

THE ECOLOGY OF A BOGGY MARSH IN  
STAFFORD COUNTY, KANSAS

A Thesis

Submitted to the Department of  
Biology and the Graduate Council of the Kansas State  
Teachers College of Emporia in Partial Fulfillment of  
the Requirements for the Degree of  
Master of Science

Approved for the Major Department

*[Signature]*

Approved for the Graduate Council

by

*[Signature]*  
Paul G. Jantzen

August, 1959

#### ACKNOWLEDGMENTS

Appreciation is expressed to the following: my advisor, Dr. Gilbert A. Leisman, for guidance, constructive criticism, and encouragement; my wife, Elaine, for assistance in field work and typing; the biology faculty of Kansas State Teachers College of Emporia for help in many ways; and various individuals and governmental agencies who aided in identification and in acquiring information and materials.

Approved for the Major Department

Gilbert A. Leisman

Approved for the Graduate Council

James W. Boyler

TABLE OF CONTENTS

	Page
INTRODUCTION . . . . .	2
REVIEW OF LITERATURE . . . . .	3
DESCRIPTION OF THE AREA . . . . .	6
Geologic History . . . . .	7
Ground-Water and Artesian Conditions . . . . .	9
Climate . . . . .	12
Vegetation . . . . .	13
<b>ACKNOWLEDGMENTS</b>	
Appreciation is expressed to the following: my adviser, Dr. Gilbert A. Leisman, for guidance, constructive criticism, and en- couragement; my wife, Elaine, for assistance in field work and typing; the biology faculty of Kansas State Teachers College of Emporia for help in many ways; and various individuals and governmental agencies who aided in identification and in acquiring information and materials.	18
RESULTS AND DISCUSSION . . . . .	21
Vegetation of the County . . . . .	21
Vegetation of the Study Area . . . . .	22
Animals . . . . .	24
Physical Conditions . . . . .	26
Climatic Conditions . . . . .	30
Soil . . . . .	33
Effects of Man . . . . .	35
SUMMARY . . . . .	
LITERATURE CITED . . . . .	
APPENDIX A: CHECKLIST OF ORGANISMS IDENTIFIED	
APPENDIX B: LINGUISTICAL PROCEDURES . . . . .	

## TABLE OF CONTENTS

	Page
INTRODUCTION . . . . .	1
REVIEW OF LITERATURE . . . . .	3
DESCRIPTION OF THE AREA . . . . .	6
Geologic History . . . . .	7
Ground-Water and Artesian Conditions . . . . .	9
Climate . . . . .	12
Vegetation . . . . .	13
METHODS AND MATERIALS . . . . .	14
Quadrats . . . . .	14
Line Transects . . . . .	14
Plant Counts . . . . .	16
Plant Identification . . . . .	16
Animal Identification . . . . .	17
Plankton Collections . . . . .	17
Depth Measurements . . . . .	18
Temperature Measurements . . . . .	18
Chemical Determinations . . . . .	18
RESULTS AND DISCUSSION . . . . .	21
Vegetation of the County . . . . .	21
Vegetation of the Study Area . . . . .	22
Animals . . . . .	24
Physical Conditions . . . . .	26
Chemical Conditions . . . . .	30
Zonation . . . . .	33
Effects of Man . . . . .	35
SUMMARY . . . . .	36
LITERATURE CITED . . . . .	38
APPENDIX A: CHECKLIST OF ORGANISMS IDENTIFIED . . . . .	41
APPENDIX B: LIMNOLOGICAL PROCEDURES . . . . .	53

## INTRODUCTION

An outstanding characteristic of Kansas lakes and ponds is their fluctuating water levels. Amplitude of water levels, according to Penfound (1953), is the most critical factor in the establishment of aquatic vegetation. Seasonal and year to year increases in rainfall result in the destruction of terrestrial plants in the flood zone of impoundments and the landward migration of aquatic plants. Reductions in rainfall result in recession of water level and subsequent destruction of aquatic vegetation.

This investigation is a study of an aquatic environment in which fluctuation of water level is virtually nonexistent. This condition is made possible by a topographic depression supplied with a constant flow of water by an adjacent artesian well (Fig. 1). Excess water from the resulting marsh drains away over a broad surface on one side and leaves the main body of water relatively undisturbed. Reducing the amplitude of the water level makes possible the investigation of other factors that contribute to plant zonation.

The present study gathers quantitative data from one small area of 4,750 m<sup>2</sup> (1.16 acres). Studies of lentic vegetation have tended to compare a number of lakes or ponds and involved some concrete data and much general observation. In some cases, investigators assumed that certain factors either were or were not instrumental in causing variation in aquatic societies. It is hoped that this study includes enough quantitative data to be useful as a basis of comparison in future aquatic studies.

The presence or absence of certain plant species is often  
determined in part or by the various stages. While many of the  
plants are not suitable for investigation because of their



h. To investigate relationships between various plant and  
**Fig. 1. General view (looking toward the southwest) of the  
boggy marsh with artesian well in left foreground.**

The presence or absence of certain plant species is often desirable in ponds or lakes of various usages. While macrophytic plants may be undesirable for impoundments designed for fish production, many of them provide necessary food for migratory waterfowl (Penfound, 1953). Knowledge of factors contributing to plant aggregations might be useful in their control. The proximity of the Quivira National Wildlife Refuge and Cheyenne Bottoms makes a study of waterfowl plants in this area pertinent.

A unique feature of the study area is the establishment of a boggy mat of Leersia oryzoides. Bog conditions are rarely if ever encountered elsewhere in Kansas.

The objectives of this study may be summarized as follows:

1. To prepare a list of seed plant species in the area.
2. To establish zonation patterns by use of line transects.
3. To study certain chemical and physical factors in the water supply and the changes in these factors at 13 selected stations.
4. To investigate relationships between various plant and animal species and between these species and environmental factors.

plant vegetation. From a study of 251 lakes and streams in Wisconsin, Rejzla (1925) concluded that, "Water chemistry appears to be the most important single factor influencing the general distribution of aquatic plants. . ." As that state, Wilson (1935), reviewing the work of Prescott and Stearns in Wisconsin, says that "these studies have clearly brought out the fact that there are definite relationships between types of aquatic plant life and lake chemistry." Wilson's own work related the distribution of vegetation to pH of the water. Metcalf (1931) correlated the distribution of aquatic plants in North Dakota lakes with the

## REVIEW OF LITERATURE

Since the inception of their science in the nineteenth century ecologists have amassed a voluminous literature. Since every community is so complex in its organization and interactions, any study of a community can be only fragmentary in scope and period of time. Attempt will be made here to list only those investigators whose published works seemed particularly helpful in this study.

Much of the basic pertinent material has been condensed or summarized in ecology texts. Excellent information on zonation and succession was prepared by Weaver and Clements (1938). Oosting (1956) had helpful paragraphs on plant succession and on chemical factors. Daubenmire (1947) published pertinent information on soil nutrients. Odum (1953) listed various basic concepts in a chapter on freshwater ecology while Coker (1954) included numerous chapters on the water of streams, lakes, and ponds. Welch (1952) discussed the limnological significance of larger aquatic plants.

Many studies have dealt with chemical and physical aspects of plant societies. From a study of 225 lakes and streams in Minnesota, Moyle (1945) concluded that, "Water chemistry appears to be the most important single factor influencing the general distribution of aquatic plants. . ." in that state. Wilson (1935), reviewing the work of Fassett and Steenis in Wisconsin, says that "these studies have clearly brought out the fact that there are definite relationships between types of aquatic plant life and lake chemistry." Wilson's own work related the distribution of vegetation to pH of the water. Metcalf (1931) correlated the distribution of aquatic plants in North Dakota lakes with the



total dissolved mineral content of the water. Various workers have related specific chemical characteristics with aquatic plant distribution. Penfound and Hathaway (1938) found salinity to be one factor determining plant distribution in Louisiana marshes. Wood (1952) reported marked correlation between species of the Characeae and salinity, methyl orange alkalinity, and pH values. Swindale and Curtis (1957), working in Wisconsin, analyzed submerged plant communities in areas of constant depth and uniform substrate. They reported gradual changes in vegetation paralleling changes in water conductivity, water acidity, and organic content of substrate. Wilson (1935) indicated that succession in Wisconsin lakes was dependent upon the type of soil accumulating in those lakes. Moyle (1945), experimenting with Lemna minor, showed that even free-floating vegetation is dependent upon the fertility of the bottom soil for successful growth. ZoBell and Feltham (1942) observed that bacteria in a California marine mud flat have increased hydrogen-ion concentration by as much as 0.02 to 0.3 pH units.

Studies relating water temperature to plant stature and seed germination were reported by Rickett (1924) and Morinaga (1926a) respectively.

Numerous studies have emphasized the productivity and taxonomy of aquatic environments. An intensive two-year study of the dynamics of a Minnesota pond was conducted by Dineen (1953). Plant communities of 32 Oklahoma lakes were studied by Penfound (1953), numerous references to the management of aquatic vegetation around lakes having been discussed in an earlier publication (1952).

In Kansas, Jewell (1927) made reference to salt marsh plants in Stafford County. McGregor (1948) listed the plants invading the Leavenworth County State Park lake after it was drained. A similar study was made by McGregor and Volle (1950) at Lake Fegan. Tiemeier (1951) mapped the vegetation and studied its changes at the Kanopolis Reservoir.

The present study area, while not having the characteristic bog flora, has a mat of vegetation and a substrate of organic matter with much silt and sandy material. The term "boggy marsh" will be used in referring to this area to emphasize the presence of the floating mat zone.

There is general agreement (Lindsay, 1953) that the term "bog" refers to a hydrophilous ground by which there the soil is greatly saturated or covered with surface water. Most authors used the term "bog" in referring to hydrophilous filled with living sphagnum, sedge, or ericaceous shrubs. Britton (1906) suggests that floating mats without the characteristic bog plants should not be included under the heading of bogs. Lindsay (1953) used the term "boggy marsh" in referring to a mat disturbed by intermittent flooding and silt deposition.

The present study area, while not having the characteristic bog flora, has a mat of vegetation and a substrate of organic matter with much silt and sandy material. The term "boggy marsh" will be used in referring to this area to emphasize the presence of the floating mat zone.

## DESCRIPTION OF THE AREA

The marsh study area is located in northeastern Stafford County (Fig. 2) and is part of the Great Bend Prairie Region of Central Kansas. The Great Bend Prairie, comprising the area bounded by the great bend of the Arkansas River, is an alluvial plain for the most part covered by wind-blown sand. The dominantly sandy soils of this undulating plain absorb rainfall readily and are productive of wheat, sorghums, and pasture grasses. Stafford County lies at the south edge of the Central Kansas uplift which developed just prior to Pennsylvanian time. This uplift with associated smaller domes is favorable for oil accumulation, and the tapping of these oil pools has become an important industry in the county.

There is general agreement (Carpenter, 1938) that the term "marsh" refers to a monocotyledonous community growing where the soil is usually saturated or covered with surface water. Most authors used the term "bog" in referring to depressions filled with living sphagnum, sedges, or ericaceous shrubs. Waterman (1926) suggests that floating mats without the characteristic bog plants should not be included under the heading of bogs. Lindsey (1953) used the term "boggy marsh" in referring to a mat disturbed by intermittent flooding and silt deposition.

The present study area, while not having the characteristic bog flora, has a mat of vegetation and a substrate of organic matter with much silt and sandy material. The term "boggy marsh" will be used in referring to this area to emphasize the presence of the floating mat zone.

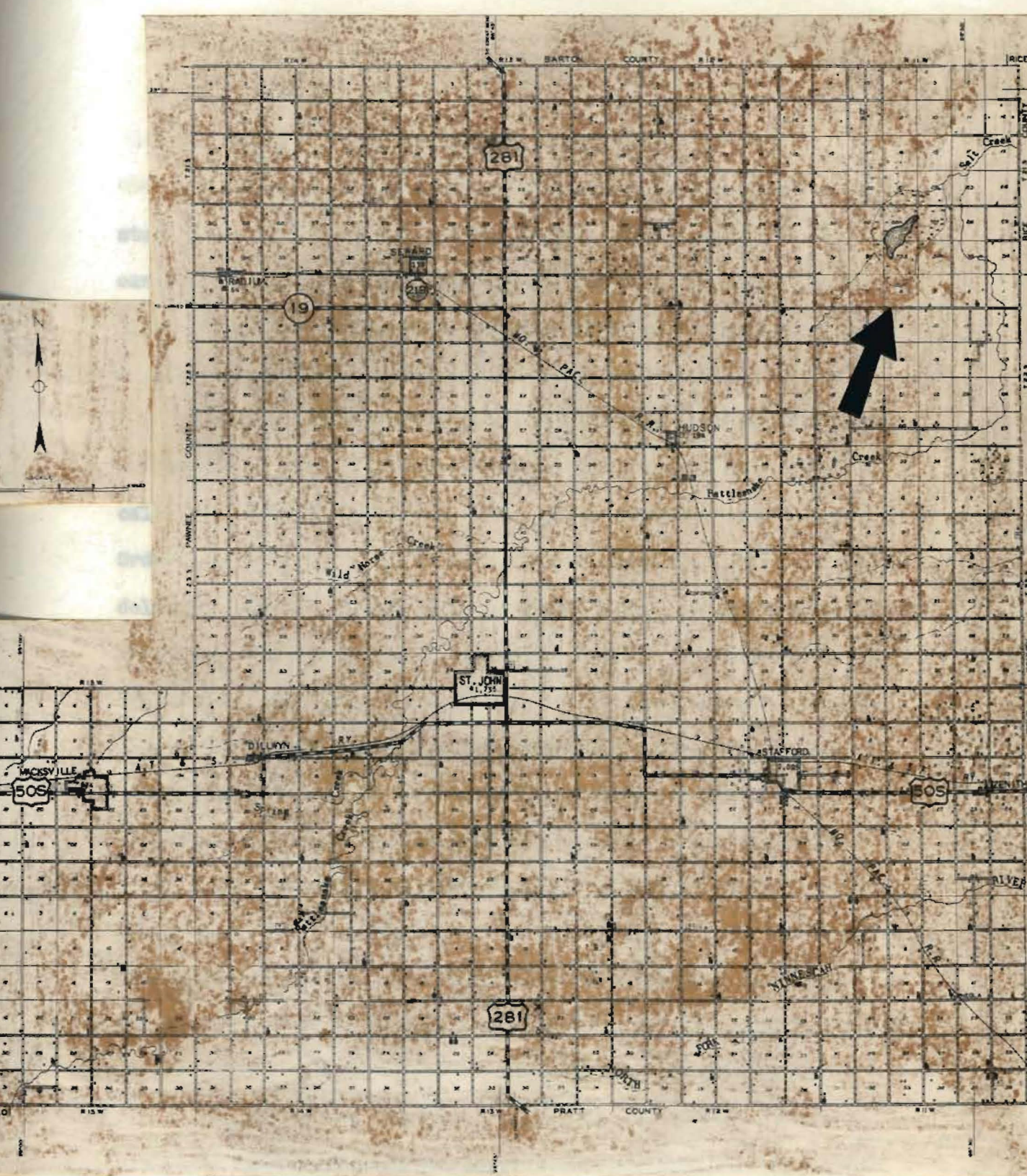
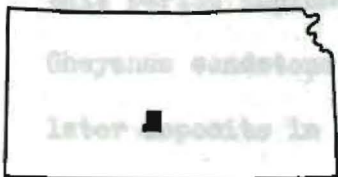


Fig. 2. Map of Stafford County showing location of study area in the NW $\frac{1}{4}$  NW $\frac{1}{4}$  sec. 9, T.22S., R. 11W. Stafford County's position in Kansas is shown at the left.



thick occurring about 1,000 feet below the surface in Stafford

County. In addition, eroded sediments from the uplands were deposited as the Permian redbeds which now underlie most of the state.

