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The Ecology of a Boggy Marsh in Stafford County, Kansas

by

Paul G. Jantzen*

The fluctuating water level of lakes and ponds is one of the most critical factors in the establishment of aquatic vegetation in Kansas. This study utilizes an artesian-fed marsh (Fig. 1) in which the amplitude of water level is reduced, making possible the investigation of other factors that contribute to plant zonation. Objectives of this study, conducted from March, 1957, to August, 1958, may be summarized as follows:

1. To establish patterns of zonation of seed plants in this marsh.
2. To study certain chemical and physical factors in the water supply and the changes in these factors at 13 selected stations.
3. To investigate relationships between various plant and animal species and between these species and environmental factors.

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 impor-

Fig. 1. General view (looking toward the southwest) of the boggy marsh with artesian well in left foreground.

*Mr. Jantzen teaches biology in the Hillsboro, Kansas High School. This study is part of a Master's thesis completed under the supervision of Dr. Gilbert A. Leisman, Associate Professor of Biology, Kansas State Teachers College.

tant 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 temperatures 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 was made possible through the help of various individuals and government agencies who aided in acquiring information and materials. Special appreciation is expressed to the following: Dr. Gilbert A. Leisman, for guidance, criticism, and encouragement; Dr. Ted F. Andrews, for editorial supervision; and my wife Elaine, for assistance in field work and typing.

DESCRIPTION OF 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-

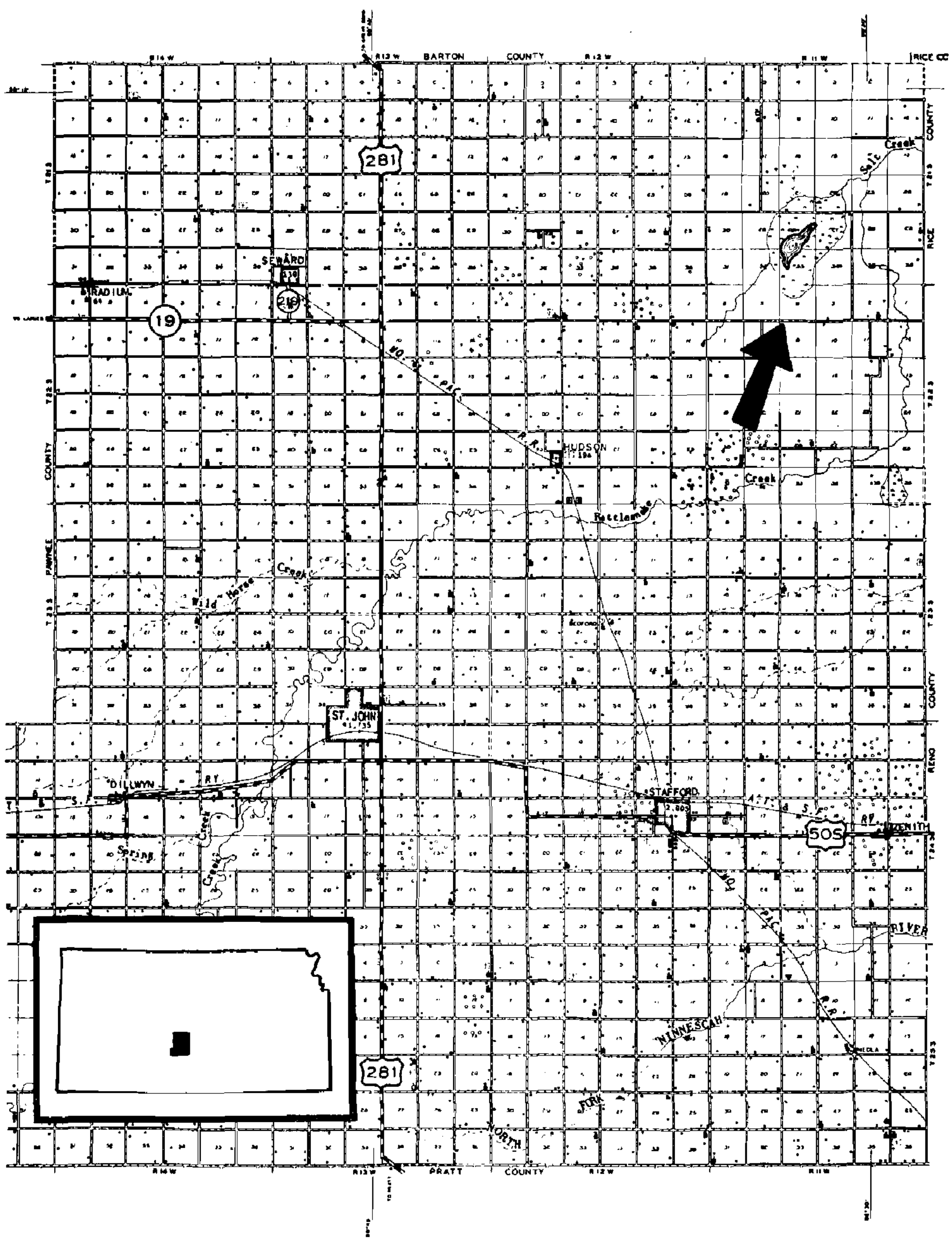

Fig. 2. Location of study area in Stafford County, in the NW¼ NW¼ sec. 9, T. 22 S., R. 11 W. Inset shows Stafford County's position in Kansas.

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 eadge 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.

A unique feature of the marsh of this study is the establishment of a boggy mat of *Leersia oryzoides* (L.) Sw. (rice cutgrass). Bog conditions are rarely encountered elsewhere in Kansas.

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.

Outcroppings and core-drillings show that much of Kansas' early geologic history involved the alternate invasion and recession of sea water. Deposits laid down during the Paleozoic era include the rock salt occuring about 1,000 feet below the surface in Stafford County (Latta, 1950) and the Permian redbeds which underlie most of the state. Sedimentation from the Cretaceous sea include the Cheyenne sandstone, Kiowa shale, and Dakota formation underlying later deposits in parts of Stafford County.

Following the Rocky Mountain Revolution which ushered in the Cenozoic era, eroding waters brought sands and gravels eastward to form the gently sloping plain extending into the western one-third of Kansas. These deposits were later sorted by wind action with the result that most of Stafford County is covered with Quarternary 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 (Schoewe, 1949).

While the great bend of the Arkansas River now bypasses northern Stafford County, 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 preciptation 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 waterbearing 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.

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

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 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 groundwater 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 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

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
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
1957												
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
1958												
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.

Kansas, with an average 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.

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.

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 showing 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 sonsidering the line to have vertical extension. This method

