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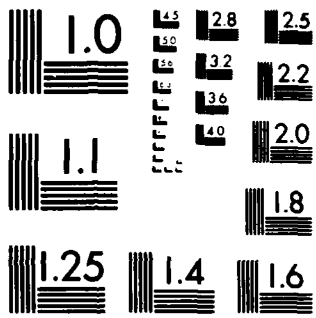
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A STUDY OF VEGETATION DEVELOPMENT IN RELATION TO AGE OF RIVER STABILIZATION STRUCTURES ALONG A CHANNELIZED SEGMENT OF THE MISSOURI RIVER

FINAL REPORT SUBMITTED TO

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ABSTRACT

During the summer of 1974, we sampled 45 sites of vegetation representative of successional trends in plant communities along the Missouri River floodplain from Sioux City, Iowa, to Rulo, Nebraska. The objective was to relate vegetation succession to age of river stabilization structures. Basal area and density data were collected for the tree species present and coverage and frequency data for all shrub and herbaceous species present in each site studied. Each site was then assigned to one of five distinct community types which were related to one another in a successional scheme. These community types listed from youngest to oldest are as follows: Salix-dominated, Populus-dominated, Platanus-Ulmus-dominated, Tilia-Quercus-dominated, and Quercus-Carya-dominated vegetation. The construction dates of the stabilization structures adjacent to the sites studied provided an accurate and quite precise method of dating the sites.

We found that the initial stages of floodplain forest succession in our region always begins with Salix spp. (willows) and Populus deltoides (cottonwood). Early herbaceous vegetation has little or no significance in the future course of succession. After approximately 18 years, Populus deltoides (cottonwood) predominates over Salix spp. (willows) in the tree union. During this same time period, the first shrub species begin to appear in the sites. Ulmus rubra (slippery elm), Celtis occidentalis (hackberry), and Platanus occidentalis (sycamore) and other mesophytic

deciduous tree species begin to appear and later replace *Populus deltoides* (cottonwood) which is not found reproducing after its initial invasion of the barren substrate. These communities are in turn replaced by a *Tilia*-*Quercus*-dominated community or a *Quercus*-*Carya*-dominated community.

In the early *Salix* communities only the tree union is well developed, but in the later *Salix* communities a new herbaceous union is formed. In the *Populus*-dominated communities there is the development of a *Cornus stolonifera* (red osier dogwood) union. In the more mature communities there is the formation of an additional shrub union dominated by *Symphoricarpos occidentalis* (wolfberry) and by *Ribes missouriense* (gooseberry). The mature floodplain communities are more diverse and have more species than the younger *Salix* or *Populus* dominated communities.

Results of the soils analyses were varied for the 45 sites and we found few relationships between soil characteristics and plant communities, probably as a result of immature soils exhibiting parent material characteristics. However, there was a tendency for soils in the mature floodplain comminities to have a higher clay content and greater amounts of nitrogen and organic matter. This is due to greater influence on the soils from biota and time both of which alter the soils characteristics.

The technique of relating vegetation succession to age of river stabilization structures was found to be useful and offered a quite precise method of developing a time scale of vegetation development. The technique should be valuable in studies of land management requiring an ecological basis.

INTRODUCTION

Floodplain communities normally develop in a relatively unstable environment, since the floodplain is by definition that portion of a river bank which is subjected to flooding. Channelization and stabilization of the Missouri River coupled with the construction and operation of the mainstream Missouri River reservoir system has practically eliminated downstream flooding, altered the nature of the river flow, and enabled more extensive utilization of the floodplain for farming which has reduced the floodplain forest along the channelized portion of the Missouri River.

Most previous floodplain studies have been done within the Eastern Deciduous forest formation (Burgess et al. 1973) and indicate considerable similarity in both vegetational and successional characteristics of floodplain forests in various regions. However very little ecologic research has been done on the forest vegetation of the Missouri River basin, and the area should be studied to provide a permanent record of a vanishing phenomenon. Additionally, basic ecologic data will be valuable in assessing the effects of management practices on these forest remnants (Lawrey et al. 1973).