Following the Paleozoic era, little deposition occurred until the encroachment of the Cretaceous sea. Sedimentation from this period includes the chalk beds of north central Kansas and the Cheyenne sandstone, Kiowa shale, and Dakota formation underlying later deposits in parts of Stafford County. The Mesozoic era was a gentle, alluvial valley that extends south from the Big Salt Marsh

closed by the profound folding, dislocation, and upthrust of strata that formed the Rocky Mountains. This great revolution lasted into the Cenozoic era.

Following the formation of the Rocky Mountains, their prolonged erosion brought Tertiary sands and gravels eastward to form the gently sloping plain extending into the western one-third of Kansas. The Kansan ice sheet of the Pleistocene did not reach Stafford County, but during its penetration of northeast Kansas, meandering streams from the Rocky Mountain foothills continued to deposit sand and gravel over the Tertiary outwash materials. These deposits were later sorted by wind action with the result that most of Stafford County is covered with Quaternary dune sand.

The Arkansas River channel has eroded into Paleozoic shales and Cretaceous deposits to form the present day depositing stream with its familiar anastomosing pattern. The channel has slowly shifted to the north across Stafford County to form a large bend, leaving conspicuous mounds and ridges of sand in its wake. While several explanations for the northward displacement of the river have been given, Schoewe (1949) suggests that none are convincing.

The great bend of the Arkansas River now bypasses northern Stafford County, but a tributary, Rattlesnake Creek, meanders from the county's southwest corner, runs between low-lying salt marshes in the northeast, and enters the river just beyond the county's northeast corner. Stream-deposited alluvium is exposed along the Rattlesnake's channel, and marsh deposits derived from dune sand underlie the Big and Little Salt Marsh areas. The present study area lies in a gentle, alluvial valley that extends south from the Big Salt Marsh

basin.

In general, the area surrounding the marshes is undulating to hummocky with little or no surface drainage because of sandy soil. The run-off that does occur collects in intermittent pools between knolls and seeps into the ground or is lost by evaporation. Most surface soils are water-lain, wind-worked sands containing variable amounts of silt and clay with occasional bodies of loess. Along the creek and in the salt marsh area, soils are too saline or alkaline to be used agriculturally.

#### Ground-Water and Artesian Conditions

Underlying the surface dune sand of Stafford County is the Meade formation of the early Pleistocene. It consists of unconsolidated silt, sand, and gravel deposited on the eroded surface of Cretaceous and Permian rocks. The sand and gravel beds of the Meade formation yield most of the water used in Stafford County for public supply, stock, and irrigation purposes. The water is generally abundant and of good quality, but in several locations has become highly mineralized.

Local highly mineralized conditions are explained by examining the motion and recharge of ground water in the county. As ground water is discharged by seepage, evaporation, transpiration, wells, and subsurface movement from the area, it is being recharged by local precipitation, seepage from streams, and subsurface percolation from the west and southwest. The highly mineralized waters at the base of the Meade formation are probably derived from the underlying Permian rocks, Cheyenne sandstone, and Kiowa shale (Latta, 1950). Where water

in these bedrock formations is under greater hydraulic head than the softer water in the overlying Meade formation it is forced upward into the Meade gravels. The highly mineralized waters, having greater specific gravity, tend to concentrate in the lower regions of this gravel layer. Meanwhile, local precipitation is recharging the underground water supply, moving it toward the east. A high bedrock ridge trending across the direction of water movement forces the highly mineralized waters upward in northeastern Stafford County where they are discharged at the surface at the Big and Little Marshes. The minerals are further concentrated by evaporation resulting in saline waters at the marshes. Several wells in the vicinity of the Big Marsh had a chloride content of 300 to 1,000 parts per million (ppm) in 1942. The artesian well of this study area, tapping water from higher regions of the formation, had a chloride content of only 6.5 ppm (Latta, 1950).

Artesian conditions exist where the outcrop of a water-bearing formation is higher than the point of discharge and a relatively impermeable bed caps the aquifer. Because recharge occurs at the outcropping which has greater altitude, hydrostatic pressure builds up where the aquifer dips. When a well is drilled through the confining cap, water rises in the well much like water streaming from a hole in the bottom of a boat.

At least five artesian wells are flowing in northeastern Stafford County. The one in the present study area, like the other four, taps the sand and gravel of the Meade formation and flows in a topographically low area. Latta (1950) reasons that since water



rises to the level of the water table in the surrounding higher areas, the artesian conditions are strictly local. Ground-water, he says, is probably confined beneath a local lens of relatively impermeable silt or clay.

As far as can be determined the present well was drilled by a core driller studying geologic formations in the early 1930's (Sledd, 1958). The water rises from a reported depth of 40 ft. through a 3 in. iron casing (Latta, 1950). At the surface the water escapes through a horizontal 1.75 in. pipe stemming from a cylindrical, iron-cased, concrete block shown in Figure 3. A second pipe, 1 in. in diameter, extends vertically from the top of the block. In October, 1942, the State Geological Survey measured a flow of 6 gal/min, the water rising to 1.47 ft. above the top of the pipe (Latta, 1950). On August 4, 1958, the present writer, using a glass tube extension, measured a water head of 6.3 ft. above the vertical pipe. On that date, the output measured 6.15 gal/min.

Water flowing from the well takes two possible routes. Some water runs in a generally southeasterly direction over a broad, flat area into the adjoining grassland, turning sharply to the east and paralleling the road, then turning north and passing through the concrete road culvert 285 m. (935 ft.) east of the well. The eventual destination of this water is the Big Salt Marsh to the north. The second course is that which flows into the boggy marsh depression west of the well where it replenishes the water lost by seepage and evaporation.

Long-time residents of the area report that the present

marsh existed before the well was drilled, suggesting the possibility of some subsurface subsiding of such areas. Several streams of



**Fig. 3. Artesian well which in part supplied water to boggy marsh.**

air from polar regions.

South winds prevail in the county from April through November, becoming northerly during January, February, and March. Average relative humidity is 40 to 45 per cent in July and about 75 per cent during winter months (Flora, 1948).

The outstanding feature of the weather during the present study period was the above-normal precipitation during the growing season. Table I shows that the 1957 precipitation totaled 16.42 in. above the average 23.19 in. for Stafford County. This total included the 8 in. of snow which blanketed the county during a storm on March

marsh existed before the well was drilled, suggesting the possibility of some subsurface recharging of marsh waters. Narrow streams of cold water in the boggy marsh area running in an easterly direction toward the well were observed on several occasions and add credence to the subsurface recharge idea. A 20-year resident of the community reported a marsh northwest of the study area which occasionally exhibited a vigorous upwelling of ground-water through the sand substrate. Other residents in the community have substantiated this observation.

#### Climate

Weather data for Stafford County are recorded by the U. S. Weather Bureau at Hudson, located 7 miles southwest of the study area (U. S. Department of Commerce, Weather Bureau, 1957, 1958).

The weather in Stafford County, like that of the whole state, exhibits frequent and often sharp changes. These changes are due to Kansas' geographic location making it subject to alternate masses of warm, moist air from the Gulf of Mexico and currents of drier, cold air from polar regions.

South winds prevail in the county from April through November, becoming northerly during January, February, and March. Average relative humidity is 40 to 45 per cent in July and about 65 per cent during winter months (Flora, 1948).

The outstanding feature of the weather during the present study period was the above-normal precipitation during the growing season. Table I shows that the 1957 precipitation totaled 16.42 in. above the average 23.19 in. for Stafford County. This total included the 8 in. of snow which blanketed the county during a storm on March

TABLE I. Monthly precipitation for January, 1957 - June, 1958 and mean precipitation in inches for Hudson, Kansas.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Mean													
1931-1955	0.63	0.89	1.14	2.32	3.78	3.88	2.88	2.75	1.97	1.34	0.83	0.78	23.19
1957	0.11	0.60	4.34	3.29	10.02	6.74	2.17	1.12	5.39	4.06	1.49	0.28	39.61
1958	0.57	1.62	2.90	1.83	4.89	5.25	--	--	--	--	--	--	--

TABLE II. Monthly average maximum and minimum temperatures for January, 1957 - June, 1958 in Fahrenheit degrees for Hudson, Kansas. \*

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Ave. Max.	37.9	51.5	53.2	62.8	72.8	83.9	94.8	93.5	78.6	64.6	50.4	54.8
Ave. Min.	14.9	28.4	33.8	43.3	52.8	62.2	70.5	66.1	53.8	44.8	33.0	29.0
Ave. Max.	46.5	40.3	40.9	63.4	79.2	87.2	--	--	--	--	--	--
Ave. Min.	24.8	20.3	25.0	40.8	55.8	61.9	--	--	--	--	--	--

\*Long term temperature averages not established for Stafford County.

22 to 25. Moisture for the first 6 months of 1958 totaled 4.42 in. more than the 12.64-in. half-year average for the county.

Seventy-six per cent of Stafford County's precipitation occurs during the growing season of April through September. This fact coupled with an average growing season of about 180 days makes the county climatically favorable to grain and pasture crops.

Long-term temperature averages have not been established for Stafford County. Table II, however, shows the average maximum and minimum temperatures recorded at Hudson during the study period.

#### Vegetation

Kansas is part of the North American grassland biome. This biome is divided into 3 zones of longitude determined by rainfall gradient. Eastern Kansas, with an average annual rainfall of about 33 in., supports the tall grass prairie and deciduously wooded streams. Western Kansas, with an annual precipitation of about 20 in., is dominated by short grasses. The central 1/3 of Kansas, including the boggy marsh under study, averages 25 in. of rainfall and is termed the mixed prairie. Here, short grasses dominate the uplands with occasional clumps of tall grasses present. Where moisture is more readily available due to run-off and seepage from higher areas or absorption by sandy soils, tall grasses predominate. Such is the case in the present study area.

#### Line Transects

Determining a method of studying both aquatic and terrestrial vegetation of this area in a detailed yet practical way posed certain problems. The quadrat method commonly used in grasslands was considered suitable for the tall grass community but inadequate for show-

## METHODS AND MATERIALS

This study was initiated in March, 1957, with the mapping of the area and the staking out of several quadrats. These quadrats were used for general observations only, specific studies being made by use of line transects. Transects were established in August, 1957, when the first plant counts were made. Following this, surface water temperatures were recorded along transect lines and water chemistry determinations were made at the well and 13 stations in the study area.

Plant counts and various measurements were repeated during the period of late May and early June, 1958. At this time measurements were also taken of the depth of surface water and bottom mud.

### Quadrats

Eight 1-meter quadrats were established in the spring of 1957. Two quadrats were placed in typical localities of each of the 3 vegetation zones of the boggy marsh and 2 were located in the flat area southeast of the well (Fig. 4). The 4 corners of each quadrat were marked with laths driven solidly into the substrate. On May 31, 1957, vegetation maps were drawn of each quadrat. On June 22, 1957, quadrats were observed and vegetational changes were noted. These observations were repeated on August 4, 1958.

### Line Transects

Determining a method of studying both aquatic and terrestrial vegetation of this area in a detailed yet practical way posed certain problems. The quadrat method commonly used in grasslands was considered suitable for the tall grass community but inadequate for show-

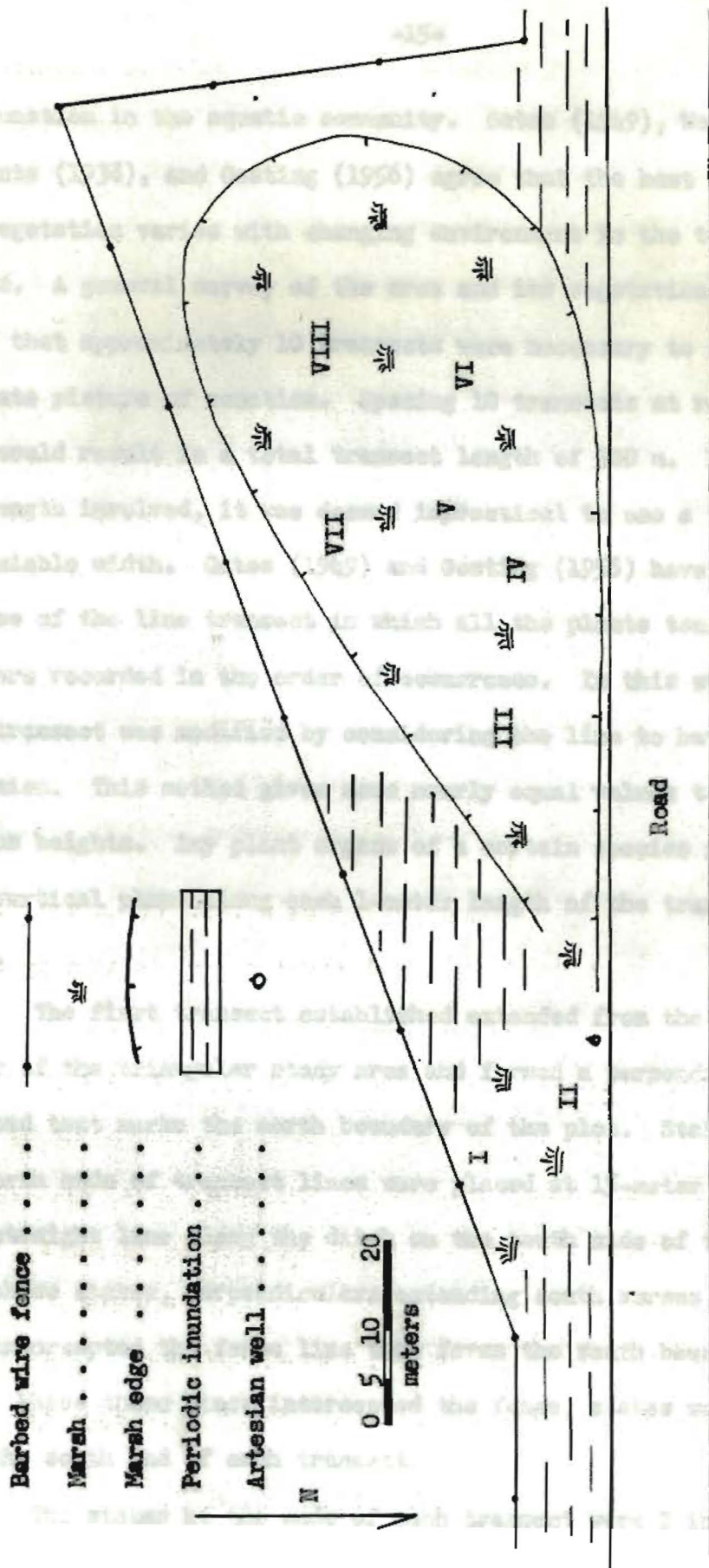


Fig. 4. General map of study area showing quadrats (numbered in Roman numerals) and general features.

ing zonation in the aquatic community. Gates (1949), Weaver and Clements (1938), and Oosting (1956) agree that the best way to show how vegetation varies with changing environment is the transect method. A general survey of the area and its vegetation zones indicated that approximately 10 transects were necessary to give an adequate picture of zonation. Spacing 10 transects at regular intervals would result in a total transect length of 300 m. Because of the length involved, it was deemed impractical to use a transect of appreciable width. Gates (1949) and Oosting (1956) have suggested the use of the line transect in which all the plants touching a line are recorded in the order of occurrence. In this study, the line transect was modified by considering the line to have vertical extension. This method gives more nearly equal values to species of various heights. Any plant organs of a certain species intercepting this vertical plane along each 1-meter length of the transect were noted.

The first transect established extended from the southwest corner of the triangular study area and formed a perpendicular with the road that marks the north boundary of the plot. Stakes marking the north ends of transect lines were placed at 15-meter intervals in a straight line along the ditch on the south side of the road. From these stakes, perpendiculars extending south across the study area intercepted the fence line that forms the south boundary of the plot. Where these lines intercepted the fence, stakes were driven to mark the south end of each transect.