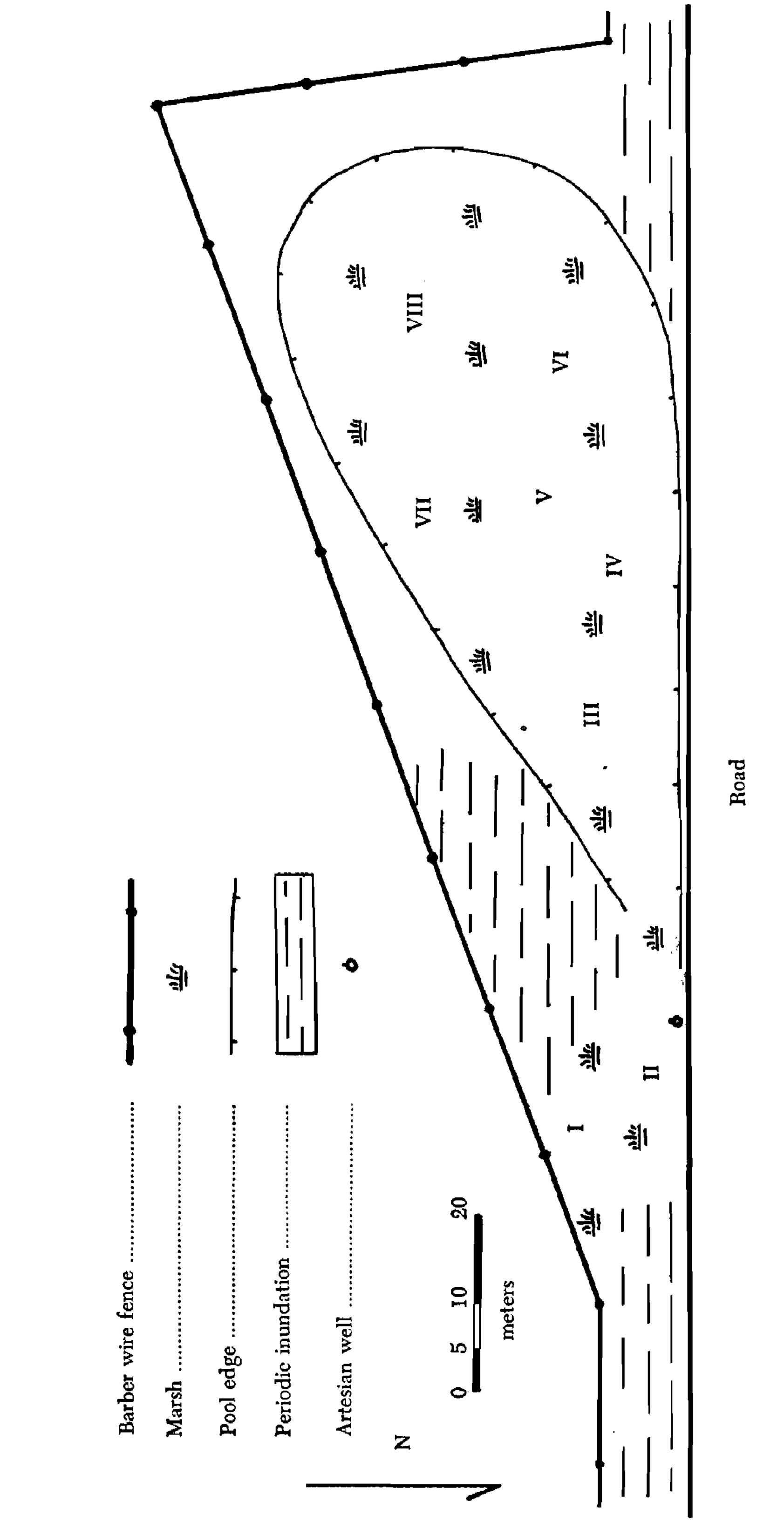

Fig. 4. General map of study area showing quadrats (numbered in Roman numerals) and general features.

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 two 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). Nomenclature of birds follows the American Ornithologists' Union Check List of North American Birds, 5th edition (1957). Indentifications 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

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

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 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 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 21, 1958, with a Beckman, battery operated, glass electrode, pH meter.

RESULTS AND DISCUSSION

Vegetation

The most abundant pasture grasses in northeast Stafford County are *Panicum virgatum* L. (switchgrass), *Andropogon gerardi* Vitman (big bluestem), and *Sorghastrum nutans* (L.) Nash (Indian grass). Associated with these tall grasses are various forbs. The more obvious include *Desmanthus illinoensis* (Michx.) MacM. (Illinois bundleflower), *Cleome serrulata Pursh* (bee spiderflower), and *Cleomella angustifolia* Torr. (Cleomella). Present in smaller numbers are *Cirsium undulatum* (Nutt.) Spreng (wavyleaf thistle), *Gaura parviflora* Dougl. (small-flowered gaura) and *Eustoma russellianum* (L.) Griseb. (Russell prairie gentian). Woody shrubs and trees include *Cornus asperfolia* Michx. (roughleaf dogwood), *Prunus americana* Marsh. (wild plum), *Populus deltoides* Marsh. (cottonwood), and *Salix nigra* Marsh. (black willow). Occasional marshy depressions abound in *Typha latifolia* L. (common cattail), *Eleocharis calva* Torr. (spike rush), and *Scirpus americanus* Pers. (sword grass) with lesser quantities of *Carex lanuginosa* Michx. (sedge), *Polygonum lapathifolium* L. (curltop lady's-thumb), and *Lippia lanceolata* Michx. (fogfruit).

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. (goldenrod), *Lactuca scariola* L. (prickly lettuce), *Happlopappus ciliatus* (Nutt.) DC. (ciliate goldenweed), *Ambrosia trifida* L. (giant ragweed), and *Helianthus maximiliani* Schrad. (Maximilian sunflower). Other roadside plants of the area are *Hordeum jubatum* L. (squirreltail grass), *Setaria genicu-*

lata (Lam.) Beauv. (knotroot bristlegrass), *S. glauca* (L.) Beauv. (yellow foxtail), *Verbena hastata* L. (blue verbena), *Melilotus alba* Desr. (white clover), *Echinochloa crusgalli* (L.) Beauv. (barnyard grass), *Digitaria sanguinalis* (L.) Scop. (crabgrass), *Poa pratensis* L. (Kentucky blue grass), *Bromus tectorum* L. (downy chess), *Chenopodium album* L. (lamb's quarters) and *Rumex crispus* L. (curly dock).

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. (sea blight), and other plants of saline or alkaline soils.

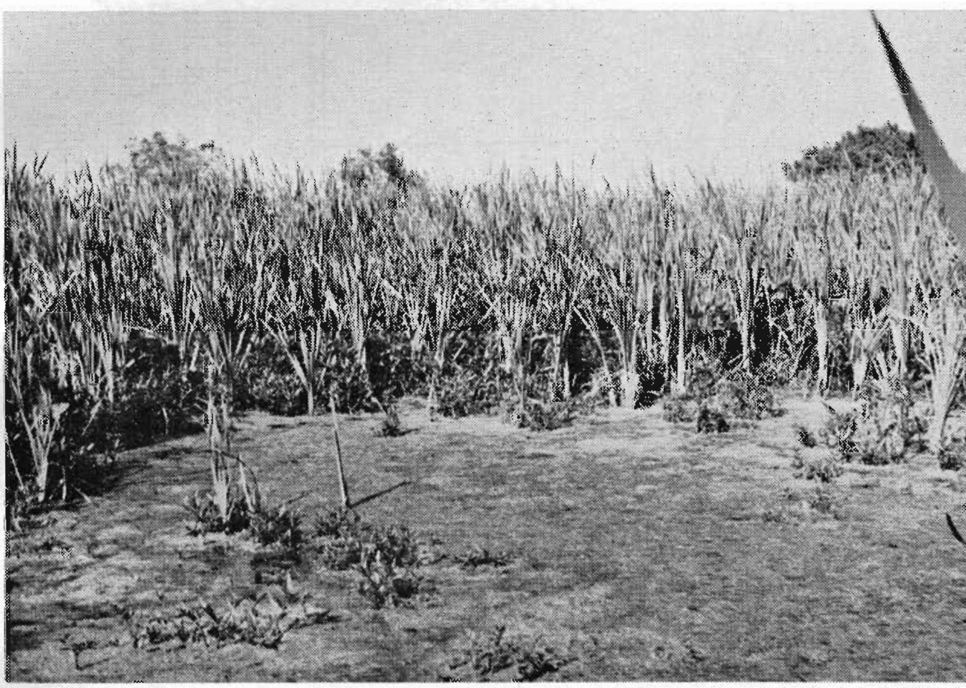

Fig. 6. Station 13 showing *Typha* zone and associated *Bidens laevis* with duckweeds covering open water area.

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. (water parsnip) as an early summer associate. *Bidens laevis* (L.) BSP. (bur marigold) 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. (duckweed) and *Spirodela polyrhiza* (L.) Schleid. (water flaxseed) with algal filaments of *Spirogyra* sp. and *Lyngbya* sp. This zone is illustrated in Figure 6 and frequency data on the dominant species are shown in Figures 7, 8 and 9. Frequency is shown as the number of interceptions of plant parts per 5-meter interval.