Cowles (1901) reported excellent growth and variety of tree species is generally characteristic of floodplain forests. Barclay (1924) demonstrated three major stages in the development of floodplain forests adjacent the Mississippi River in

Minnesota. The pioneer stage is dominated by Populus deltoides (cottonwood)-Salix (willow) followed by a Populus deltoides (cottonwood)-Acer saccharinum (silver maple) stage; the mature floodplain forest is dominated by Acer saccharinum (silver maple), Ulmus americana (American elm), and Fraxinus pennsylvanica (green ash).

On the Tippecanoe River floodplain in Indiana, Petty (1958) described seven stages of vegetation development as follows: a pioneer annual grass-forb stage; a perennial grass-sedge stage; a perennial forb-grass stage; a perennial forb-sapling stage; a sapling-woodland forb stage; an Acer saccharinum (silver maple)-Ulmus americana (American elm)-Salix nigra (black willow) stage; and ultimately an edaphic climax stage. Petty (1958) reported five stages of vegetation development on the Wabash River in Indiana as follows: a pioneer annual grass-Polygonum (dock-leaved Persicaria)-Acnida (water hemp) stage; a perennial forb-grass stage; a perennial forb-sapling stage; an Acer saccharinum (silver maple)-Ulmus americana (American elm)-Populus deltoides (cottonwood) community, and the terminal floodplain forest stand. In the Illinois River Valley, Turner (1936) found the dominant trees in the floodplain forest to be Ulmus americana (American elm)and Acer saccharinum (silver maple).

In Oklahoma, Hefley (1937) reported the edaphic climax community on the Canadian River floodplain was an Ulmus americana (American elm)-Quercus macrocarpa (bur oak) association. Burns (1941) and Featherly (1941) both concluded that riparian woodlands develop into *Quercus macrocarpa* (bur oak) - *Quercus borealis* (red oak) - *Carya illinoensis* (pecan) association. Rice (1965) found *Ulmus americana* (American elm) the dominant bottomland forest tree in 38 of 47 stands studied in north central Oklahoma.

Bellah (1974) reported that forest succession on the Republican River in Kansas began with *Salix interior* (sandbar willow), *Salix amygdaloides* (peach-leaved willow), and *Populus deltoides* (cottonwood). *Polygonum lapathifolium* (dock-leaved Persicaria), *Ambrosia trifida* (giant ragweed), and *Conyza canadensis* (horseweed) were the most common herbs in the young stands. After 100 years, the dominant trees were *Ulmus americana* (American elm), *Celtis occidentalis* (hackberry), *Fraxinus pennsylvanica* (green ash), *Morus alba* (mulberry), and *Acer negundo* (boxelder), though the climax community had not yet developed.

Along the Missouri River, Aikman (1926) described the first woody invaders as *Salix interior* (sandbar willow), *Salix nigra* (black willow), and *Salix amygdaloides* (peach-leaved willow) followed by *Populus deltoides* (cottonwood). Later development is characterized by *Acer negundo* (boxelder), *Ulmus americana* (American elm), *Ulmus rubra* (slippery elm), *Fraxinus pennsylvanica* (green ash), and *Juglans nigra* (black walnut). These may be replaced by *Tilia americana* (basswood), the *Ulmus americana* (American elm) and *Ulmus rubra* (slippery elm) remaining as co-dominants. Weaver (1960) also reported the successional changes that take place on the Missouri River floodplains that border Nebraska.

In a more recent study, Lawrey et al. (1973) described the general scheme of succession on the Missouri River floodplain between Yankton, South Dakota, and Rulo, Nebraska, to consist of five stages: *Typha* (narrow-leaved cattail); *Typha* (narrow-leaved cattail)-*Salix* (willow)-*Populus* (cottonwood); *Populus* (cottonwood)-*Salix* (willow); *Populus* (cottonwood)- *Cornus* (dogwood); and *Ulmus* (elm)-*Fraxinus* (ash)-*Celtis* (hackberry).

Although all these descriptions of various vegetation types and seral communities are important to consider, few are based on adequate quantitative data to establish a time-scale succession of the vegetation. Shelford (1954) found in the lower Mississippi Valley floodplain that for 18 years *Populus deltoides* (cottonwood) and *Salix interior* (sandbar willow) and *Salix nigra* (black willow) are approximately equal in vigor and growth rate. *Salix* (willow) then declines and *Populus deltoides* (cottonwood) continues to grow and remain in vigorous condition for an additional 10 to 20 years before being replaced.