The stakes at the ends of each transect were 2 in. square and



12 to 15 in. long. They were driven into the ground with only 1 in. left above the surface to avoid disturbance by road equipment or livestock. To make these points more easily visible, strings were tied to the south fence above the stakes. Along the road wooden laths marked the location of the more permanent markers.

Transects in this study were designated by the letters A through J beginning at the east end of the plot. Distance along each transect was measured in meters beginning at the north end.

#### Plant Counts

A 70-meter length of binder twine comprised the transect line. Short lengths of white cord were tied at 1-meter intervals, with yellow ribbons marking every 15 m. for easy visibility. Counts were made with the aid of a hand tally register. Each species, with its number of interceptions along a 1-meter length, was recorded. Records were kept by an assistant, leaving the hands of the investigator free for operating the tally register and manipulating the vegetation during the counting process. Extremities of the 1-meter length under count were marked with vertical wires extending from the line to the ground to help establish the vertical plane.

All seed plants were included in the counts with 2 general exceptions. Trees forming the overstory and duckweeds whose location changed with water currents were not counted. When dense grass societies of homogeneous structure were encountered, experimental counts were made and bunch estimates were recorded.

#### Plant Identification

Most plants were identified in the field. Gates' (1937) key

was used to identify grasses while keys of Fernald (1950), Rydberg (1932), Fassett (1957), and Stevens (1948) were consulted to identify forbs. Some identifications were made or confirmed by Dr. Lloyd C. Hulbert, Kansas State University.

Nomenclature follows Fernald (1950) where possible. Species not listed in that publication follow the nomenclature of Rydberg (1932).

Voucher specimens of plants in the study area, whether or not encountered in transects, were dried in presses and deposited in the herbarium of Kansas State Teachers College at Emporia.

#### Animal Identification

Nomenclature of mammals observed in the study area follows Hall (1955). Field identifications of birds were made according to Peterson (1947). Identifications of reptiles and amphibians were according to Smith (1950). A species of fish was identified by Dr. Frank B. Cross, University of Kansas. Nomenclature of crayfish and insects followed Pennak (1953) and Smith (1943) respectively.

#### Plankton Collections

Plankton samples were taken with a 70-mesh, bolting silk tow net fitted with a 130 ml. glass collecting bottle. Collections were made in mid-afternoon on July 26, 1958, from stations 3, 4 and 13. Some plankters were identified from samples scooped from near the well on March 16, 1957, and June 28, 1958. Specimens were preserved in 5 per cent formalin solution and identified in the laboratory.

Zooplankters were identified according to Pennak (1953).

Dr. Mildred S. Wilson of the Arctic Health Research Center identified a species of Attheyella. Phytoplankters were determined by Dr. Rufus

H. Thompson, University of Kansas, with the nomenclature according to Fritsch (1935, 1945).

#### Depth Measurements

In June, 1958, water depth was measured at each meter along transect lines. For this purpose an iron sounding rod 15 mm. thick and 1.5 m. long was divided into 0.1 m. graduations by small hacksaw cuts along one side. A flat, wooden shoe, 11.5 cm. square (Fig. 5), was attached to the lower end to retard the sinking of the rod into the soft bottom deposits. No attempt was made to measure the distance to the bottom in the area of the grass mat zone.

The same improvised sounding rod, minus the wooden shoe, was used to measure the distance from the water's surface through the mud to the packed sand underlying the mud bottom. The beveled end of the rod was easily forced down to the sandy layer. These measurements were also recorded to the nearest 0.1 m.

#### Temperature Measurements

Temperatures of surface water were recorded every 2 m. along each transect in an attempt to establish patterns of water currents. Temperatures were recorded to the nearest 0.5°C. and were taken during the late afternoon hours to record the greatest possible amplitude. Thermometer readings were taken on August 17, 1957, and June 28, 1958. At the same times temperatures were taken of the air and of the water issuing from the well.

#### Chemical Determinations

Chemical analyses of water from 13 stations and the artesian well were made on August 19, 1957, and June 7, 1958. Analyses were

side during the afternoon hours to allow recording of the full effects of sediment on the suspension. To avoid the disturbing of

Fluorimetric  
the results  
ly affect  
definitive  
should be  
and pro  
con  
method  
(1963)  
of water  
by affect  
and the  
ppm phos



1964  
1965  
1966  
1967  
1968  
1969  
1970  
1971  
1972  
1973  
1974  
1975  
1976  
1977  
1978  
1979  
1980  
1981  
1982  
1983  
1984  
1985  
1986  
1987  
1988  
1989  
1990  
1991  
1992  
1993  
1994  
1995  
1996  
1997  
1998  
1999  
2000  
2001  
2002  
2003  
2004  
2005  
2006  
2007  
2008  
2009  
2010  
2011  
2012  
2013  
2014  
2015  
2016  
2017  
2018  
2019  
2020  
2021  
2022  
2023  
2024  
2025

Fig. 5. Iron sounding rod with wooden shoe to prevent its sinking into bottom mud.

Dissolved oxygen determinations involved the Winkler method as given by Threlkoff et al. (1963) and were recorded as ppm dissolved oxygen.

Free carbon dioxide in ppm was calculated from titration procedures described by Welch (1968).

Immediately following the collection of samples in 135 ml. reagent bottles, water was tested with portable titration units and pipettes at the study area.

Determinations of pH were made on August 20, 1957, and June

made during the afternoon hours to allow recording of the full effects of sunlight on the ecosystem. To avoid the disturbing influence of run-off water entering the west end of the boggy marsh via the roadside ditch, care was exercised not to run analyses immediately after rains. Collecting stations were established at points where definite vegetation zones intercepted transects. Determinations included hardness, alkalinity, dissolved oxygen, free carbon dioxide, and pH.

Total hardness of water was determined by the soap titration method using a standard soap solution as described by Theroux et al. (1943). Results were recorded in equivalent parts per million (ppm) of total hardness as produced by calcium carbonate.

Phenolphthalein and methyl orange alkalinities were determined by titration methods shown in Figure 6 and described by Welch (1948) and Theroux et al. (1943). The results were expressed in terms of ppm phenolphthalein alkalinity and ppm methyl orange alkalinity respectively.

Dissolved oxygen determinations involved the Winkler method as given by Theroux et al. (1943) and were recorded as ppm dissolved oxygen.

Free carbon dioxide in ppm was calculated from titration procedures described by Welch (1948).

Immediately following the collection of samples in 135 ml. reagent bottles, water was tested with portable titration units and pipettes at the study area.

Determinations of pH were made on August 20, 1957, and June



Fig. 6. Alkalinity determination using field titration unit.



## RESULTS AND DISCUSSION

### Vegetation of the County

The most abundant pasture grasses in northeast Stafford County are Panicum virgatum L., Andropogon gerardi Vitman, and Sorghastrum nutans (L.) Nash. Associated with these tall grasses are various forbs. The more obvious include Desmanthus illinoensis (Michx.) MacM., Cleome serrulata Pursh, and Cleomella angustifolia Torr. Present in smaller numbers are Cirsium undulatum (Nutt.) Spreng, Gaura parviflora Dougl. and Eustoma russellianum (L.) Griseb. Woody shrubs and trees include Cornus asperifolia Michx., Prunus americana Marsh., Populus deltoides Marsh., and Salix nigra Marsh. Occasional marshy depressions abound in Typha latifolia L., Eleocharis calva Torr., and Scirpus americanus Pers.

Roadside ditches within a 1-mile radius of the artesian well support an assemblage of plants in addition to those mentioned above. Numerous societies of composites occur, notably Solidago canadensis L., Lactuca scariola L., Haplopappus ciliatus (Nutt.) DC., Ambrosia trifida L., and Helianthus maximiliani Schrad. Other roadside plants of the area are Hordeum jubatum L., Setaria spp., Verbena hastata L., and Melilotus alba Desr.

The margins of the Big Salt Marsh support various aquatics. During dry periods the salt flats are invaded by Flaveria campestris J. R. Johnston, Suaeda depressa (Pursh) S. Wats., and other plants of saline or alkaline soils.

The main body of the boggy marsh is dominated by Spartina peruviana with Panicum virgatum, Sorghastrum nutans, and Andropogon



### Vegetation of the Study Area

The study area itself supports both aquatic and terrestrial vegetation. The boggy marsh, comprising 2/3 of the plot, contains three main zones. In the southwest zone Typha latifolia dominates with Berula pusilla (Nutt.) Fern. as an early summer associate. Bidens laevis (L.) BSR partially supplants Berula as a marginal subdominant in late summer and fall. The open water patches within this Typha zone often abound in Lemna minor L. and Spirodela polyrrhiza (L.) Schleid. with algal filaments of Spirogyra sp. and Lyngbya sp. This zone is illustrated in Figure 7 and frequency data on the dominant species are shown in Figures 8, 9 and 10. Frequency is shown as the number of interceptions of plant parts per 5-meter interval.

Bordering the Typha zone on the north and northeast is a flourishing mat of Leersia oryzoides (L.) Sw. which reaches to the northwest edge of the boggy marsh (Fig. 11). Frequencies of Leersia are shown in Figure 12. Included in this zone are scattered individuals of Asclepias incarnata L. A zone of emergent Sagittaria latifolia Willd. funnels from the northeast border of the Leersia mat into the channel leading toward the well (Fig. 13). Filamentous algae are present here as well as diatoms of the genera Cocconeis and Rhopalodia.

The north bank of the boggy marsh borders the roadside and supports Spartina pectinata Link., Apocynum cannabinum L., Scirpus americanus Pers., and Salix nigra Marsh. with Typha spp. and Sagittaria latifolia emerging near the water's edge.

The west bank of the boggy marsh is dominated by Spartina pectinata with Panicum virgatum, Sorghastrum nutans, and Andropogon



Fig. 7. Station 13 showing Typha zone and associated Bidens laevis with duckweeds covering open water area.



Fig. 6. Diagram of plot per 5-10 to 1000 June, 1951

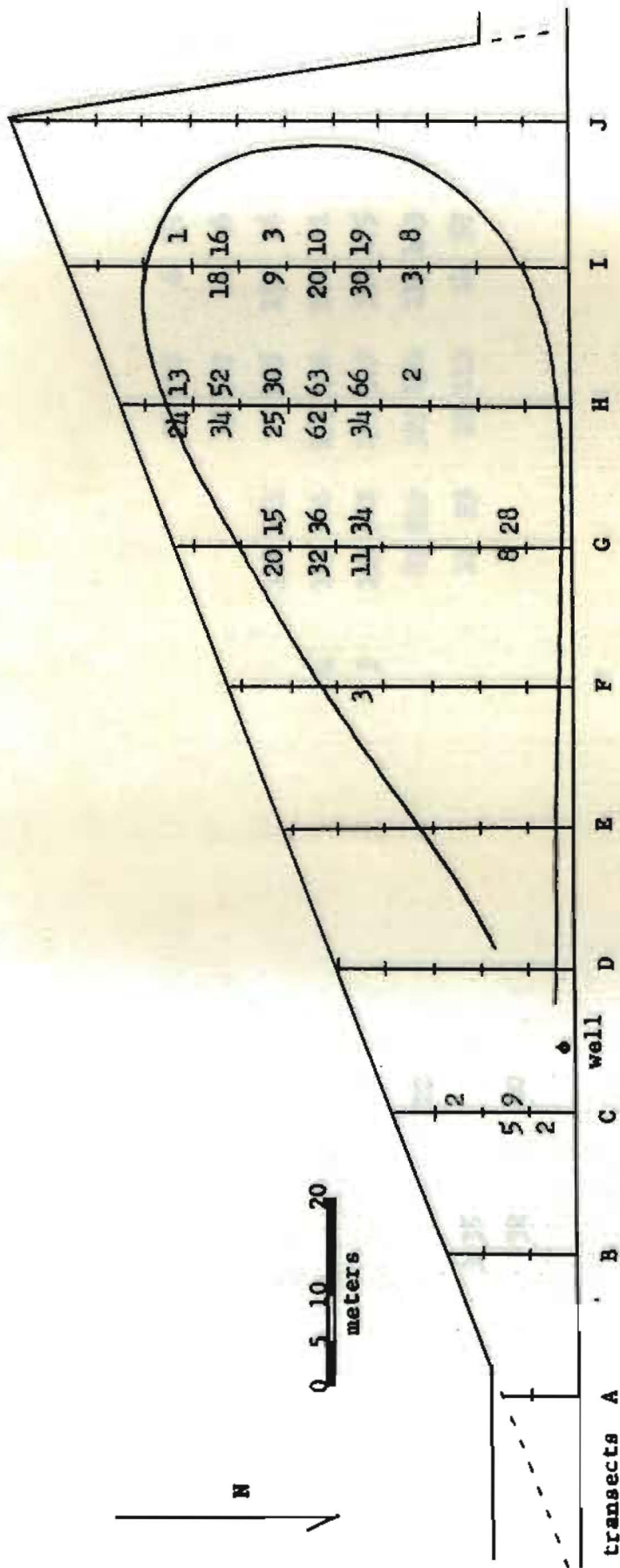


Fig. 8. Transect map showing number of interceptions of *Typha* spp. per 5-meter interval. Number left of transect line refers to count of August, 1957; number right of line to count of June, 1958.

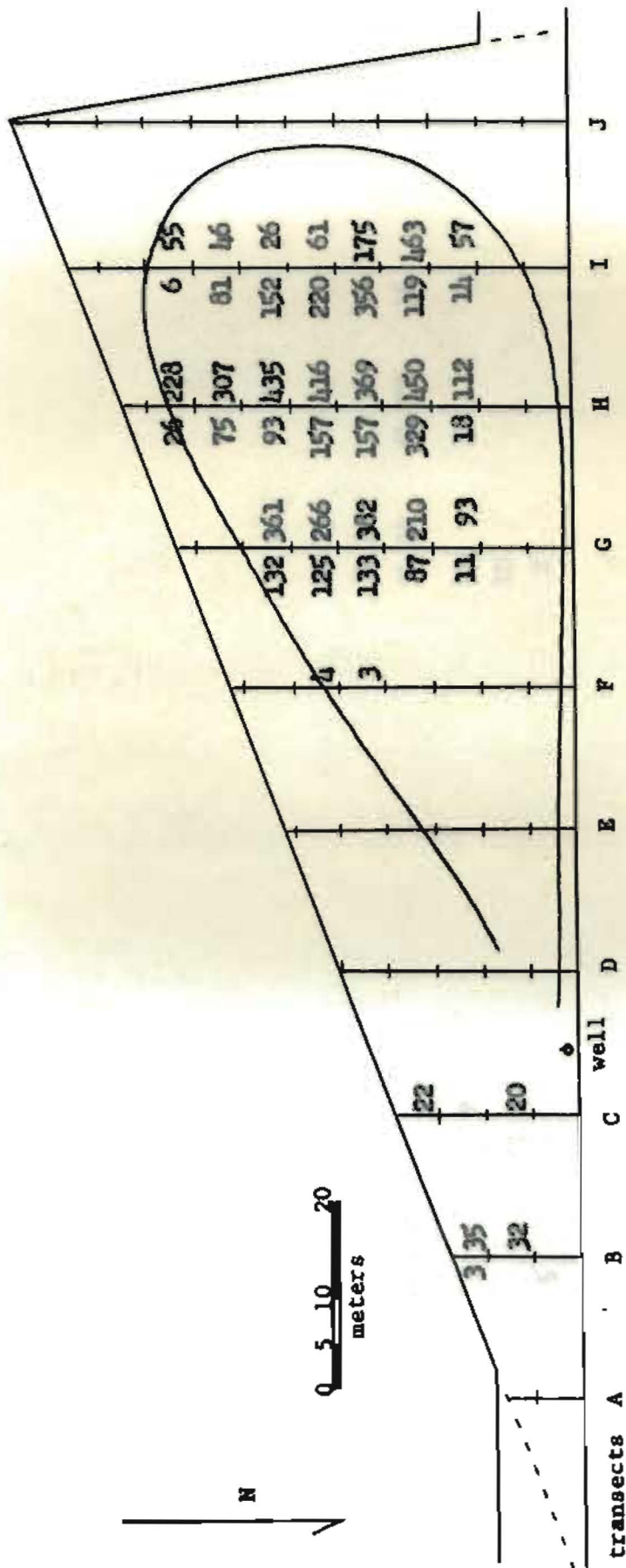


Fig. 9. Transect map showing number of interceptions of *Berula pusilla* per 5-meter interval. Number left of transect line refers to count of August, 1957; number right of line to count of June, 1958.