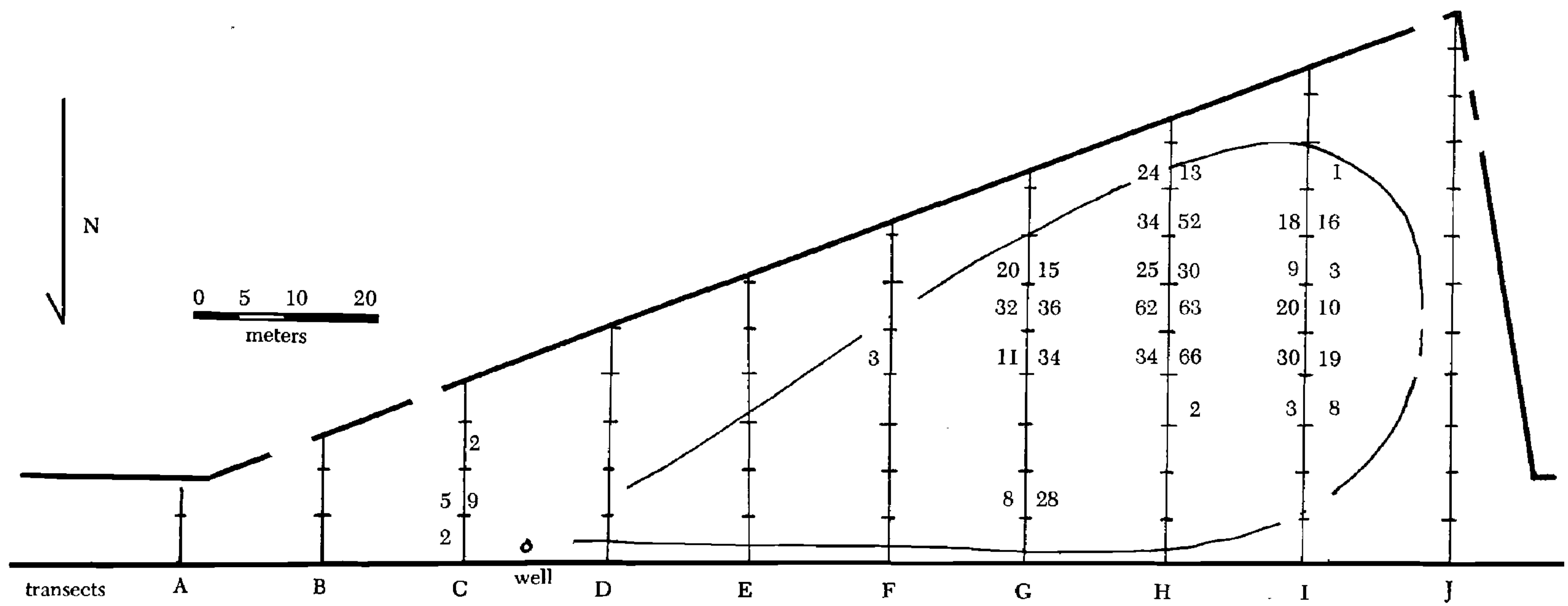

Fig. 7. Transect map showing number of interceptions of *Typha* spp. per 5-meter interval. Transect lines are lettered A through J and are crosshatched at 5-meter intervals. Number left of transect line refers to count of August, 1957; number right of line to count of June, 1958. The heavy boundary lines indicate the fence-line which encloses the triangular study area on the south and west, and the road which bounds the area on the north. Limits of the pool are indicated by the curved line within the triangle.

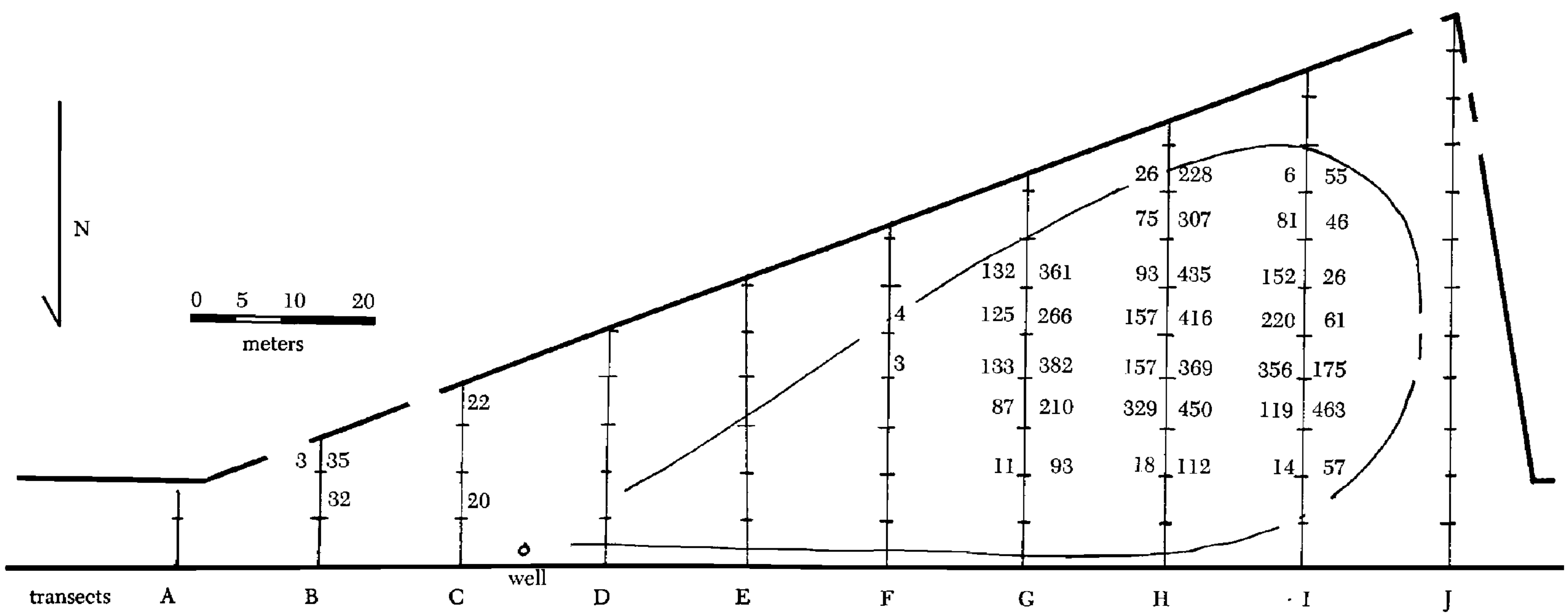

Fig. 8. Transect map showing number of interceptions of *Berula pusilla* per 5-meter interval. Number left of transect line refers to count of August, 1957; number right of line to count of June, 1958.

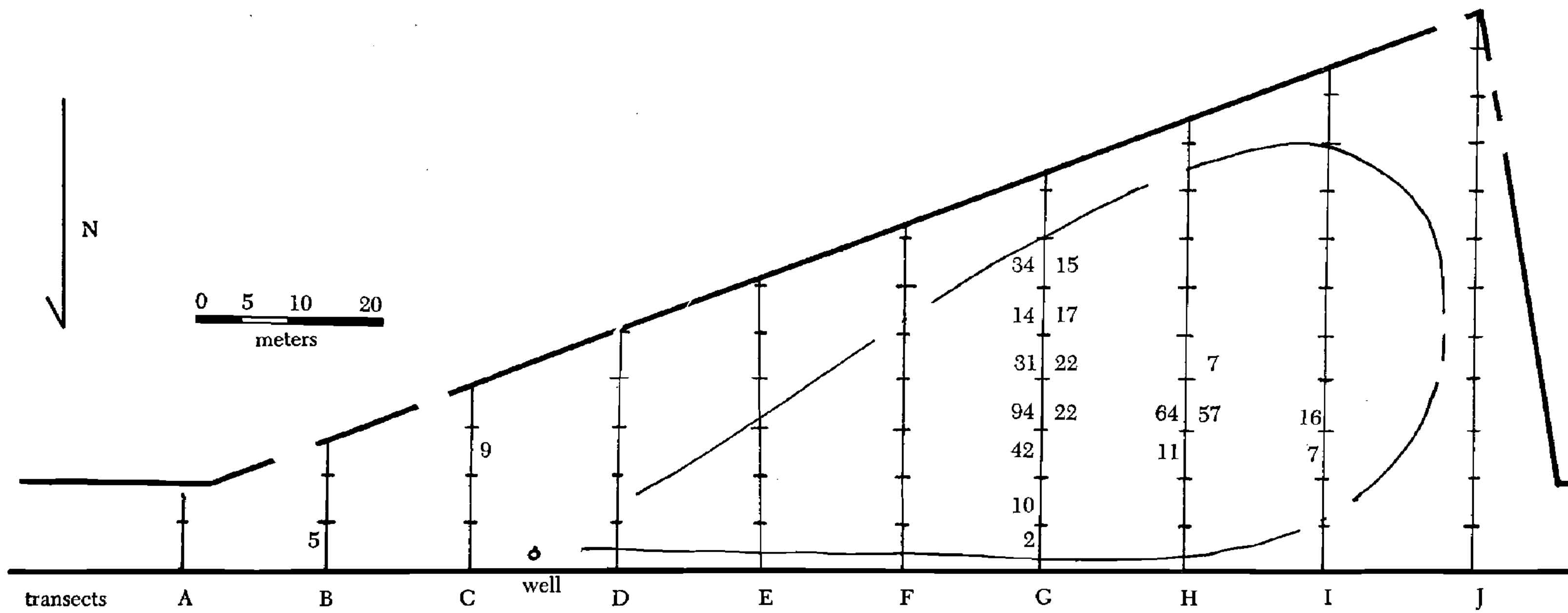

Fig. 9. Transect map showing number of interceptions of *Bidens laevis* per 5-meter interval. Number left of transect line refers to count of August, 1957; number right of line to count of June, 1958.