Edaphic factors can be important in determining seed germination and seedling developing in floodplain succession. *Populus deltoides* (cottonwood) and *Salix interior* (sandbar willow) and *Salix nigra* (black willow) seedlings occur most often on bare mineral soil and in full sun (Hosner and Minckler 1960).

The occurrence of lowland species and the development of communities are strongly affected by moisture factors which are related to the physiographic maturity of the site (Oosting, 1942). Abdul-Wahab (1970) found a negative correlation between percentage sand and organic carbon, phosphorus, potassium, nitrogen, and base exchange capacity on the floodplain soils in Oklahoma.

Barclay (1924) found that shade reduced the reproduction of Populus (cottonwood). According to Baker (1949), Salix (willow) and Populus (cottonwood) were found to be very shade intolerant; Quercus rubra (red oak), Juglans nigra (black walnut), Platanus occidentalis (sycamore), Carya spp. (hickories), Gleditsia triacanthos (honey locust), Gymnocladus dioica (Kentucky coffee-tree), Fraxinus pennsylvanica (green ash), and Catalpa speciosa (catalpas) were found to be shade intolerant; Quercus macrocarpa (bur oak), Ulmus americana (American elm), Ulmus rubra (slippery elm), Fraxinus pennsylvanica (green ash), Celtis occidentalis (hackberry), Platanus occidentalis (sycamore), Quercus rubra (red oak), Acer saccharinum (silver maple), and Tilia americana (basswood) were found to be intermediate; Ulmus rubra (slippery elm), Platanus occidentalis (sycamore), Acer saccharinum (river maple), Acer negundo (boxelder), and Tilia americana (basswood) were found to be shade tolerant; and only Cornus stolonifera (flowering dogwood) was found to be very shade tolerant.

Good information

Inundation of seedlings can be an important limiting factor in the floodplain environment, as tree species exhibit considerable differences in their responses to flooding (Kramer 1950). Hosner (1958) ranked six floodplain tree species according to their decreasing tolerance to flooding as follows: Salix nigra (black willow), Fraxinus pennsylvanica (green ash), Liquidamber styraciflua (sweet gum), Acer negundo (boxelder), Populus deltoides (cottonwood), and Acer saccharinum (silver maple). Water fluctuations affect seeds as well as seedlings. The crop of

Populus deltoides (cottonwood) seedlings for any one year is determined by the stage of the river during the period of flying seeds and some time after. Since *Populus deltoides* (cottonwood) and *Salix* (willow) seeds remain viable for less than 14 days, a gradual lowering of the water table following seed release provides the most favorable condition while a rise in the river following germination practically destroys the crop for that year (Barclay 1924).

The Missouri River Stabilization and Navigation Project established by the Corps of Engineers began construction of the dike and pile structures along the Missouri River in the 1930's. A complete record has been kept on the dates of construction, repair and extension of each of these structures. As a result, it is possible to determine quite precisely a time scale of vegetation succession along the channelized portion of the Missouri River. The major objective of this study was to determine the course of vegetation development between the river stabilization structures along the channelized portion of the Missouri River. Secondary objectives included comparing stands of similar age along a north-south gradient, and to determine the influence of the soil and other habitat factors on the development of vegetation.

THE STUDY AREA

The floodplain is the portion of the river valley, adjacent to the river channel, which is built of sediments during the present regimen of the stream and which is covered with water when the river overflows its banks at flood stages (Howell 1957). Our study area was the floodplain of the channelized portion of the Missouri River from Sioux City, Iowa, to Rulo, Nebraska. This area exhibits man-made stabilization structures that were constructed under authority of the Stabilization and Navigation Project of the Corps of Engineers. Construction began in Rulo, Nebraska, and gradually worked northward. At the present time, the Missouri River Stabilization and Navigation Project is 97% complete and is the most complete bank stabilization program to affect the central portion of the Missouri River (Lawrey *et al*. 1973). The major objectives of the project are to shape the course of the river using a system of dike and pile structures, and to hold the newly formed banks in place with rock revetment. The stream bed is channelized naturally by the scouring action of the flowing water (U.S. Army Corps of Engineers 1960).