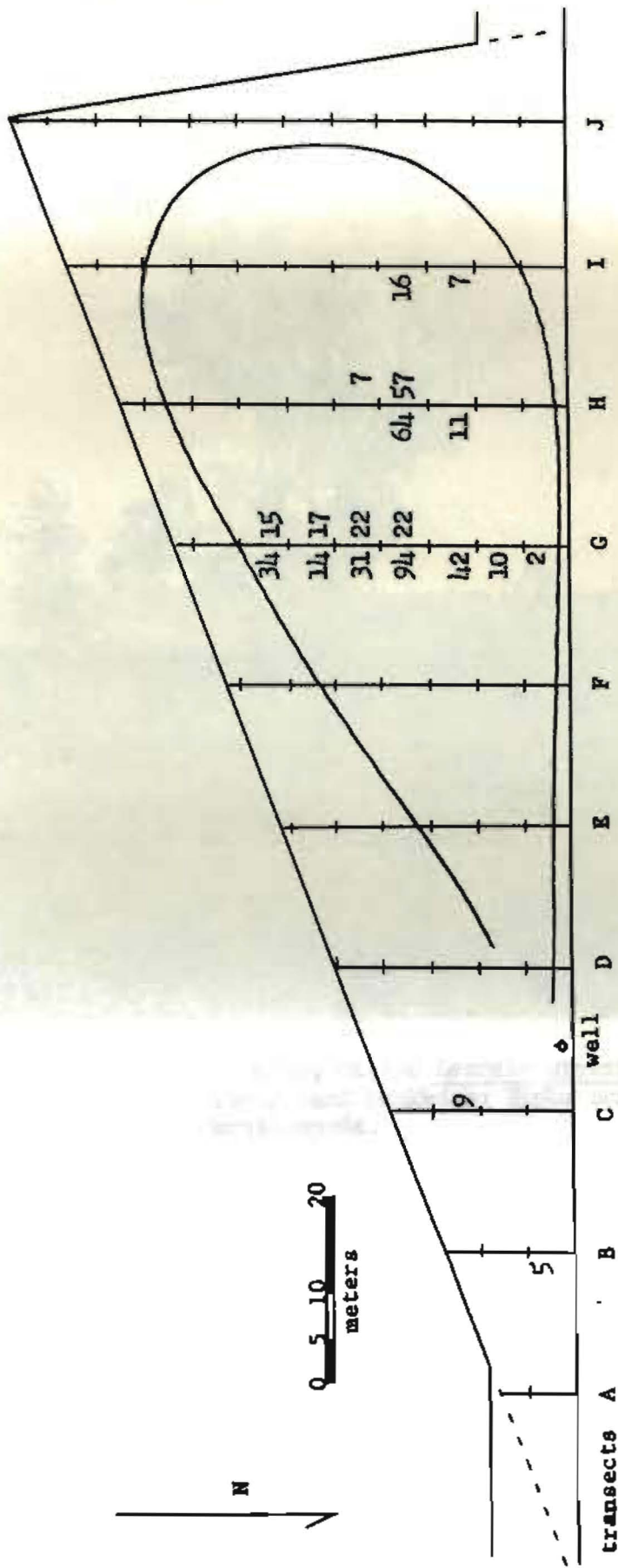
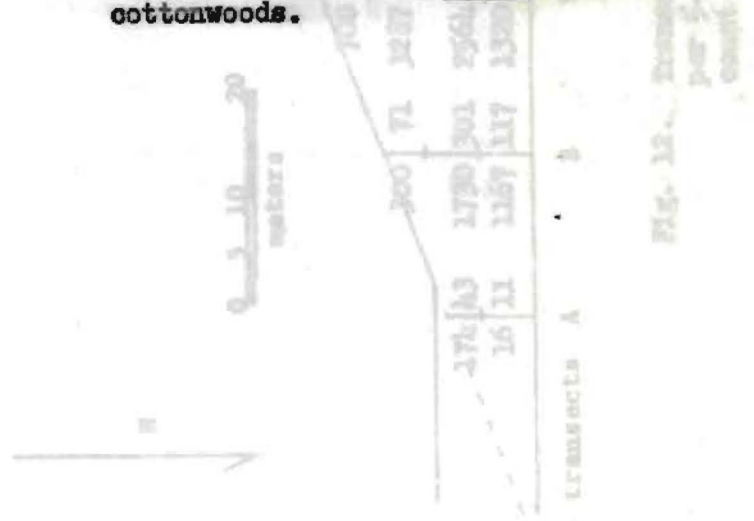


Fig. 10. Transect map showing number of interceptions of *Bidens laevis* per 5-meter interval. Number left of transect line refers to count of August, 1957; number right of line to count of June, 1958.



Fig. 11. Floating mat of Leersia oryzoides in foreground backed by Typha zone and cottonwoods.



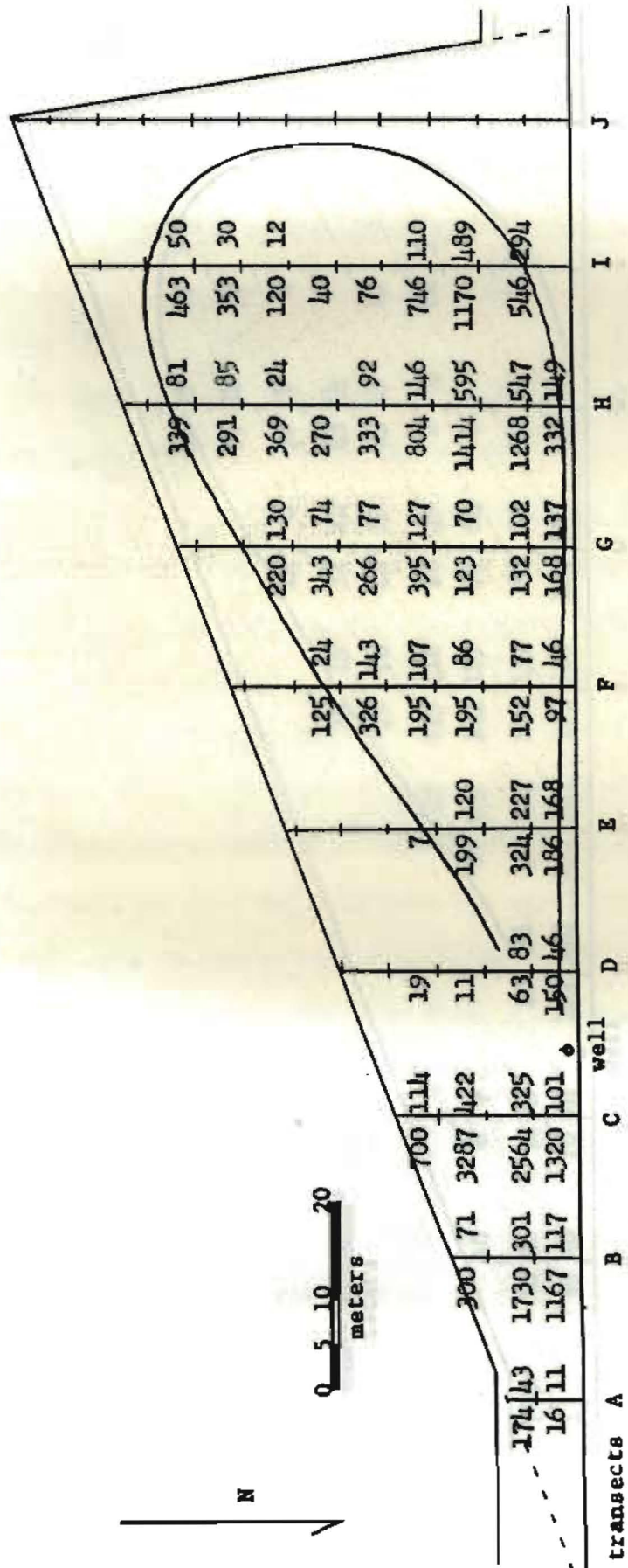


Fig. 12. Transect map showing number of interceptions of *Leersia oryzoides* per 5-meter interval. Number left of transect line refers to count of August, 1957; number right of line to count of June, 1958.





gerardi invading from the adjacent pasture. Associated with these grasses were numerous plains forbs including Asclepias speciosa Torr., Ambrosia trifida, A. psilostachya DC., Helianthus maximiliani, Artemisia ludoviciana Nutt., Galium aparine L., and Callirhoe involucrata (T. & G.) Gray.

The south bank of the marsh is shaded by a mature cottonwood, Populus deltoides Marsh., and several younger cottonwoods. Ground cover here includes Rhus radicans L. and Vitis vulpina L.

The southeast bank is dominated by Spartina pectinata (Fig. 14) and supports Helianthus maximiliani, Solidago canadensis, Cornus asperifolia, and Prunus americana. The eastern extension of this bank is the overflow plain draining water from the marsh during heavy rains.

The overflow plain extends south and east of the artesian well. This eastern extension is covered with Leersia oryzoides and drains excess water from the well into the adjoining pasture. The soil in this area is comparatively solid considering that much of it is continuously submerged under 1 to 8 cm. of water. Vegetation here differs from that in the marsh by the greater abundance of Scirpus validus Vahl., Cicuta maculata L., and Eupatorium perfoliatum L. These forms are found only occasionally in the marsh. Where this overflow plain extends under the fence into the pasture, Sagittaria latifolia and Eleocharis calva are joined by Ranunculus sceleratus L. and Mimulus glabratus HBK.

In the immediate vicinity of the well (Fig. 15), a pure colony of Nasturtium officinale R. Br. produces several crops per year. A willow, Salix nigra, lends partial shade to this colony in

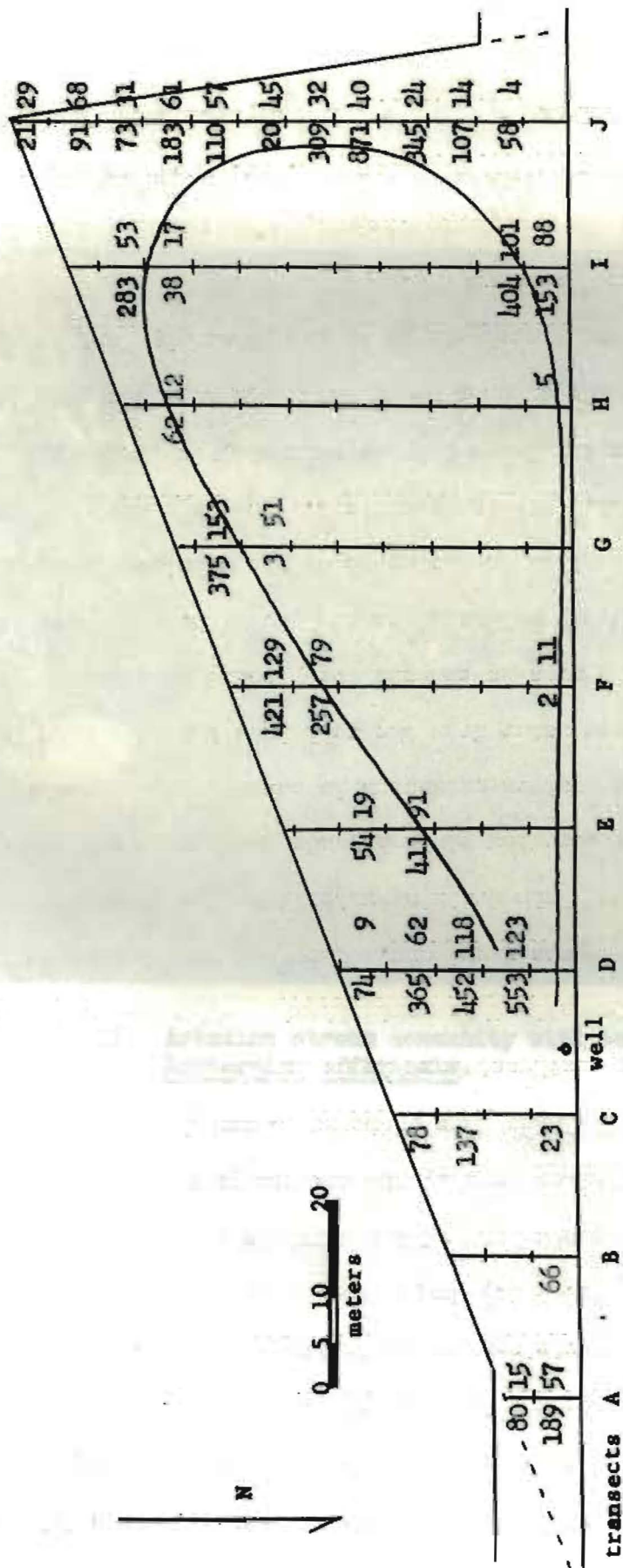


Fig. 14. Transect map showing number of interceptions of *Spartina pectinata* per 5-meter interval. Number left of transect line refers to count of August, 1957; number right of line to count of June, 1958.



Fig. 15. Artesian stream community with colony of Nasturtium officinale.

... and the ...  
 ... were the Spizella pusillus, Sturnella neglecta ...  
 ... crow, Corvus brachyrhynchos ... the Polioptila caerulea, Icterus galbula  
 (L.); the Archaeocephala, I. ... and Wilson's snipe, Gallinago  
gallinago (L.). Unidentified ducks often passed over the area. Un-  
 doubtedly many additional species pass over the region as it lies in  
 the central flyway of birds migrating from northern Alaska and north-  
 western Canada to South America.

Species identified from the area were the bullfinch, Pitangus

the late afternoons. In and near the Nasturtium zone are a few plants of the genus Najas associated with filaments of Rhizoclonium crispum Kuetz and Oedogonium sp. Also collected in this area were species of Vaucheria, and the diatoms, Cocconeis and Rhoicosphenia.

#### Animals

Wild mammals in or near the study area were represented by the eastern cottontail, Sylvilagus floridanus (J. A. Allen); the coyote, Canis latrans Say; the striped skunk, Mephitis mephitis (Schreber); and various unidentified rodents.

By far the most frequently observed birds were redwings, Agelaius phoeniceus (L.), which nested in the Typha and Asclepias incarnata. Dicksissels, Spiza americana (Gmelin), nested in a Prunus americana shrub. Other birds seen frequently were the eastern meadowlark, Sturnella magna (L.); the yellowthroat, Geothlypis trichas (L.); the mourning dove, Zenaidura macroura (L.); the eastern kingbird, Tyrannus tyrannus (L.); the American bittern, Botaurus lentiginosus (Rackett); the ring-necked pheasant, Phasianus colchicus L.; and the marsh hawk, Circus cyaneus (L.). Seen or heard occasionally were the western meadowlark, Sturnella neglecta Audubon; the crow, Corvus brachyrhynchos Brehm; the Baltimore oriole, Icterus galbula (L.); the orchard oriole, I. spurius (L.); and Wilson's snipe, Capella gallinago (L.). Unidentified ducks often passed over the area. Undoubtedly many additional species pass over the region as it lies in the central flyway of birds migrating from northern Alaska and northwestern Canada to South America.

Snakes identified from the area were the bullsnake, Pituophis

catenifer (Blainville); the massasauga rattlesnake, Sistrurus catenatus (Rafinesque); and a garter snake, Thamnophis sp. Other snakes and lizards were observed but not identified.

The only amphibians observed were the leopard frog, Rana pipiens Schreber, and the cricket frog, Acris crepitans Baird.