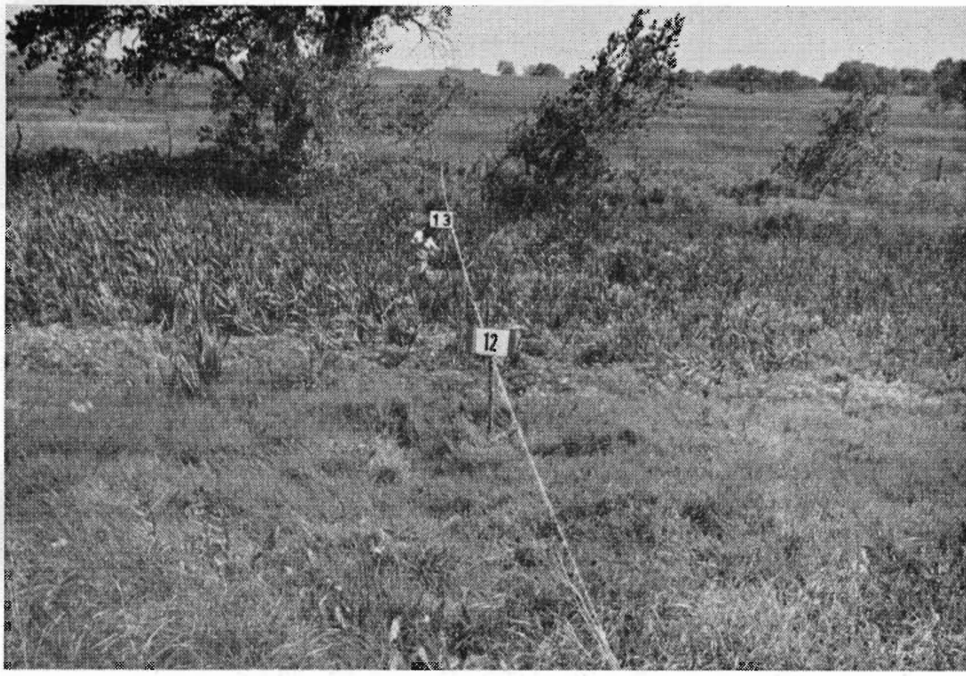

Fig. 10. Floating mat of *Leersia oryzoides* in foreground backed by *Typha* zone and cottonwoods. Stations 12 and 13 are shown along transect I.

Bordering the *Typha* zone on the north and northeast is a flourishing mat of *Leersia oryzoides* (L.) Sw. (rice cutgrass) which reaches to the northwest edge of the boggy marsh (Fig. 10). Frequencies of *Leersia* are shown in Figure 11. Included in this zone are scattered individuals of *Asclepias incarnata* L. (swamp milkweed) and *Lycopus americanus* Muhl. (bugleweed). A zone of emergent *Sagittaria latifolia* Willd. (arrowhead) funnels from the northeast border of the *Leersia* mat into the channel leading toward the well (Fig. 12). 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. (sloughgrass), *Apocynum cannabinum* L. (hemp dogbane), *Scirpus americanus,* 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 gerardi* invading from the adjacent pasture. Associated with these grasses were numerous plains forbs including *Asclepias speciosa* Torr. (showy milkweed), *Ambrosia trifida, A. psilostachya* DC. (western ragweed), *Helianthus maximiliani, Artemisia ludoviciana* Nutt. (mugwort wormwood), *Galium apartue* L. (catchweed bedstraw), *Callirhoe involucrata* (T. & G.) Gray (low poppymallow), and *Viola papilionacea* Pursh. (butterfly violet).

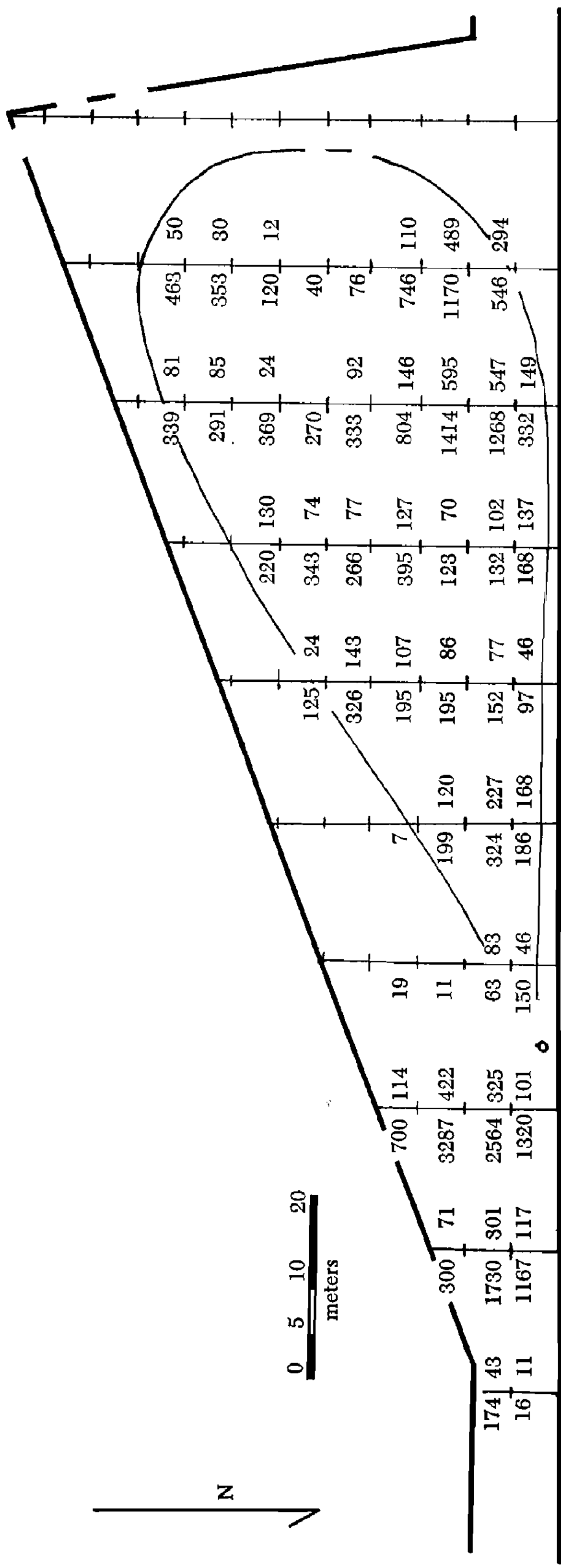

Fig. 11. Transect map showing number of interceptions of *Leersia oryzoides* per 5-meter interval. Number left of transect line refers to count of August, 1957; number right of line to count of June, 1958.