These river stabilization structures were built perpendicular to the flow of water which is decelerated and the suspended sand, silt, and clay settles out. The deposited sand, silt, and clay between adjacent stabilization structures eventually reaches a level at which plant species can become established. Often these stabilization structures are lengthened after a period of time which both decreases the width of the channel and initiates anew the process of substrate deposition and formation of a new bare area on which vegetation can become established. Of the 45 sites selected for study (Figure 1), 1 through 39 were located between stabilization structures and the six remaining sites, 40 through 45, were located behind these structures in more mature floodplain forests.

The climate of the study area is continental with sizeable ranges in both temperature and precipitation. Climatic data for Sioux City, Iowa, Omaha, Nebraska, and Tarkio, Missouri, are shown in Table 1. A gradual increase in monthly average temperature and in total monthly precipitation occurs from north to south. These differences might be reflected in different vegetation compositions.

Soils of the Missouri River floodplain consist of the following alluvial soils: Albaton, heavy soil (clays); Onawa, heavy soil of medium and moderately coarse clay over silt and sand; Haynie, soils of medium textures (loams and silts over sand); and Sarpy, a coarse sandy soil (Worster et al. 1972). Weaver (1960) also reported that sandy soils often contain good supplies of most nutrients but are low in organic matter and nitrogen content.