The volume of their evening chorus, however, indicated that the number of individuals compensated for the small number of species.

Occasional schools of immature fathead minnows, Pimephales promelas Rafinesque, were observed in water depths of 10 to 20 cm. and usually within a radius of 25 meters of the well.

Spiders were especially noticeable in the fall when most vegetation had become dormant.

Insects were numerous. Lepidopterans were represented by the sulphur butterfly, Phoebis sennae var. eubule (L.), which congregated on moist places near the well, and the monarch butterfly, Danaus plexippus (L.), seen on blooming Asclepias incarnata. Odonates, horseflies, and deerflies were present through much of the summer. An ant colony produced a 15-in. mound of alluvial soil in a Spartina colony near the southeast flood plain.

Crustaceans collected from the boggy marsh included cladocerans, copepods, ostracods, amphipods, and decapods. Several sweeps of a tow net in relatively open-water areas produced the following cladocerans: Simocephalus vetulus (O.F.M.), Glydorus sphaericus (O.F.M.), Pleuroxus denticulatus Birge, and Alona rectangularis Sars. The copepod, Eucyclops agilis (Koch), was present in numbers exceeding that of all cladocerans. Colonies of Attheyella nordenskioldii (Lilljeborg) imparted an appar-

ent red color to parts of the sand bottom stream near the well. This, apparently, is the only locality in Kansas from which this species has been reported to date. Ostracods frequented the substrate at various collecting points as well as some near-surface areas. One amphipod, Hyaella azteca (Saussure), was collected from the Sagittaria zone. While crayfish chimneys were seen at the edges of the boggy marsh, the only individual collected was an Orconectes immunis (Hagen) found dead in the roadside ditch near the culvert east of the study area.

Snails or their shells, all less than 5 mm. in diameter, were encountered frequently. The turbellarian, Dugesia dorotocephala (Woodworth), was found concentrated in the clear stream near the well, although several individuals were seen devouring a dragonfly in the water near the fence south of the well.

Tow net samples contained the green hydra, Chlorohydra viridissima (Pallas), with its algal symbiont, Chlorella conductrix Brandt.

#### Physical Conditions

Underlying the mud of the boggy marsh is a firm layer of sand. The top of this sand deposit lies from 0.4 to 1.0 m. below the water's surface as measured during the last week of June, 1958. The slope of this concave substrate is generally gradual, the deepest point being near the center of transect I, about 12 m. from the west end of the marsh.

Bottom mud varies in thickness from 0.4 m. in the Sagittaria zone to nearly 1 m. at transects H and I. Where the mud is not re-

inforced by fibrous root systems, it is rather soft. In such places the writer often sank 0.5 m. into the mud which was topped by an additional 0.2 m. of water.

During the last 11 months of the study the water level in the boggy marsh raised 8 to 10 cm. as measured at station 13. The increased water height was obvious in all marsh quadrats except where the Leersia mat was well established and presumably raised with the water. Masses of Leersia roots, intermingled with sediments, were easily lifted from loose underlying deposits making flotation of the mat a definite possibility. The rise in water level is attributed to the above-average precipitation during the study period resulting in an elevated water table. That even the relatively low magnitude of this water level fluctuation affected the firmness of the juvenile mat was illustrated by the writer's frequent sinking through the surface in the Typha zone which had provided adequate support earlier in the study period.

Marsh waters were not deep enough for measuring turbidity but general observations indicated that it was relatively low as compared to that of Kansas ponds. On slight disturbance, however, bottom sediments clouded the water, slowly settling when the disturbance ceased. Stirring action of the wind was negligible due to topography and the vegetation throughout most of the marsh.

Bottom illumination in an impoundment is affected by both turbidity and water depth. On June 28, 1958, water above the loose bottom mud varied in depth from 0.2 m. to only a trace. The deepest water was found near station 4 in the Sagittaria zone and near sta-

tion 13 in the open water area within the Typha zone. Effective light was somewhat reduced in various areas by the Leersia mat, large Sagittaria leaves, emerging Typha, and the tall cottonwood tree south of the Typha zone. During the summer months duckweeds covered the open surface areas in the Typha zone.

Surface water temperatures were recorded every 2 m. along transect lines in an attempt to discover water movements. Welch (1952) reported that temperatures of shallow waters tend to follow those of the atmosphere. In this marsh, however, the constant source of cool water suggested the possibility of ascertaining current patterns by studying temperature gradients. Temperature readings are reported in Figure 16. Four temperature readings are available for the water from the supplying well. Latta (1950) reported a water temperature of 57°F. (14°C.) on October 26, 1942. During this study period the following temperatures were recorded at the well: 13.5°C. on August 17, 1957; 13.4°C. on February 16, 1958; and 14°C. on June 28, 1958. Surface waters in the marsh ranged from 15°C. to atmospheric temperature.

The afternoon air temperature on August 17, 1957, was 22°C. Marsh water temperatures ranged from 15 to 22.5°C. Gradually increasing temperatures of water at points progressively farther from the well indicated a definite flow spreading out toward the southeast. Water in the vicinity of station 2 on transect C registered 15°C. The point of the marsh-proper nearest the well along transect D showed 21°C. compared with a 15°C. reading at station 13 at the west side of the marsh. The temperature at station 13 approximates the 13.5°C. reading at the well and supports the idea of ground water supplying



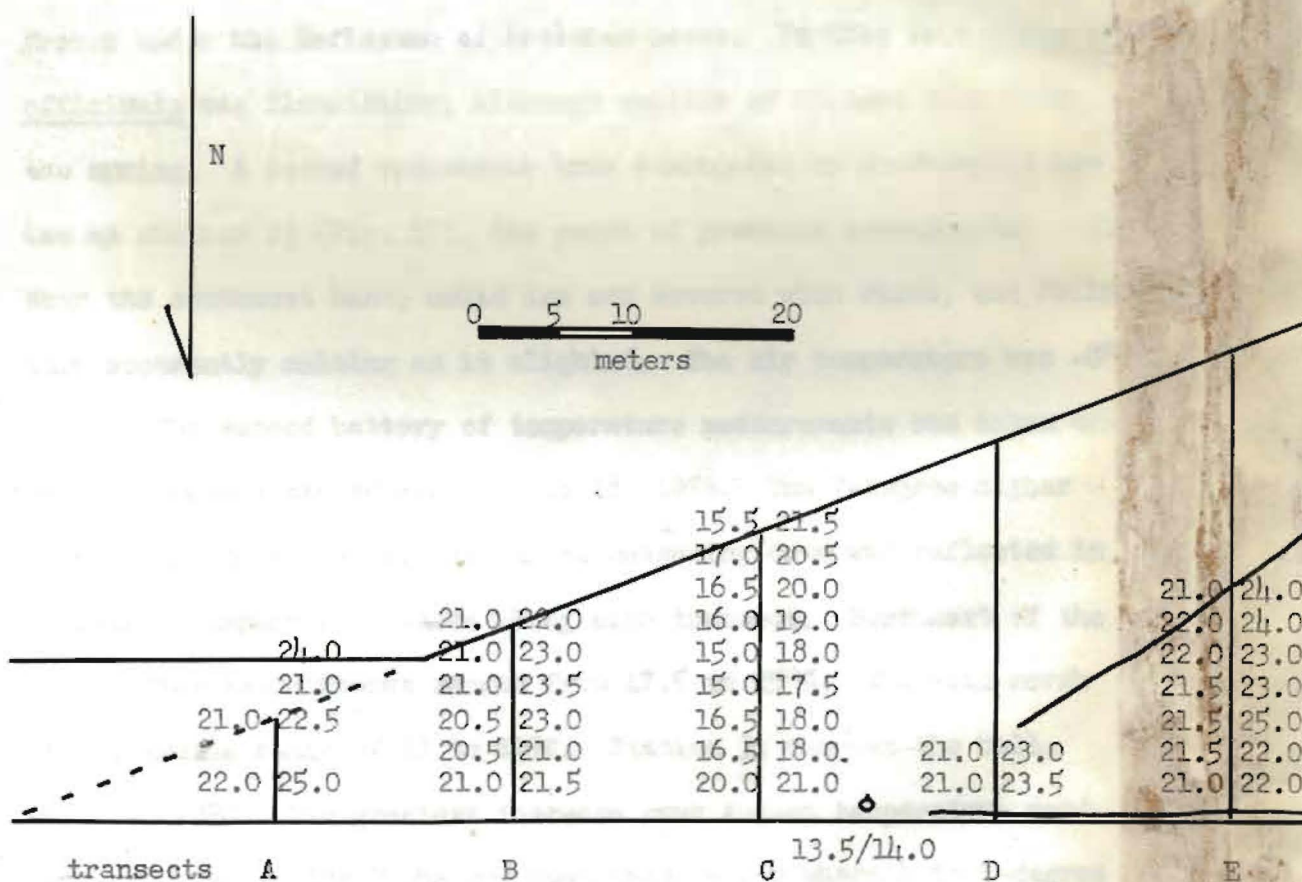
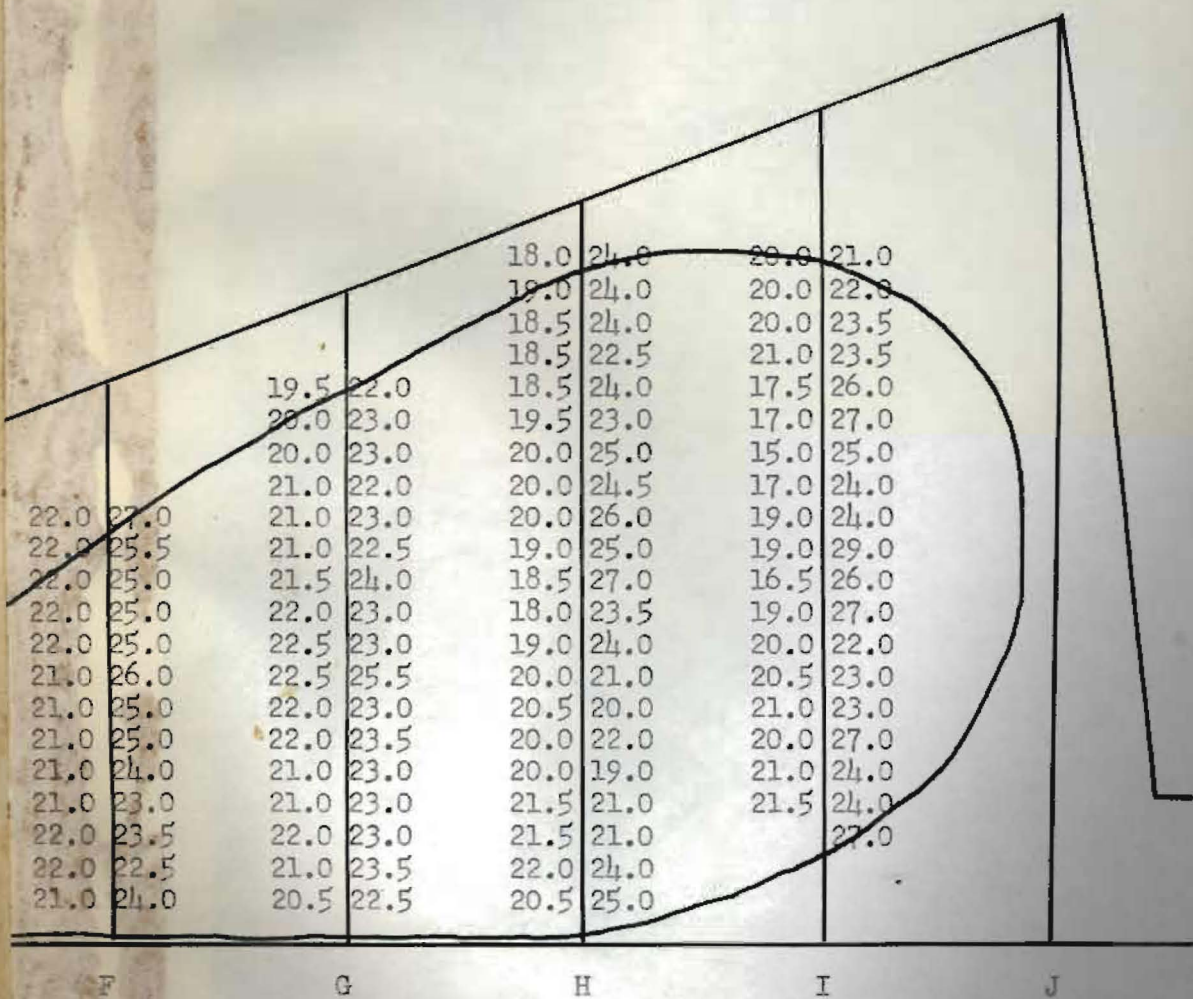


Fig. 16. Map showing temperature readings (°C.) of surface water every 2 m. along transect lines. Readings left of transect lines are for August 17, 1957; those right of lines for June 28, 1958.



the marsh in that area. Probing in the vicinity found the usually firm sand substrate easily penetrable due, perhaps, to the upward flow of water. Along transects G, H, and I water temperatures were generally highest in the Leersia mat. Where the mat was well established, the water was so completely pocketed that little current was produced by either convection or wind.

The only winter observation of the boggy marsh was made on the afternoon of February 16, 1958. The water areas were capped with several centimeters of ice with the exception of two localities. A 2-m<sup>2</sup> area immediately south and southeast of the well remained unfrozen under the influence of artesian water. In this area Nasturtium officinale was flourishing, although smaller of stature than during the spring. A second open-water area surrounded by snow-capped ice was at station 13 (Fig. 17), the point of presumed ground-water inflow. Near the southwest bank, solid ice was covered with slush, the falling snow apparently melting as it alighted. The air temperature was -8°C.

The second battery of temperature measurements was taken under a 29-degree atmosphere on June 28, 1958. The 7-degree higher temperature than that of the August measuring date was reflected in increased temperature ranges along each transect. Southeast of the well, water temperatures ranged from 17.5 to 25°C. The main marsh area showed a range of 19 to 29°C. Station 3, nearest the well, measured 23°C. The greatest increase over August temperature readings occurred in the Typha and open water zones where 4 to 7-degree increases were common. The Sagittaria zone showed moderate increases of 2 to 3 degrees. The Leersia mat showed the least increase over

August readings, 1 to 2 degrees being common with some points show-

ing a few in the range of 3 to 4 degrees.



Fig. 17. Station 13 in Typha zone on February 16, 1958. pH values ranged from 7 to 8.3. The well water showed a pH of 7.7, stations in the Sagittaria zone varying no more than 0.1 unit from that value. All other stations showed lower values except Station 13. There a pH of 8.3 was observed. Water standing in the roadside ditch at the west end of the marsh had a pH of 8.2. Mean pH values in August and June were 7.0 and 7.5 respectively.

Hardness of the water issuing from the well (Fig. 19) was due to the presence of calcium and magnesium bicarbonates, commonly called carbonate hardness. This temporary hardness measured 129 ppm in October, 1942 (Latta, 1950). Both August and June determinations registered

August readings, 1 to 2 degrees being common with some points showing a drop in temperature. Station 13, farthest from the well, registered 25°C. with little indication of underground recharging of marsh waters. The June temperature pattern may have resulted from well water replacing the loss of marsh water due to evaporation. Depth soundings failed to locate the loose bottom sand encountered during the August soundings. Recharging from a subsurface source apparently is operative only intermittently.

#### Chemical Conditions

Results of chemical analyses are tabulated in Figures 18 through 22. August pH determinations (Fig. 18) showed a range of 6.6 to 7.2, the latter being the pH of the well water. Stations in and near the Sagittaria zone all had a pH of 7.1 except the one nearest the well. Its pH was 7.2, like that of the well. Stations 9, 10, 12, and 13 had a pH range of 6.7 to 6.9. Southeast of the well, station 2 had a pH of 6.6, the lowest of all stations. June determinations ranged from 7 to 8.3. The well water showed a pH of 7.7, stations in the Sagittaria zone varying no more than 0.1 unit from that value. All other stations showed lower values except station 13. There a pH of 8.3 was observed. Water standing in the roadside ditch at the west end of the marsh had a pH of 8.2. Mean pH values in August and June were 7.0 and 7.5 respectively.