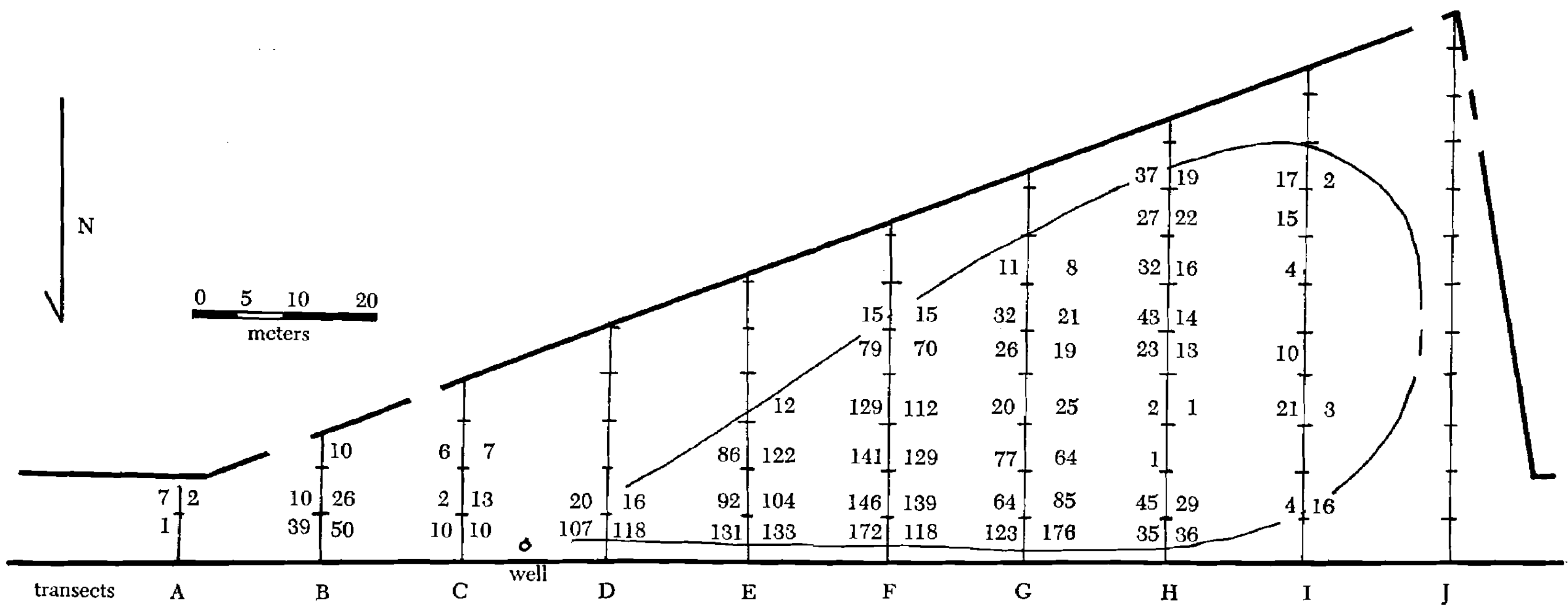

Fig. 12. Transect map showing number of interceptions of *Sagittaria latifolia* per 5-meter interval. Number left of transect line refers to count of August, 1957; number right of line to count of June, 1958.

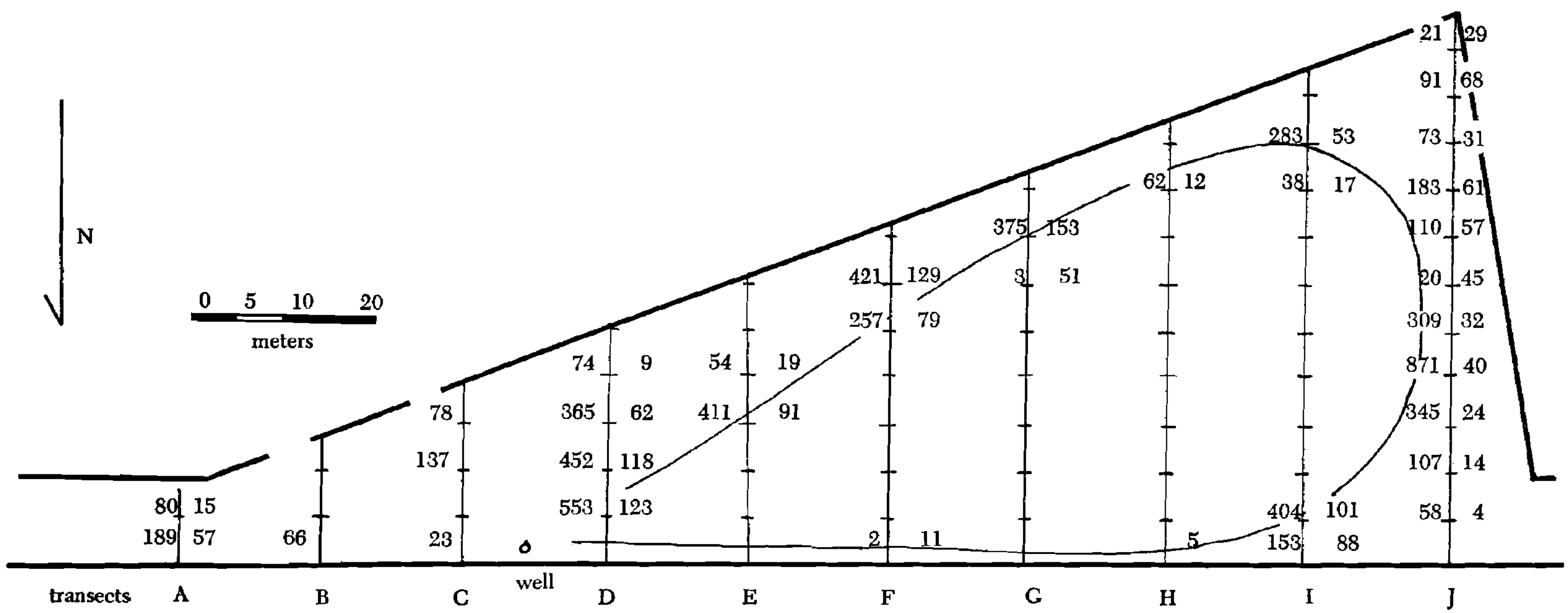

Fig. 13. Transect map showing number of interceptions of *Spartina pectinata* per 5-meter interval. Number left of transect line refers to count of August, 1957; number right of line to count of June, 1958.

The south bank of the marsh is shaded by a mature cottonwood, *Populus deltoides,* and several younger cottonwoods. Ground cover here includes *Rhus radicans* L. (poison ivy), *Vitis vulpina* L. (riverbank grape), *Parietaria pensylvanica* Muhl. (pellitory), and *Ribes adoratum* Wendland f. (clove currant).

The southeast bank is dominated by *Spartina pectinata* (Fig. 13) and supports *Helianthus maximiliani, Solidago canadensis, Cornus asperfolia, Prunus americana, Glycyrrhiza lepidota* (Nutt.) Pursh (American licorice) and *Solanum nigrum* L. (black nightshade). 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. (great bulrush), *Cicuta maculata* L. (water hemlock), and *Eupatorium perfoliatum* L. (boneset). These forms are found only sparingly 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. (cursed crowfoot) and *Mimulus glabratus* HBK. (yellow monkeyflower).

Fig. 14. Artesian stream community with colony of *Nasturtium officinale.*

In the immediate vicinity of the well (Fig. 14), a pure colony of *Nasturtium officinale* R. Br. (watercress) produces several crops per year. A willow, *Salix nigra,* lends partial shade to this colony in 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 *Sylvilagus floridanus* (J. A. Allen) (eastern cottontail); *Canis latrans* Say (coyote); *Mephitis mephitis* (Schreber) (striped skunk); and various unidentified rodents.

By far the most frequently observed birds were *Agelaius phoeniceus* (L.) (redwinged blackbirds) which nested in the *Typha* and *Asclepias incarnata. Spiza americana* (Gmelin) (dicksissels) nested in a *Prunus americana* shrub. Other birds seen frequently were *Sturnella magna* (L.) (eastern meadowlark); *Geothlypis trichas* (L.) (yellowthroat); *Zenaidura macroura* (L.) (mourning dove); *Tyrannus tyrannus* (L.) (eastern kingbird); *Botaurus lentiginosus* (Rackett) (American bittern); *Phasianus colchicus* (L.) (ring-necked pheasant); and *Circus cyaneus* (L.) (marsh hawk). Seen or heard occasionally were *Sturnella neglecta* Audubon (western meadowlark); *Corvus brachyrhynchos* Brehm. (crow); *Icterus galbula* (L.) (Baltimore oriole); *Icterus spurius* (L.) (orchard oriole); *Capella gallinago* (L.) (common snipe); *Colinus virginianus* (L.) (bobwhite); *Coccyzus americanus* (L.) (yellow-billed cuckoo); and *Melanerpes erythrocephalus* (L.) (red-headed woodpecker). 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 *Pituophis catenifer* (Blainville) (bullsnake); *Sistrurus catenatus* (Rafinesque) (massasauga rattlesnake); and *Thamnophis* sp. (garter snake). Other snakes and lizards were observed but not identified.

The only amphibians observed were *Rana pipiens* Schreber (leopard frog) and *Acris crepitans* Baird (cricket frog). The volume of their evening chorus, however, indicated that the number of individuals compensated for the small number of species.

