacher. 1963. Communities of algae in North Carolina streams and their seasonal relations. Hydrobiol. 22:133-196.

Williams, L. G. 1964. Possible relationships between plankton-diatoms species numbers and water-quality estimates. Ecol. 45:809-823.

VITA 2

Elmer Ray Brown

Candidate for the Degree of

Doctor of Education

Thesis: A TAXONOMIC SURVEY OF THE NON-VASCULAR FLORA OF THE UPPER BLUE RIVER

Major Field: Higher Education

Biographical:

Personal Data: Born in Talihina, Oklahoma, December 8, 1934, the son of Elmer and Ruth Brown.

Education: Graduated from Talihina High School, Talihina, Oklahoma in May, 1953; received the Bachelor of Science degree in Education from Southeastern State College, Durant, Oklahoma, with a major-minor in Natural Science in May, 1957; received the Master of Science degree in Botany and Plant Pathology from Oklahoma State University, Stillwater, Oklahoma in August, 1959.

Professional Experience: Graduate Teaching Assistant, Oklahoma State University, 1957-59; Assistant Professor, Hardin-Simmons University, Abilene, Texas, 1959-61; Assistant Professor, East Central State College, Ada, Oklahoma, 1961-present.