Hardness of the water issuing from the well (Fig. 19) was due to the presence of calcium and magnesium bicarbonates, commonly called carbonate hardness. This temporary hardness measured 129 ppm in October, 1942 (Latta, 1950). Both August and June determinations registered

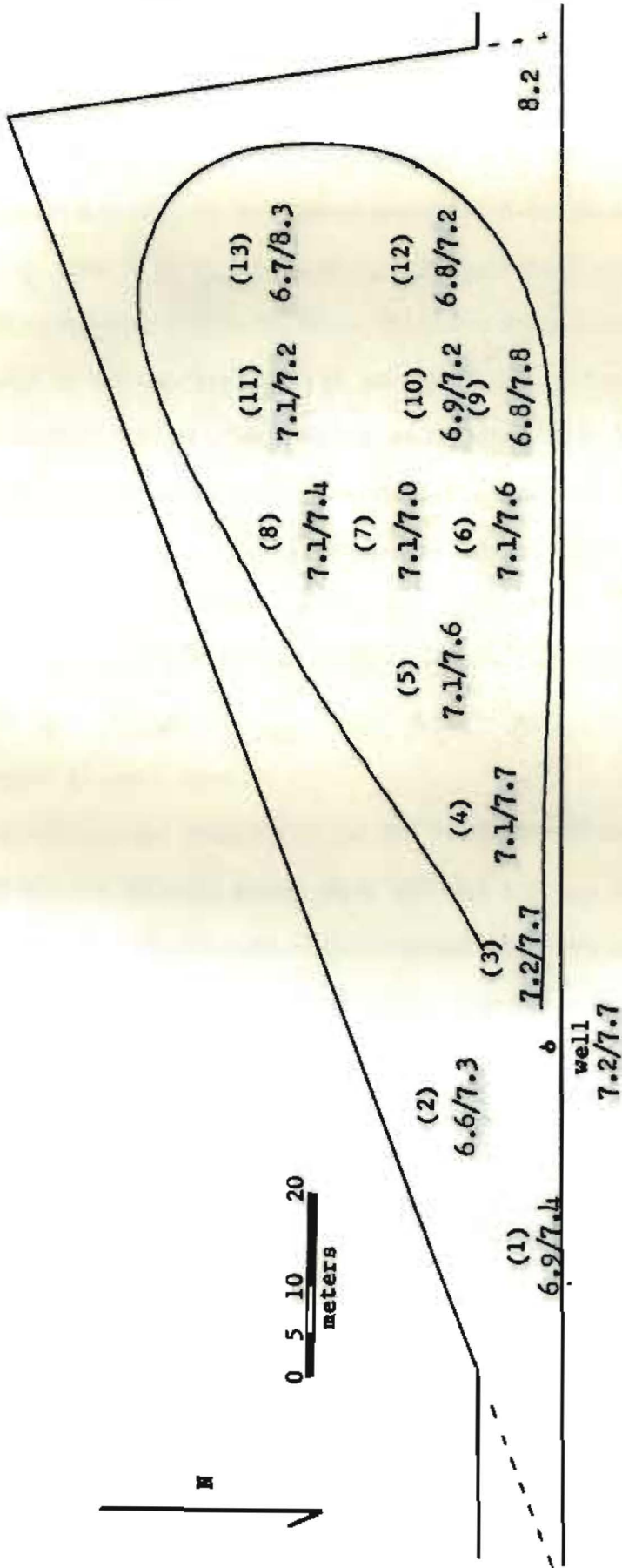


Fig. 18. Map showing pH determinations of water at various stations and the well on August 20, 1957 (left of diagonal), and on June 21, 1958 (right of diagonal). Value at lower right of map is for water standing in roadside ditch on latter date.

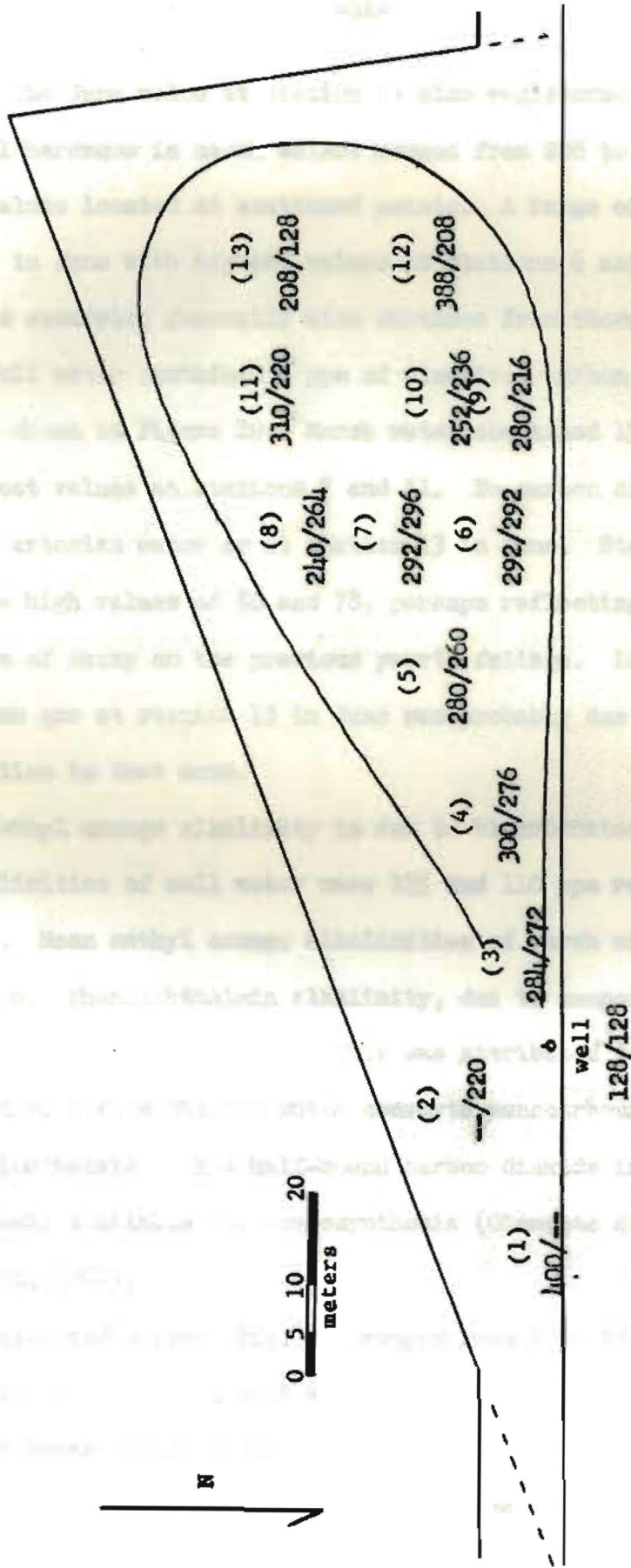


Fig. 19. Map showing water hardness in ppm as calcium carbonate at various stations and the well on August 19, 1957 (left of diagonal), and June 7, 1958 (right of diagonal).

128 ppm. The June value at station 13 also registered 128. In August total hardness in marsh waters ranged from 208 to 400 ppm with highest values located at scattered points. A range of 128 to 296 was noted in June with highest values at stations 6 and 7 and downward gradations occurring generally with distance from those stations.

Well water contained 4 ppm of dissolved carbon dioxide in August as shown in Figure 20. Marsh water contained 15 to 60 ppm with highest values at stations 7 and 11. No carbon dioxide was detected in artesian water or at station 13 in June. Stations 9 and 11 showed the high values of 80 and 78, perhaps reflecting rapid bacterial action of decay on the previous year's foliage. Lack of the decomposition gas at station 13 in June was probably due to sparseness of vegetation in that area.

Methyl orange alkalinity is due to bicarbonates. August and June alkalinities of well water were 125 and 110 ppm respectively (Fig. 21). Mean methyl orange alkalinities of marsh water were 256 and 264 ppm. Phenolphthalein alkalinity, due to monocarbonates, was absent from all samples tested. This was attributed to the high concentration of carbon dioxide which converts monocarbonates into soluble bicarbonates. The half-bound carbon dioxide in bicarbonates is reportedly available for photosynthesis (Clements and Shelford, 1939; Welch, 1952).

Dissolved oxygen (Fig. 22) ranged from 0 to 10 ppm in August with a mean of 5 ppm. Highest values in general were in more nearly open water areas probably due to algal photosynthesis and aeration. Decomposition reduced dissolved oxygen to a mean of 2 ppm in June,



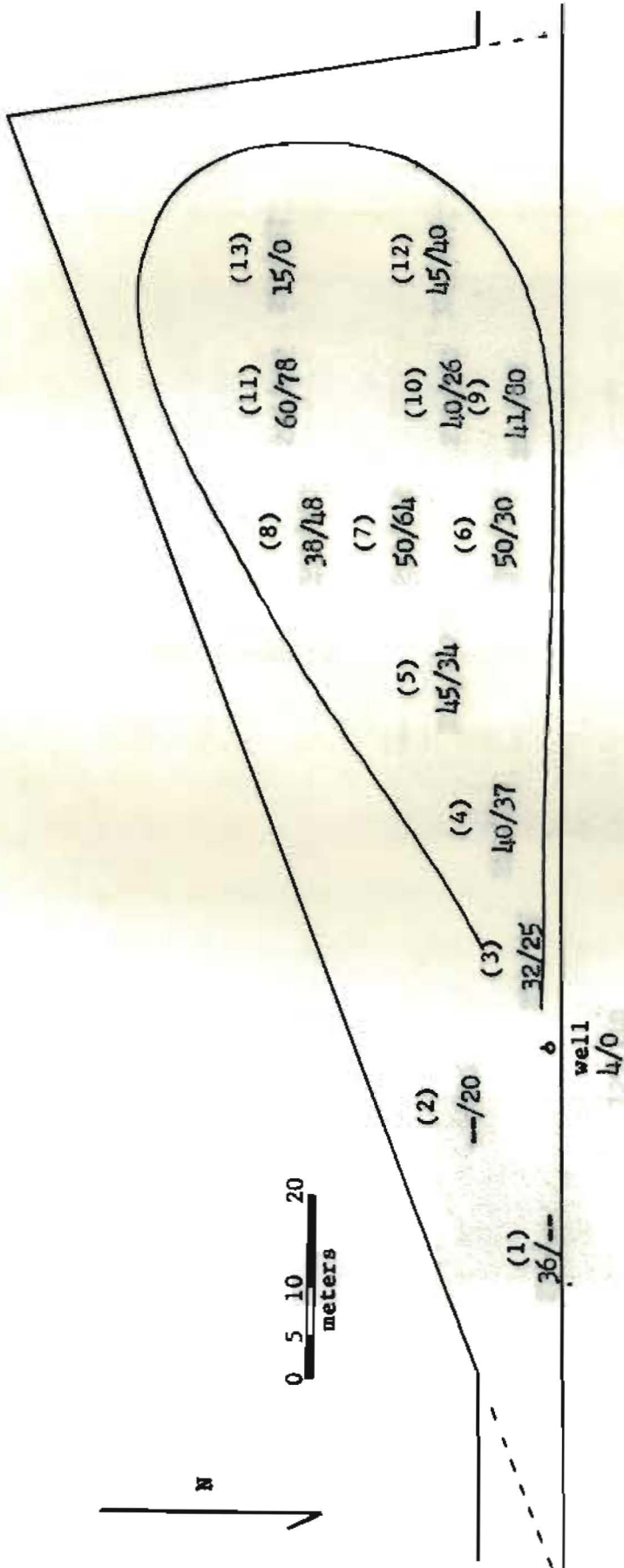


FIG. 20. Map showing free carbon dioxide in ppm of water at various stations and the well on August 19, 1957 (left of diagonal), and on June 7, 1958 (right of diagonal).

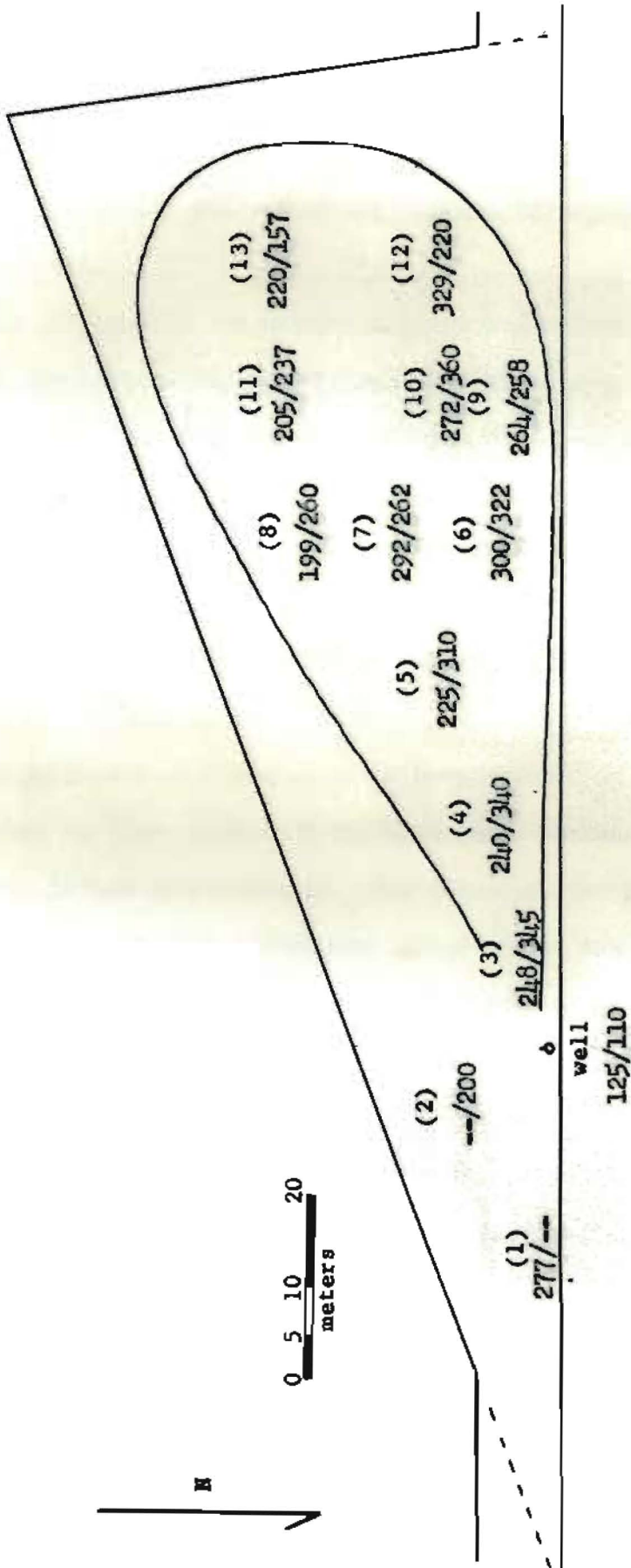


Fig. 21. Map showing methyl orange alkalinity in ppm of water at various stations and the well on August 19, 1957 (left of diagonal), and June 7, 1958 (right of diagonal).