Occasional schools of immature *Pimphales promelas* Rafinesque (fathead minnows) 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 *Phoebis sennae* var. *eubule* (L.) (sulphur butterfly) which congregated on moist places near the well, and *Danaus plexippus* (L.) (monarch butterfly) 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.), *Chydorus sphaericus* (O.F.M.), *Pleuroxus denticulatus* Birge, and *Alona rectangula* Sars. The copepod, *Eucyclops agilis* (Koch), was present in numbers exceeding that of all cladocerans. Colonies of *Attheyella nordenskioldii* (Lilljeborg) imparted an apparent 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, *Hyalella 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 *Chlorohydra viridissima* (Pallas) (green hydra), 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 reinforced 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 station 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 15. 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 the marsh in that area. Probings in the vicinity found the usually firm sand substrate easily pentrable 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

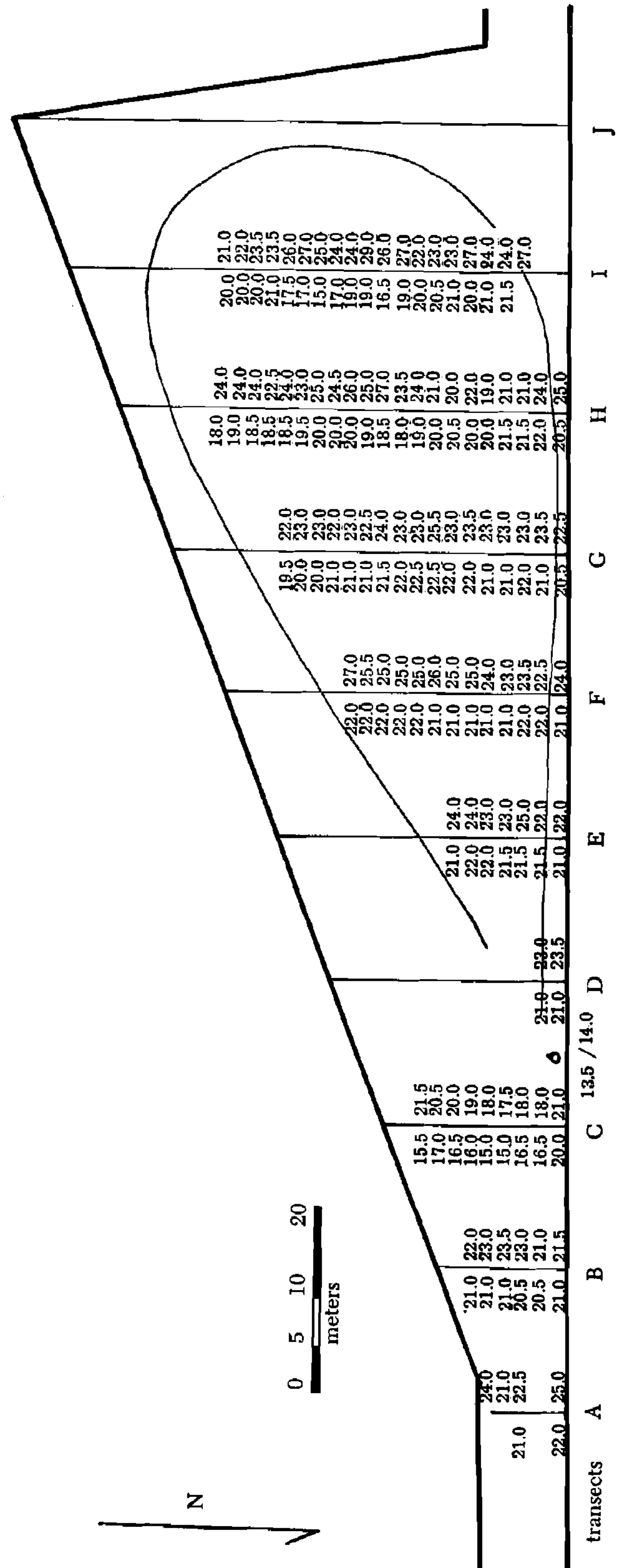

Fig. 15. Map showing temperature readings (°C.) of surface water every 2 m. along transect lines. Readings left of transect lines are for August 17, 1957; those right of lines for June 28, 1958.

afternoon of February 16, 1958. The water areas were capped with several centimeters of ice with the exception of two localities. A 2-m^2 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. 16), 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.

Fig. 16. Station 13 in *Typha* zone on February 16, 1958.

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 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 17 through 21. August pH determinations (Fig. 17) 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. 18) 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 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 graduations occurring generally with distance from those stations.

Well water contained 4 ppm of dissolved carbon dioxide in August as shown in Figure 19. 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. 20). 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 bicorbonates. The half-bound carbon dioxide in bicarbonates is reportedly available for photosynthesis (Clements and Shelford, 1939: Welch, 1952).

Dissolved oxygen (Fig. 21) 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. Decompo-

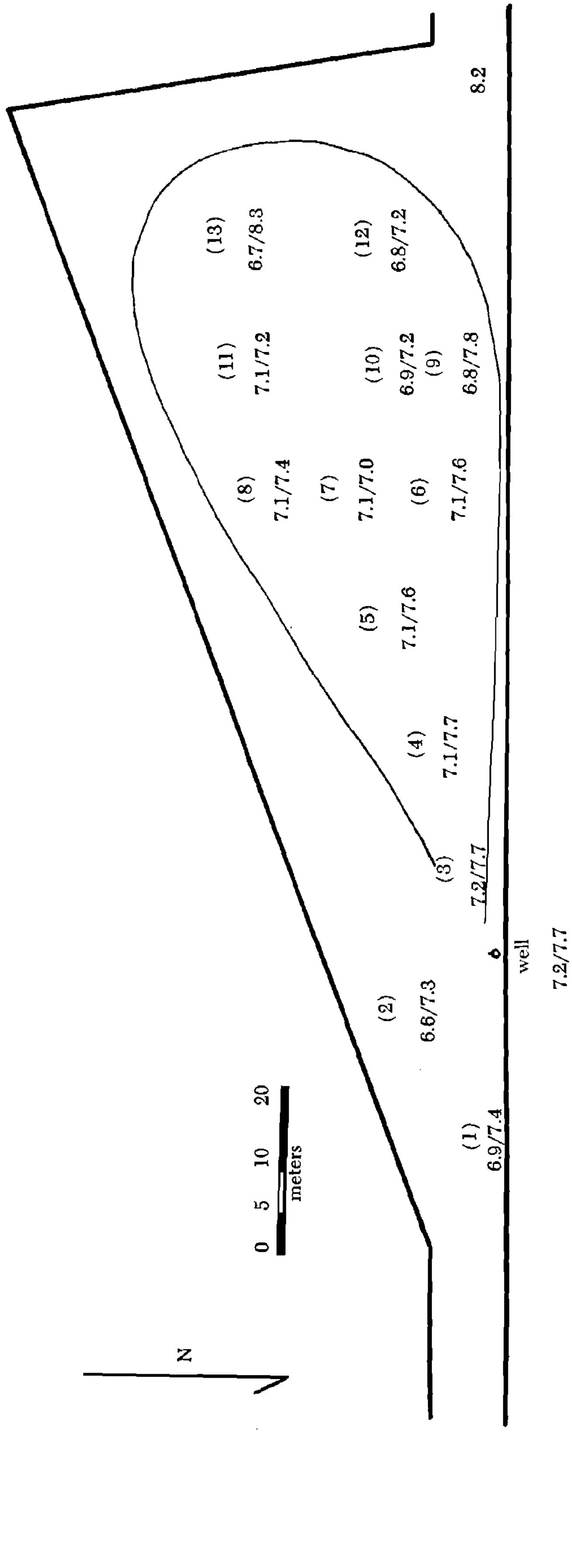

Fig. 17. Map showing pH determinations of water at the well and 13 stations along transect lines on August 20, 1957 (left of diagonal), and on June 21, 1958 (right of diagonal). Value at lower right of map is for water standing in roadside ditch on latter date.