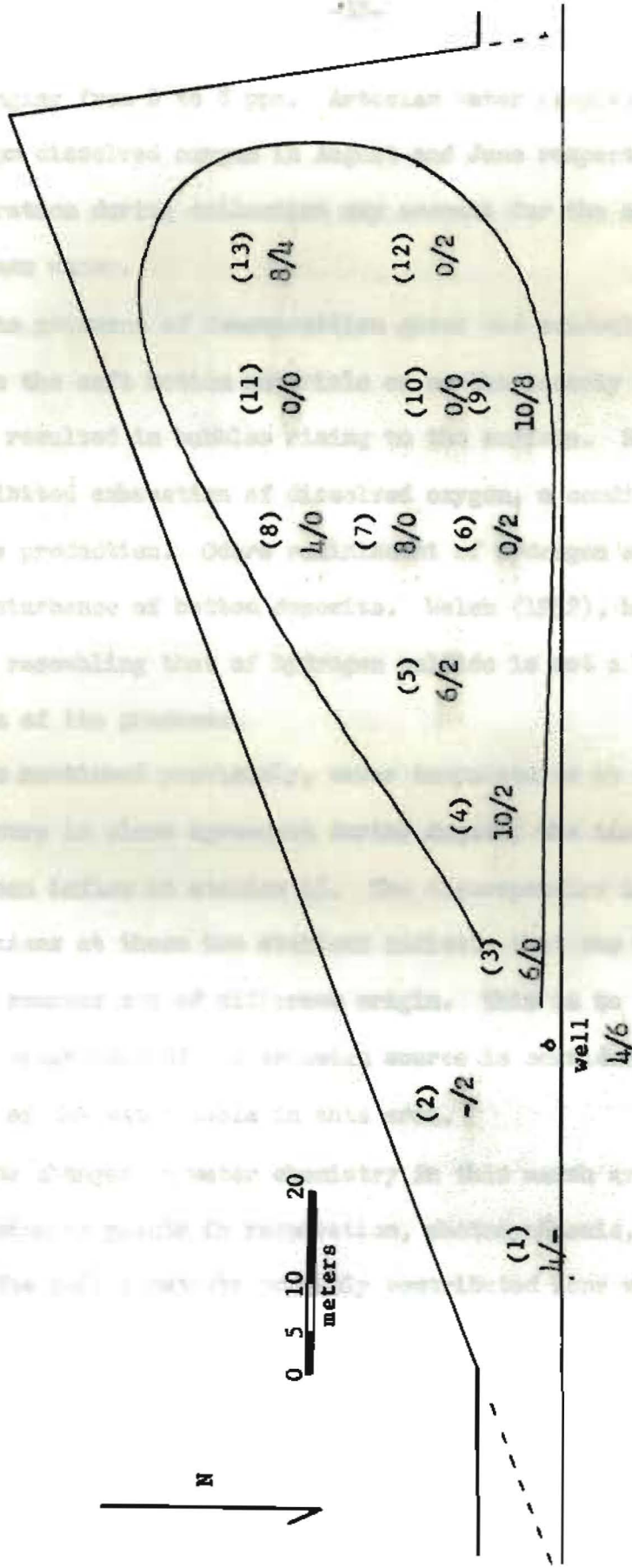


Fig. 22. Map showing dissolved oxygen in ppm of water at various stations and the well on August 1, 1957 (left of diagonal), and June 7, 1958 (right of diagonal).

values ranging from 0 to 8 ppm. Artesian water samples contained 4 and 6 ppm dissolved oxygen in August and June respectively. Accidental aeration during collection may account for the oxygen in the subterranean water.

The presence of decomposition gases was evident at times. Walking on the soft bottom materials or on the loosely constructed Typha mat resulted in bubbles rising to the surface. Some of these areas exhibited exhaustion of dissolved oxygen, a condition conducive to methane production. Odors reminiscent of hydrogen sulfide accompanied disturbance of bottom deposits. Welch (1952), however, states that odor resembling that of hydrogen sulfide is not a dependable indication of its presence.

As mentioned previously, water temperatures at station 13 and the well were in close agreement during August, the time of presumed subterranean inflow at station 13. The discrepancies in the chemical determinations at these two stations indicate that the waters from these two sources are of different origin. This is to be expected since the water head of the artesian source is considerably greater than that of the water table in this area.

The changes in water chemistry in this marsh are likely due to the action of plants in respiration, photosynthesis, and decomposition. The soil substrate probably contributed ions which affected pH, alkalinity and hardness. Within the small range of variations in this marsh, water chemistry had no apparent effect on the distribution of the aquatic seed plants present.

Positive determination of succession was impossible due to the short

### Zonation

While variations in water chemistry did not play an obvious role in the distribution of aquatic seed plants, physical factors affected the establishment of various communities. They will be discussed in terms of the artesian stream community and the Leersia mat.

Artesian stream communities share with spring communities their relatively constant chemical composition, water temperature, and water velocity. These features remain nearly constant for, as organisms modify the water, the modified water passes downstream to be replaced by more subterranean water. Pennak (1953) and Odum (1953) note that the number of species in such environments is relatively small, the stable conditions providing fewer ecological niches. The animal species concentrated near the artesian flow of this study included Attheyella nordenskioldii not encountered elsewhere in the boggy marsh. The planerian, Dugesia dorotocephala, was usually observed very near the well outlet. Pennak (1953) describes this species as a spring brook animal which prefers well oxygenated headwaters. Vaucheria, found near the well, is also usually found in well aerated waters (Fritsch, 1935). Nasturtium officinale was conspicuous for its lush growth in the artesian stream and the narrow limits of its distribution. Morinaga (1926a) reported an optimum germination temperature of 15°C. for water-cress seeds. This compares favorably with the 13.7°C. mean temperature of the well water.

The formation of the boggy mat was of special interest. Positive determination of succession was impossible due to the short

study period. However, observations led to speculation which may, in subsequent investigations, be substantiated or refuted. Succession probably began with the emergent Typha which dominated the deeper marsh area where conditions are generally conducive to germination and growth of cattail seeds. Morinaga (1926b, 1926c) reported that optimum conditions for the germination of intact Typha latifolia seeds include light and reduced oxygen pressure. Water transparency in this marsh was high enough for easy penetration of light to the bottom mud. Oxygen concentration was favorable considering water as a diluent. Once established, the plants spread vegetatively under water. Seasonal accumulation of organic matter settles to the bottom and remains largely where formed since the bottom slope is slight and currents not pronounced. The bottom subtending the open water area at station 13, probably being disturbed by occasional inflow of subterranean water, did not allow development of Typha colonies.

Associated with Typha latifolia was Typha angustifolia with which it hybridizes, Berula pusilla, and Bidens laevis. Berula is a perennial developing during the early summer, its fibrous roots feeding in the organic mud deposited among the Typha tussocks. Prostrate floating stems develop adventitious roots at the nodes which help to establish at least a surface mat of vegetation. During mid-summer, Bidens laevis (Fig. 23) replaces the then-waning Berula in the margins of the Typha zone. General observation indicated an increase in Bidens individuals for the late 1958 season over that indicated by transect counts the previous year.

Frequency of Leersia oryzoides along transects was by far the



highest in the area southeast of the well, characterized by a firm substrate and only a few centimeters of water. The boggy mat of Leersia occurred largely at the northwest margin of the marsh bounding the Typha zone on the north. Presumably Typha, Berula, and Bidens persist until the bottom deposits offer enough consistency to serve as anchorage for the creeping Leersia rhizomes. The sprawling posture of the Leersia in this marsh and its tendency to root at the nodes result in a substantial mat.

#### Effects of Man

The road marking the north border of the study area is the only straight-through route which runs between the Big and Little Salt Marshes. This results in relatively heavy traffic for a country road in this area. The artesian well's proximity to the road makes this area a favorite stopping place for travelers. The well is the main water supply for various local residents and hunting clubs whose wells produce water too highly mineralized for normal use.

Sagittaria latifolia and Typha spp. from this marsh are sometimes transplanted into private fish ponds. Nasturtium officinale is collected for table use. While these activities temporarily disturb the biotic equilibrium, recovery is rapid.

The development of the Quivira National Wildlife Refuge in the general vicinity of the study area may bring presently unforeseen changes to this boggy marsh.

0.5 to 1.0 m. Water depth increased about 15 cm. during the study period and ranged from a trace to 0.2 m. Water temperatures at the supplying well ranged from 13.4°C. to 14°C. Temperatures of surface



SUMMARY

Plant zonation and accompanying physical-chemical conditions in a boggy marsh in Stafford County, Kansas, were studied from March, 1957, to August, 1958. The constant supply of subterranean water reduced the amplitude of water level fluctuation, allowing a study of other factors which affect aquatic vegetation.

Seed plant zonation was studied by quadrat and line transect methods in the summer of 1957 and the spring of 1958. At these times water from 13 selected stations and the adjacent artesian well was analyzed quantitatively for hardness, alkalinity, dissolved oxygen, free carbon dioxide, and pH. Depth of water and bottom mud, and water temperature were recorded along transect lines. General observations of animal species and lower plants were recorded.

Three zones of emergent aquatic plants were apparent in the littoral area of the marsh: the Typha zone with associated Berula pusilla and Bidens laevis; the Sagittaria zone; and the zone of mat-forming Leersia oryzoides. Spring brook organisms were concentrated in the stream leading water from the artesian well with Nasturtium officinale dominating, Leersia becoming dominant where this stream broadens to form a seepage area. An overflow plain, inundated only periodically, was dominated by Spartina pectinata.

Soft bottom mud in the boggy marsh ranged in thickness from 0.4 to 1.0 m. Water depth increased about 10 cm. during the study period and ranged from a trace to 0.2 m. Water temperatures at the supplying well ranged from 13.4°C. to 14°C. Temperatures of surface

water ranged to 22.5°C. in August and to 29°C. in June. Temperature patterns in August indicated a subterranean water supply in the marsh in addition to the well.

August and June water pH ranges were 6.6 to 7.2 and 7.0 to 8.3 respectively. Temporary hardness of water at the well was 128 ppm, marsh waters ranging from 208 to 400 ppm in August and from 128 to 296 ppm in June. Free carbon dioxide content ranged from 15 to 60 ppm and from 0 to 80 ppm in August and June. Mean methyl orange alkalinity due to bicarbonates was 256 ppm in August and 264 ppm in June compared to 125 ppm or less in the well water. Dissolved oxygen ranged from 0 to 10 ppm in August and from 0 to 8 ppm in June. Variations in water chemistry were probably due to plant metabolism and bottom soil. Water chemistry had no apparent effect on the distribution of aquatic seed plants.

Consideration of physical and anatomical factors led to the speculation that the formation of the Leersia mat followed a succession of Typha, Berula pusilla, Bidens laevis, and Leersia oryzoides. Each of these species is probably dependent upon its ability to root at the nodes of stems and upon the effect of the preceding species in consolidating bottom sediments.

Hall, S. August. 1895. Handbook of mammals of Kansas. Univ. Kans. Mus. Bot. Hist., Misc. Publ. No. 7.

Jewell, Diana S. 1927. Aquatic biology of the prairie. Ecology 3:289-296.

Little, Bruce F. 1950. Geology and ground-water resources of Barton and Stafford counties, Kansas. Kansas Geol. Survey, Bull. 80:1-226.

Lindsay, Alton A. 1953. Notes on some plant communities in the northern Mackenzie basin, Canada. Bot. Gaz. 115(2):44-55.

LITERATURE CITED

- Carpenter, John Richard. 1938. An ecological glossary. University of Oklahoma Press, Norman, Okla.
- Clements, Frederic E. and Victor E. Shelford. 1939. Bio-ecology. John Wiley and Sons, Inc., New York.
- Coker, Robert E. 1954. Streams, lakes, ponds. The University of North Carolina Press, Chapel Hill, North Carolina.
- Daubenmire, Rexford F. 1947. Plants and environment, a textbook of plant autecology. John Wiley and Sons, Inc., New York.
- Dineen, Clarence F. 1953. An ecological study of a Minnesota pond. Amer. Midland Nat. 50(2):349-376.
- Fassett, Norman C. 1957. A manual of aquatic plants. The University of Wisconsin Press, Madison, Wisc.
- Fernald, Merritt Lyndon. 1950. Gray's manual of botany. 8th Ed. American Book Company, New York.
- Flora, Snowden D. 1948. Climate of Kansas. Rpt. Kans. St. Bd. Agr. 67(285):1-320.
- Fritsch, F. E. 1935. The structure and reproduction of the algae. Vol. 1. Cambridge University Press, London.
- \_\_\_\_\_. 1945. The structure and reproduction of the algae. Vol. 2. Cambridge University Press, London.
- Gates, Frank C. 1937. Grasses in Kansas. Rpt. Kans. St. Bd. Agr. 55(220-A):1-349.
- \_\_\_\_\_. 1949. Field manual of plant ecology. McGraw-Hill Book Company, Inc., New York.
- Hall, E. Raymond. 1955. Handbook of mammals of Kansas. Univ. Kans. Mus. Nat. Hist., Misc. Publ. No. 7.
- Jewell, Minna E. 1927. Aquatic biology of the prairie. Ecology 8:289-298.
- Latta, Bruce F. 1950. Geology and ground-water resources of Barton and Stafford counties, Kansas. Kansas Geol. Survey, Bull. 88:1-228.
- Lindsey, Alton A. 1953. Notes on some plant communities in the northern Mackenzie basin, Canada. Bot. Gaz. 115(1):44-55.

- McGregor, R. L. 1948. First year invasion of plants on an exposed lake bed. *Trans. Kans. Acad. Sci.* 51 (3):324-327.
- \_\_\_\_\_ and L. D. Volle. 1950. First year invasion of plants on the exposed bed of Lake Fegan. *Trans. Kans. Acad. Sci.* 53(3):372-376.
- Metcalf, F. P. 1931. Wild-duck foods of North Dakota lakes. U. S. Dept. Agric. Tech. Bull. 221:1-72.
- Miller, William J. 1952. An introduction to historical geology. D. Van Nostrand Company, Inc., New York.
- Morinaga, Toshitaro. 1926a. Germination of seeds under water. *Amer. Jour. Bot.* 13:126-140.
- \_\_\_\_\_. 1926b. Effect of alternating temperature upon germination of seeds. *Amer. Jour. Bot.* 13:141-158.
- \_\_\_\_\_. 1926c. The favorable effect of reduced oxygen supply upon the germination of certain seeds. *Amer. Jour. Bot.* 13:159-166.
- Moyle, J. B. 1945. Some chemical factors influencing the distribution of aquatic plants in Minnesota. *Amer. Midland Nat.* 34:402-420.
- Odum, Eugene P. 1953. Fundamentals of ecology. W. B. Saunders Company, Philadelphia.
- Oosting, Henry J. 1956. The study of plant communities. W. H. Freeman and Company, San Francisco.
- Penfound, William T. 1952. Management of state lakes. *Oklahoma Quarterly* 1(3):31-32.
- \_\_\_\_\_. 1953. Plant communities of Oklahoma lakes. *Ecology* 34(3):561-583.
- \_\_\_\_\_ and E. S. Hathaway. 1938. Plant communities in the marshlands of southeastern Louisiana. *Ecol. Monom.* 8:1-56.
- Pennak, Robert W. 1953. Fresh-water invertebrates of the United States. The Ronald Press, New York.
- Peterson, Roger Tory. 1947. A field guide to the birds. Houghton Mifflin Company, Boston.
- Rickett, H. W. 1924. A quantitative study of the larger aquatic plants of Green Lake, Wisconsin. *Trans. Wis. Acad. Sci.* 21:381-414.
- Rydberg, Per Axel. 1932. Flora of the prairies and plains of central North America. New York Botanical Garden, New York.

- Schoewe, Walter H. 1949. The geography of Kansas. Part II. Physical geography. Trans. Kans. Acad. Sci. 52(3):261-333.
- Sledd, Bertie. 1958. Personal correspondence.
- Smith, Hobart M. 1950. Handbook of reptiles and amphibians of Kansas. Univ. Kans. Mus. Nat. Hist., Misc. Publ. No. 2.
- Smith, Roger C. 1943. Common insects of Kansas. Rpt. Kans. St. Bd. Agr. 62(255):1-440.
- Stevens, William Chase. 1948. Kansas wild flowers. University of Kansas Press, Lawrence, Kans.
- Swindale, Delle N. and John T. Curtis. 1957. Phytosociology of the larger submerged plants in Wisconsin lakes. Ecology 38(3):397-407.
- Theroux, F. R., E. F. Eldridge, and W. L. Mallman. 1943. Laboratory manual for chemical and bacterial analysis of water and sewage. 3d Ed. McGraw-Hill Book Company, Inc., New York.
- Tiemeier, Otto W. 1951. Studies on Kanopolis Reservoir in 1950. Trans. Kans. Acad. Sci. 54:175-189.
- U. S. Department of Commerce, Weather Bureau. 1957. Climatological data Kansas 71:1-228.
- \_\_\_\_\_. 1958. Climatological data Kansas 72:1-111.
- Waterman, W. G. 1926. Ecological problems from the sphagnum bogs of Illinois. Ecology 7:255-272.
- Weaver, John E. and Frederic E. Clements. 1938. Plant ecology. McGraw-Hill Book Company, Inc., New York.
- Welch, Paul S. 1948. Limnological methods. The Blakiston Company, Philadelphia.
- \_\_\_\_\_. 1952. Limnology. 2nd Ed. McGraw-Hill Book Company, Inc., New York.
- Wilson, L. R. 1935. Lake development and plant succession in Vilas County, Wisconsin. Part I. The medium hard water lakes. Ecol. Monog. 5:207-247.
- Wood, R. D. 1952. An analysis of ecological factors in the occurrence of Characeae of the Woods Hole region, Massachusetts. Ecology 33:104-109.
- ZoBell, Claude E. and Catherine B. Feltham. 1942. The bacterial flora of a marine mud flat as an ecological factor. Ecology 23:69-78.

APPENDIX 24 - CHECKLIST OF ORGANISMS IDENTIFIED

Kingdom: Plantae

Subkingdom: Embryophyta

Division: Charophyta

Class: Chlorophyceae

Order: Chloridiales

Family: Chloridaceae

*Chloridaceae* sp.

Order: Cladophorales

Family: Cladophoraceae

*Cladophoraceae* sp.

Order: Ulvales

Family: Ulvaceae

*Ulvaceae* sp.

Order: Zygnematales

Family: Zygnemataceae

*Zygnemataceae* sp.

Division: Charophyta

Class: Xanthophyceae

Order: Xanthophyceales

Family: Xanthophyceae

*Xanthophyceae* sp.

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Tetrasporales

APPENDIX

APPENDIX A: CHECKLIST OF ORGANISMS IDENTIFIED

Kingdom: Plantae

Subkingdom: Thallophyta

Division: Chlorophyta

Class: Chlorophyceae

Order: Oedogoniales

Family: Oedogoniaceae

Oedogonium sp.

Order: Cladophorales

Family: Cladophoraceae

Rhizoclonium crispum Kuetz

Order: Chlorecoccales

Family: Oocystaceae

Chlorella conductrix Brandt

Order: Zygnematales

Family: Zygnemataceae

Spyrogyra sp.

Division: Chrysophyta

Class: Xanthophyceae

Order: Heterosiphonales

Family: Vaucheriaceae

Vaucheria sp.

Class: Bacillariophyceae

Order: Pennales

Suborder: Achnanthinea

Synedra laevigata Willd.

Family: Achnanthaceae

Rhoicosphenia sp.

Cocconeis sp.

Suborder: Naviculineae

Family: Cymbellaceae

Rhopalodia sp.

Division: Cyanophyta

Class: Cyanophyceae

Order: Oscillatoriales

Suborder: Oscillatorineae

Family: Oscillatoriaceae

Lyngbya sp.

Subkingdom: Embryophyta

Division: Tracheophyta

Subdivision: Pteropsida

Class: Angiospermae

Subclass: Monocotyledoneae

Order: Pandanales

Family: Typhaceae

Typha angustifolia L.

Typha latifolia L.

Order: Helobiales

Family: Najadaceae

Najas sp.

Family: Alismataceae

Sagittaria latifolia Willd.



Order: Graminales

Family: Gramineae

Andropogon gerardi Vitman

Bromus tectorum L.

Digitaria sanguinalis (L.) Scop.

Echinochloa crusgalli (L.) Beauv.

Elymus canadensis L.

Eragrostis megastachya (Koel.) Link

Hordeum jubatum L.

Leersia oryzoides (L.) Sw.

Panicum virgatum L.

Poa pratensis L.

Setaria geniculata (Lam.) Beauv.

Setaria glauca (L.) Beauv.

Spartina pectinata Link.

Sorghastrum nutans (L.) Nash

Family: Cyperaceae

Carex lanuginosa Michx.

Eleocharis calva Torr.

Scirpus americanus Pers.

Scirpus validus Vahl.

Order: Arales

Family: Lemnaceae

Lemna minor L.

Spirodela polyhriza (L.) Schleid.

Order: Liliales

Family: Juncaceae

Juncus torreyi Coville

Subclass: Dicotyledoneae

Order: Salicales

Family: Salicaceae

Populus deltoides Marsh.

Salix nigra Marsh.

Order: Urticales

Family: Ulmaceae

Celtis occidentalis L.

Family: Urticaceae

Parietaria pennsylvanica Muhl.

Order: Polygonales

Family: Polygonaceae

Polygonum lapathifolium L.

Rumex crispus L.

Order: Centrospermales

Family: Chenopodiaceae

Chenopodium album L.

Order: Ranales

Family: Ranunculaceae

Ranunculus sceleratus L.

Order: Papaverales

Family: Cruciferae

Nasturtium officinale R. Br.

Order: Rosales

Family: Saxifragaceae

Ribes odoratum Wendland f.

Family: Rosaceae

Prunus americana Marsh.

Family: Leguminosae

Desmanthus illinoensis (Michx.) MacM.

Glycyrrhiza lepidota (Nutt.) Pursh

Melilotus alba Desr.

Order: Geraniales

Family: Euphorbiaceae

Euphorbia marginata Pursh

Order: Sapindales

Family: Anacardiaceae

Rhus radicans L.

Order: Rhamnales

Family: Vitaceae

Vitis vulpina L.

Order: Malvales

Family: Malvaceae

Callirhoe involucrata (T. & G.) Gray

Order: Parietales

Family: Violaceae

Viola papilionacea Pursh

Order: Myrtales

Family: Onagraceae

Gaura parviflora Dougl.

Order: Umbellales

Family: Umbelliferae

Berula pusilla (Nutt.) Fern.

Cicuta maculata L.

Family: Cornaceae

Cornus asperifolia Michx.

Order: Gentianales

Family: Apocynaceae

Apocynum cannabinum L.

Family: Asclepiadaceae

Asclepias incarnata L.

Asclepias speciosa Torr.

Order: Tubiflorales

Family: Verbenaceae

Lippia lanceolata Michx.

Verbena hastata L.

Family: Labiatae

Lycopus americanus Muhl.

Family: Solanaceae

Solanum nigrum L.

Family: Scrophulariaceae

Mimulus glabratus HBK. var. fremontii (Benth.) Grant

Order: Rubiales

Family: Rubiaceae

Galium aparine L.

Order: Campanulales

Family: Compositae

Ambrosia psilostachya DC.

Ambrosia trifida L.

Artemisia ludoviciana Nutt.

Aster ericoides L.

Bidens laevis (L.) BSP.

Cirsium undulatum (Nutt.) Spreng.

Eupatorium perfoliatum L.

Haplopappus ciliatus (Nutt.) DC.

Helianthus maximiliani Schrad.

Lactuca scariola L.

Solidago canadensis L. var. glivocanescens Rydb.

Kingdom: Animalia

Phylum: Coelenterata

Class: Hydrozoa

Order: Hydroida

Family: Hydridae

Chlorohydra viridissima (Pallas)

Phylum: Platyhelminthes

Class: Turbellaria

Order: Tricladida

Family: Planariidae

Dugesia derotocephala (Woodworth)

Phylum: Arthropoda

Class: Crustacea

Subclass: Branchiopoda

Division: Oligobranchiopoda

Order: Cladocera

Family: Chydoridae

Subfamily: Chydorinae

Alona rectangula Sars

Pleuroxus denticulatus Birge

Chydorus sphaericus (O.F.M.)

Family: Daphnidae

Simocephalus vetulus (O.F.M.)

Subclass: Copepoda

Order: Eucopepoda

Suborder: Cyclopoida

Family: Cyclopidae

Eucyclops agilis (Koch)

Suborder: Harpacticoida

Family: Canthocamptidae

Attheyella nordenskioldii (Lilljeborg)

Subclass: Malacostraca

Division: Peracarida

Order: Amphipoda

Family: Talitridae

Hyalella asteca (Saussure)

Division: Eucarida

Order: Decapoda

Family: Astacidae

Subfamily: Cambarinae

Orconectes immunis (Hagen)

Class: Insecta

Subclass: Pterygota

Division: Holometabola

Order: Lepidoptera

Family: Danaidae

Danaus plexippus (L.)

Family: Pieridae

Phoebis sennae var. eubule (L.)

Phylum: Chordata

Subphylum: Gnathostomata

Superclass: Pisces

Class: Osteichthyes

Order: Ostariophysi

Family: Cyprinidae

Pimephales promelas Rafinesque

Superclass: Tetrapoda

Class: Amphibia

Subclass: Salientia

Order: Procoela

Family: Hylidae

Acris crepitans Baird

Order: Diplasiocela

Family: Ranidae

Rana pipiens Schreber

Class: Reptilia

Order: Squamata

Suborder: Serpentes

Family: Colubridae

Pituophis catenifer (Blainville)

Thamnophis sp.

Family: Crotalidae

Sistrurus catenatus (Rafinesque)

Class: Aves

Subclass: Neornithes

Superorder: Neognathae

Order: Ciconiiformes

Family: Ardeidae

Botaurus lentiginosus (Rackett)

Order: Falconiformes

Family: Accipitridae

Circus cyaneus (L.)

Order: Galliformes

Family: Phasianidae

Colinus virginianus (L.)

Phasianus colchicus L.

Order: Charadriiformes

Family: Scolopacidae

Capella gallinago (L.)

Order: Columbiformes

Family: Columbidae



Zenaidura macroura (L.)

Order: Cuculiformes

Family: Cuculidae

Coccyzus americanus (L.)

Order: Piciformes

Family: Picidae

Melanerpes erythrocephalus (L.)

Dendrocopos villosus (L.)

Order: Passeriformes

Suborder: Tyranni

Family: Tyrannidae

Tyrannus tyrannus (L.)

Suborder: Oscines

Family: Corvidae

Corvus brachyrhynchos Brehm

Family: Parulidae

Geothlypis trichas (L.)

Family: Icteridae

Sturnella magna (L.)

Sturnella neglecta Audubon

Agelaius phoeniceus (L.)

Icterus spurius (L.)

Icterus galbula (L.)

Family: Fringillidae

Spiza americana (Gmelin)

Class: Mammalia

Subclass: Theria

Infraclass: Eutheria

Order: Lagomorpha

Family: Leporidae

Sylvilagus floridanus (J. A. Allen)

Order: Carnivora

Suborder: Fissipedia

Family: Canidae

Canis latrans Say

Family: Mustelidae

Mephitis mephitis (Schreber)

Total Surface Determination Adopted from Barrett et al. (1963)

1. Collect 2 25 ml. samples in a 100 ml. glass-stoppered bottle.
2. Add standard milk solution, about 0.5 ml. at a time, shaking the bottle vigorously after each addition, until a uniform foam about 1 cm. deep is obtained.
3. The manufacturer's stated water content is subtracted from the ml. of standard milk solution used, the difference multiplied by 10 giving total surface area in cm<sup>2</sup> produced by this amount of milk solution.

## APPENDIX B: LIMNOLOGICAL PROCEDURES

### Carbon Dioxide Determination Adapted from Welch (1948)

1. Collect the water sample in a 135 ml. glass-stoppered bottle using caution not to agitate the sample which may allow carbon dioxide to escape.
2. Immediately after collection, 100 ml. of the sample is transferred to a white porcelain evaporation dish.
3. Add 10 drops of phenolphthalein indicator if pink color is not evident before all 10 drops have been added.
4. If the solution turns pink when the phenolphthalein is added there is no free carbon dioxide present.
5. If the solution does not turn pink when the phenolphthalein is added, add  $N/44$  sodium hydroxide with a graduated pipette until the entire solution shows the first tinges of pink. The end point is the first tinge of pink shown uniformly throughout the solution, not the permanent pink obtainable by adding more sodium hydroxide.
6. The ml. of  $N/44$  sodium hydroxide used multiplied by 10 equals the quantity of free carbon dioxide in ppm.

### Total Hardness Determination Adapted from Theroux et. al. (1943)

1. Collect a 25 ml. sample in a 135 ml. glass-stoppered bottle.
2. Add standard soap solution, about 0.3 ml. at a time, shaking the bottle vigorously after each addition, until a lather forms which stands for 5 minutes.
3. The manufacturer's stated lather factor is subtracted from the ml. of standard soap solution used, this difference multiplied by 40 giving total hardness equivalent to that produced by that many ppm of calcium carbonate.

Alkalinity Determination Adapted from Welch (1948)

1. Collect the water sample in a clean glass bottle.
2. Deliver 100 ml. of the sample into a white porcelain evaporating dish.
3. Add 3 or 4 drops of phenolphthalein indicator. If color appears, hydroxide or normal carbonate is present.
4. If the sample turns pink, add N/50 (0.02N) sulfuric acid until the pinkness just disappears. (This end point occurs at a pH of 8.3).
5. Record the number of ml. of acid used.
6. To the same sample add 2 or 3 drops of methyl orange indicator. If yellow color is produced, hydroxide, normal carbonate, or bicarbonate is present.
7. If the sample becomes yellow, add N/50 sulfuric acid until the orange or salmon color appears.
8. Record the number of ml. of acid used.
9. The phenolphthalein alkalinity (P) in ppm as calcium carbonate is equal to the number of ml. of acid used in step 5 multiplied by 10.
10. The methyl orange alkalinity in ppm as calcium carbonate is the number of ml. of acid used in step 8 multiplied by 10.
11. The total alkalinity (T) is the sum of the products derived in steps 9 and 10.

The differentiation of hydroxides, carbonates, and bicarbonates may be obtained by the use of the following table:

Result of titration	Alkalinities expressed as ppm as Calcium Carbonate		
	Hydroxide	Carbonate	Bicarbonate
P equals 0	0	0	$T \times 10$
P less than $\frac{1}{2}T$	0	$2P \times 10$	$(T - 2P) \times 10$
P equals $\frac{1}{2}T$	0	$2P \times 10$	0
P greater than $\frac{1}{2}T$	$(2P - T) \times 10$	$2(T - P) \times 10$	0
P equals T	$T \times 10$	0	0

Oxygen Determination by the Winkler Method Adapted from  
Theroux et. al. (1943)

1. Collect the water sample in a 135 ml. glass-stoppered bottle using care not to modify the sample by aeration. (Samples were all collected at the surface).
2. Immediately after collection add 0.5 to 0.6 ml. of manganous sulfate, dipping the end of the pipette below the water's surface. (Medicine droppers which hold about 0.5 ml. were used.)
3. Add 0.5 to 0.6 ml. of alkaline potassium iodide in a similar manner.
4. Insert the stopper and mix by inverting the bottle several times.
5. Allow the precipitate to settle.
6. Add 0.5 to 0.6 ml. of concentrated sulfuric acid.
7. Allow the solution to stand at least 5 minutes. At this point in the procedure, the solution may stand for several hours if refrigerated.
8. Deliver 100 ml. of the solution into a white porcelain evaporating dish and immediately add  $N/40$  (0.025N) sodium thiosulfate drop by drop until the yellow color almost disappears.
9. Add a few drops of starch solution and continue to add  $N/40$  sodium thiosulfate drop by drop until the blue color just disappears. (Disregard any return of the blue color).
10. Record the ml. of sodium thiosulfate used.
11. The ml. of  $N/40$  sodium thiosulfate used multiplied by 2 equals the dissolved oxygen in the sample in ppm.