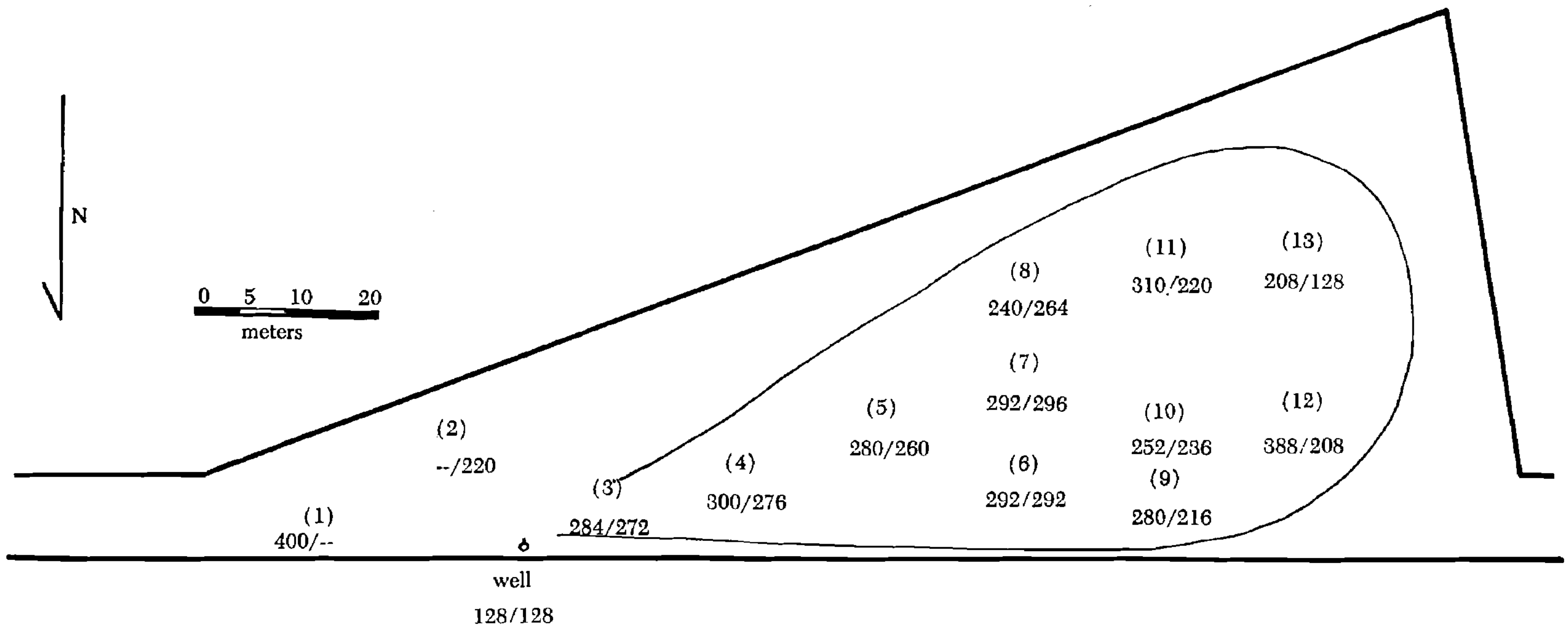

Fig. 18. Map showing hardness in ppm as calcium carbonate at the well and 13 stations along transect lines on August 19, 1957 (left of diagonal), and June 7, 1958 (right of diagonal).

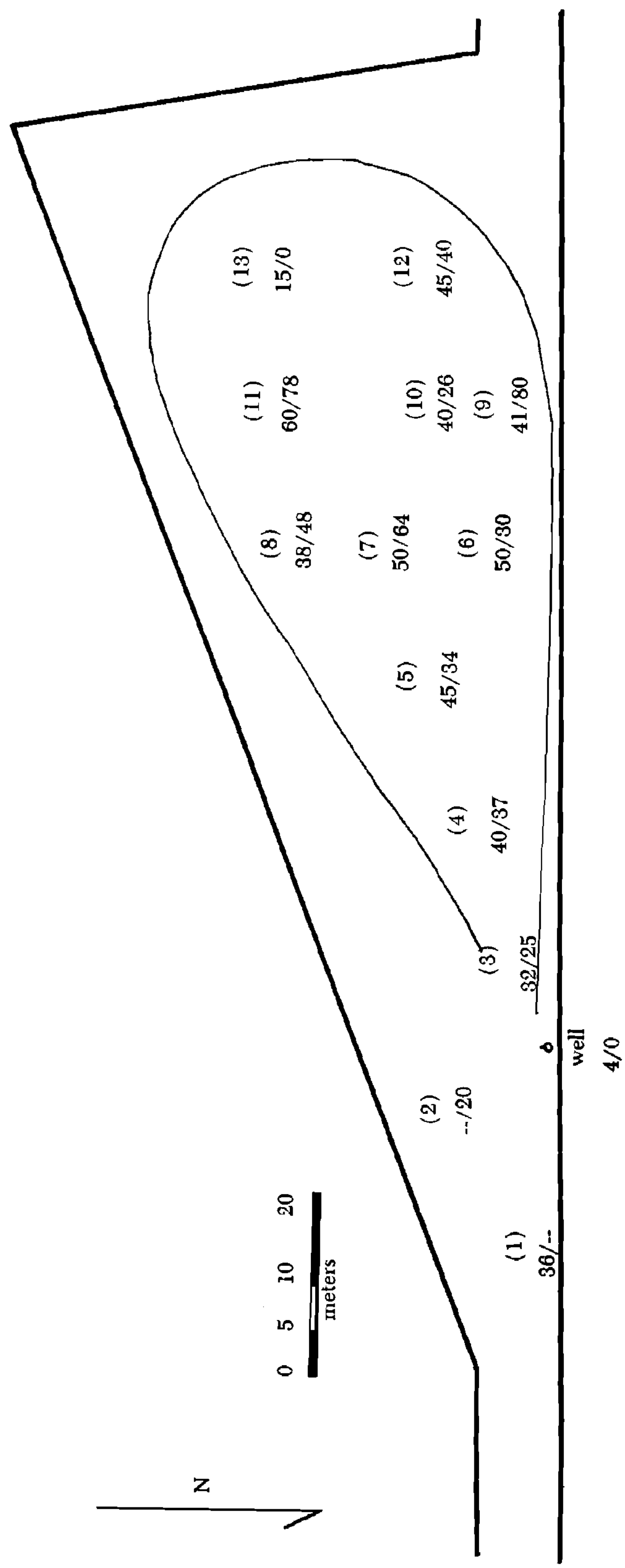

Fig. 19. Map showing free carbon dioxide in ppm of water at the well and 13 stations along transect lines on August 19, 1957 (left of diagonal), and on June 7, 1958 (right of diagonal).

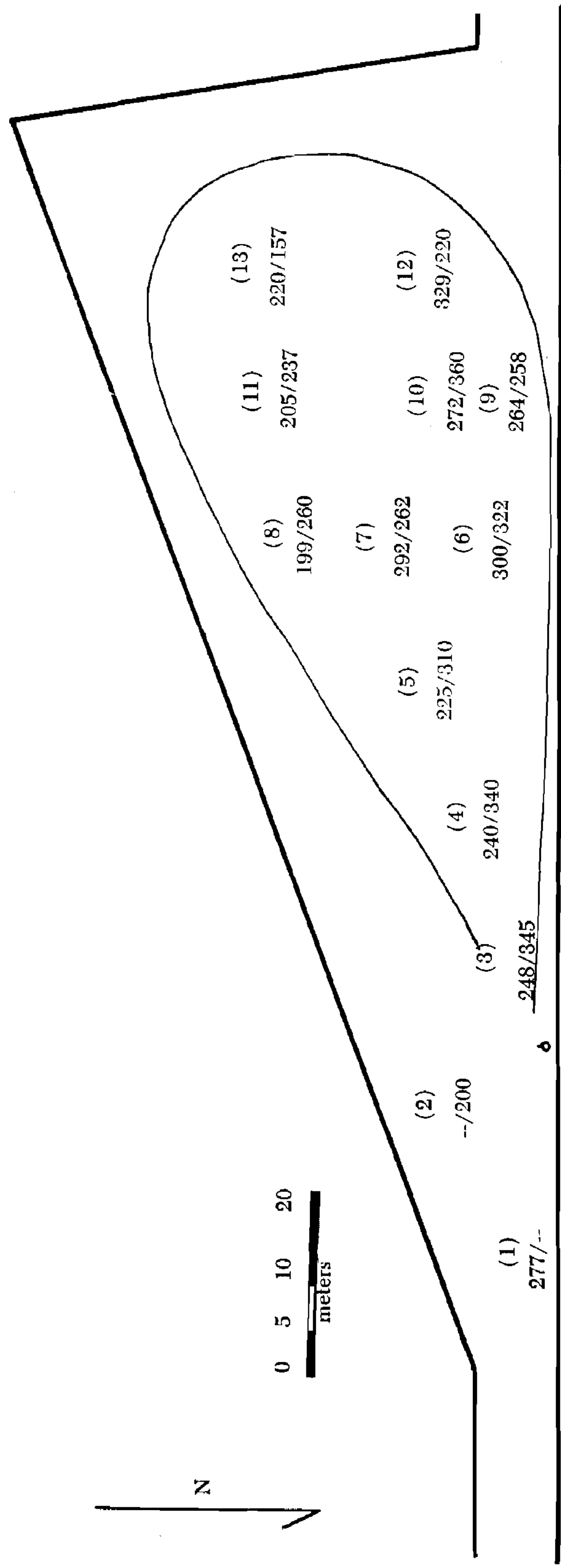

Fig. 20. Map showing methyl orange alkalinity in ppm of water at the well and 13 stations along transect lines on August 19, 1957 (left of diagonal), and June 7, 1958 (right of diagonal).

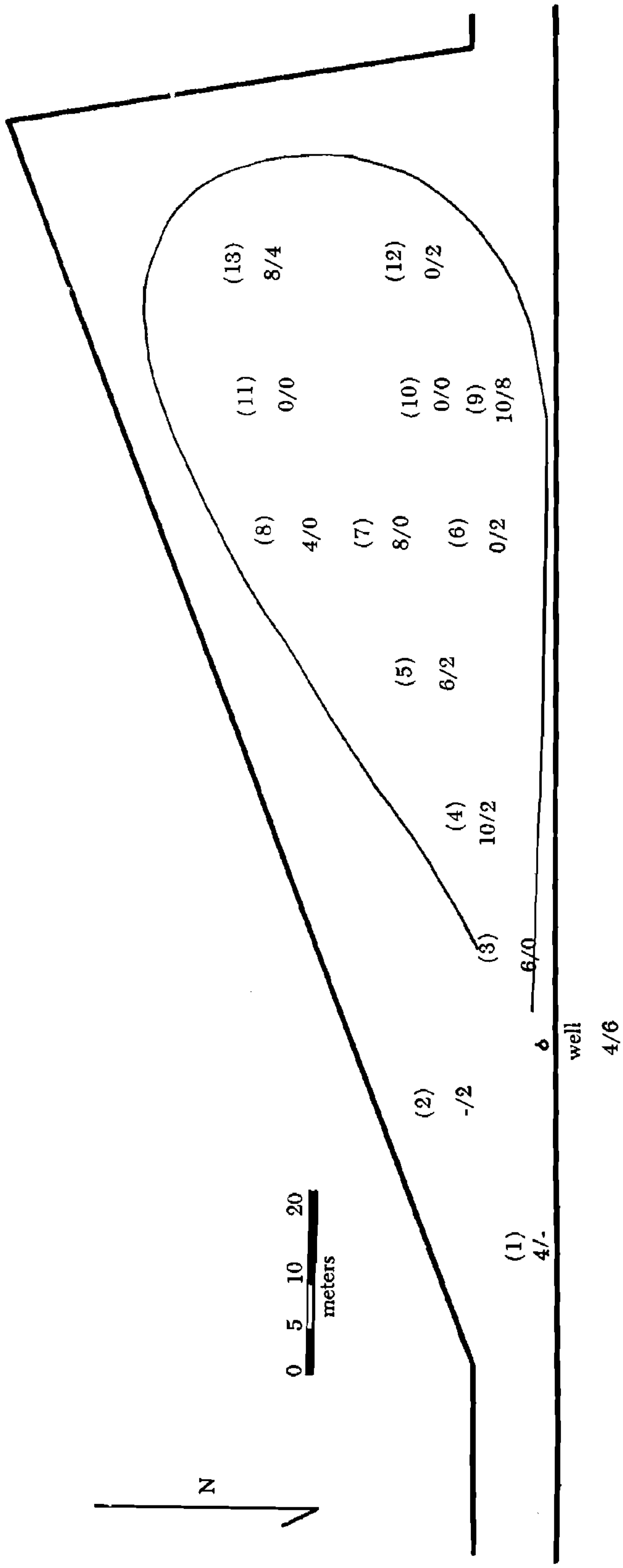

Fig. 21. May showing dissolved oxygen in ppm of water at the well and 13 stations along transect lines on August 1, 1957 (left of diagonal), and June 7, 1958 (right of diagonal).

sition reduced dissolved oxygen to a mean of 2 ppm in June, 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 discrepencies 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.

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. Pannak (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 planarian, *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 (Fig. 22, A). During midsummer, *Bidens laevis* (Fig. 22, B) 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 (Fig. 22, C). 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 direct 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 hunt-

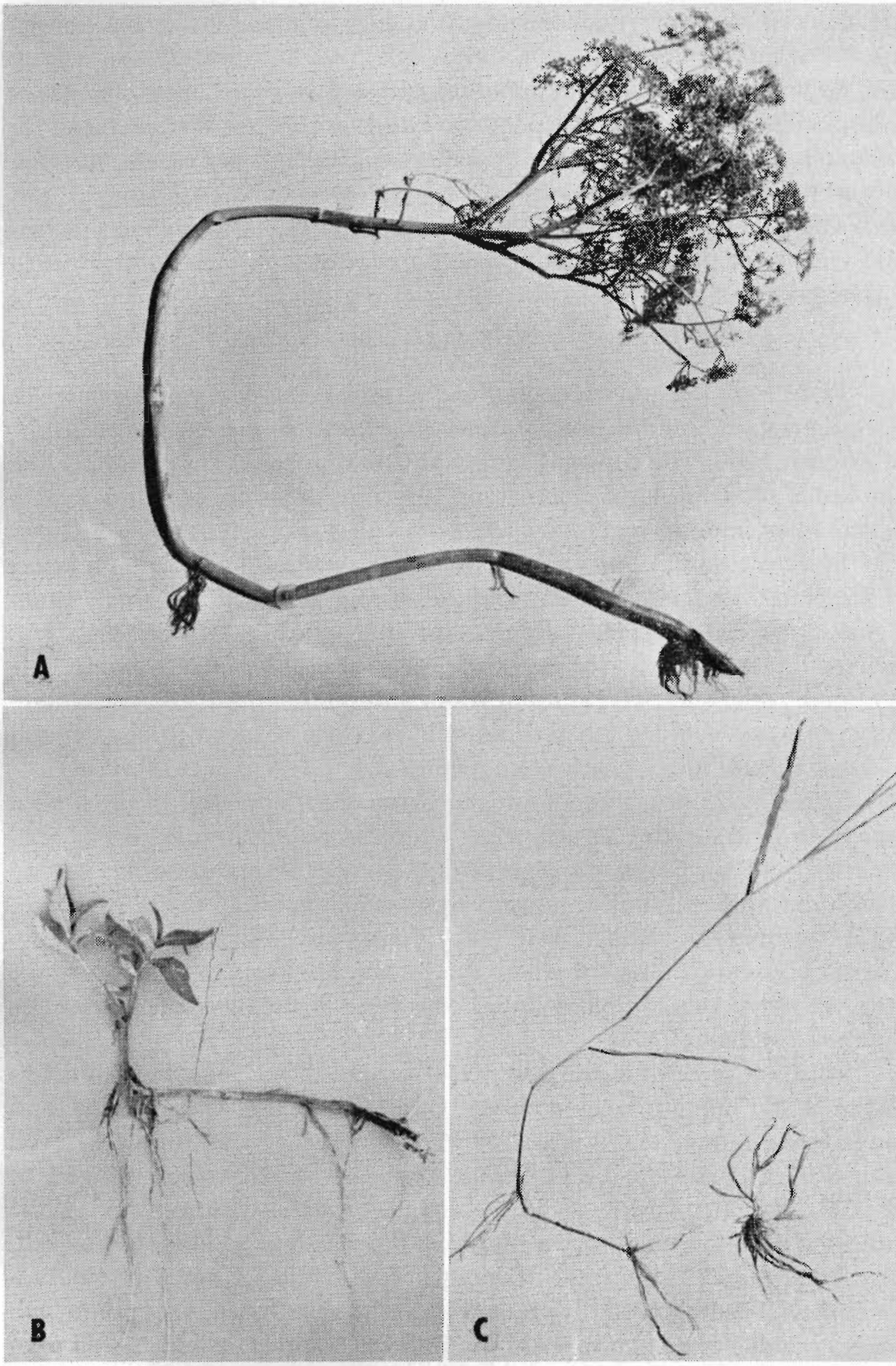

Fig. 22. Plants contributing to mat formation by rooting at the nodes of stems. A. *Berula pusilla*, an early summer perennial among the *Typha* tussocks. B. *Bidens laevis*, which replaces *Berula* during mid-summer. C. *Leersia oryzoides*, which forms the boggy mat.

ing 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.

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, innundated 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.

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