MISSOURI RIVER

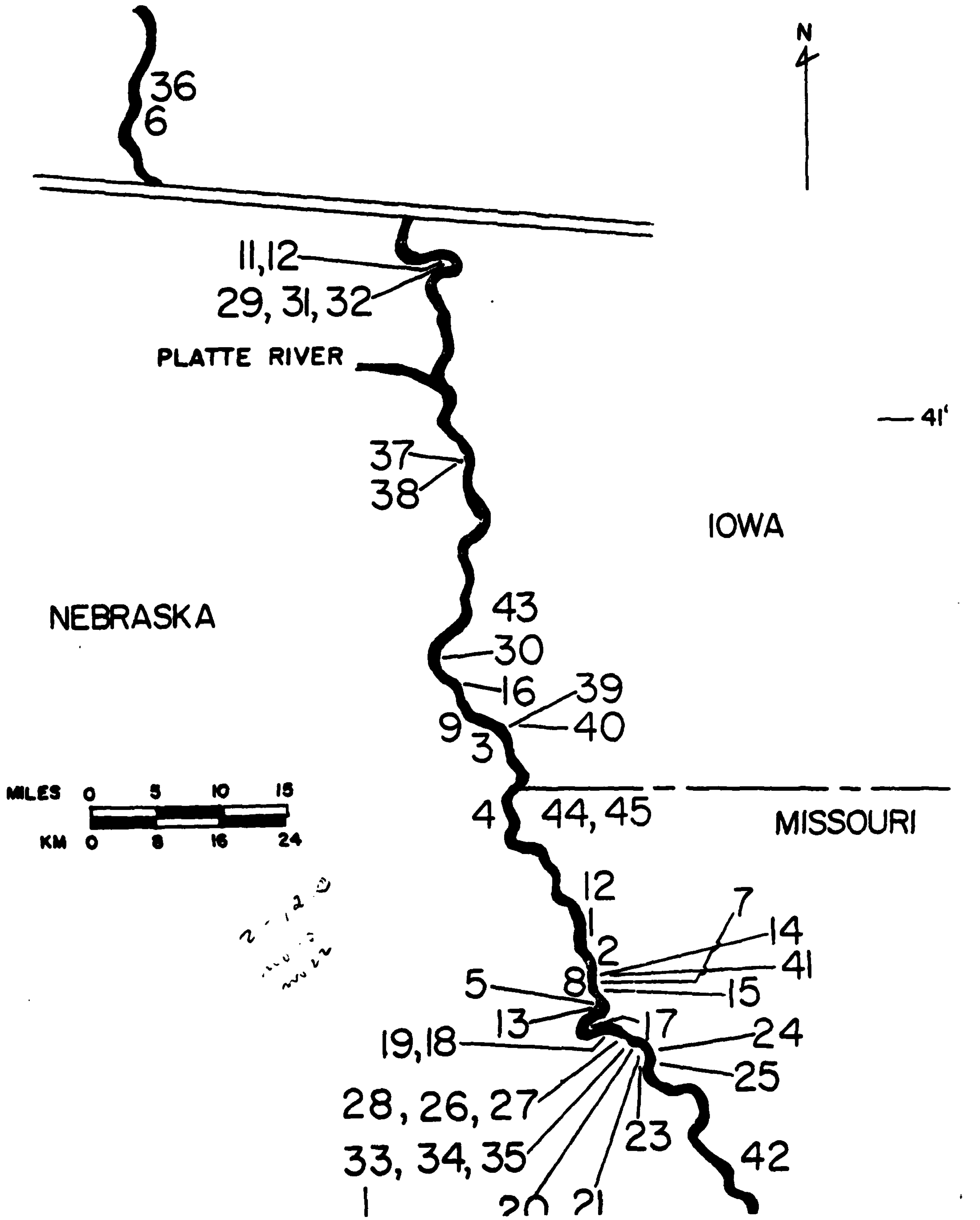

Table 1. Climatic data from Sioux City, Iowa, Omaha, Nebraska, and Tarkio, Missouri. Total monthly precipitation (P) in cm and average monthly temperature (T) in °C are shown (U.S. Dept. Commerce, 1959, 1969, 1971).

	Sioux City, Iowa		Omaha, Nebraska		Tarkio, Missouri	
Month	T	P	T	P	T	P
January	-7.3	1.9	-7.9	2.4	-4.1	2.6
February	-5.4	2.3	-3.7	6.2	-1.8	2.5
March	0.6	3.7	2.9	1.2	3.5	5.5
April	9.3	5.7	12.4	2.3	11.2	7.4
May	16.2	8.2	15.8	18.3	17.0	11.9
June	21.7	10.9	25.2	8.4	22.5	15.0
July	24.9	7.8	23.4	4.5	25.1	8.3
August	23.7	6.7	23.7	4.1	24.0	11.8
September	18.4	6.9	19.9	1.4	19.2	8.9
October	12.1	3.6	14.9	10.7	13.2	6.2
November	2.3	2.9	5.1	7.9	4.3	4.3
December	3.8	1.8	-1.7	2.7	1.5	2.6
Totals	9.4	62.9	10.8	70.1	11.0	86.9

METHODS

<u>Vegetational Analyses</u>. During the summer of 1974, we carried out considerable reconnaissance along the 390 km Missouri River study area from Sioux City, Iowa, to Rulo, Nebraska. This area is approximately 360 linear km from north to south and includes portions of three states. We concentrated on the area between Rulo, Nebraska, and Omaha, Nebraska, as this area has the oldest stabilization structures and therefore the most developed floodplain communities. Sites were also selected for study near Sioux City, Iowa, to make comparisons among stands along a north-south gradient. Younger sites were selected in both areas to complete the time-scale of succession along this portion of the Missouri River.

Within this study area, 45 study sites, representing various stages of succession, were selected along the channelized portion of the Missouri River. Our sampling was conducted from May through August, 1974. We sampled forest vegetation within 15 X 25 m macroplots. All trees in these plots were recorded within the following diameter at breast height (dbh) size classes: 0-0.5 dm, 0.5-1.0 dm, 1.0-2.0 dm, 2.0-3.0 dm, 3.0-4.0 dm, 4.0-5.0 dm, 5.0-6.0 dm, 6.0-7.0 dm, 7.0-8.0 dm, 8.0+. This method provided data not only for density and basal area determinations, but also provided information regarding the tree population structure of each stand.

Additionally, we determined the coverage of each shrub species within each macroplot by the line intercept method of Bauer (1943) using two 25 m transects. In each macroplot, we sampled herbaceous undergrowth within fifty 2 X 5 dm plots placed systematically along the 25 m sides and the transects within the macroplot. We recorded a number to represent the actual cover for each species, using the following cover classes: 1=0-5%, 2=6-25%, 3=26-50%, 4=51-75%, 5=76-95%, 6=96-100% (Daubenmire 1959). From these data, we determined frequency, the percentage of plots in a given stand in which a species occurs, and percentage cover for each herbaceous species. The stands were then arranged according to the construction dates of the stabilization structures which presumably would also show the successional trends along the Missouri River. These dates were obtained from the records on file with the U.S. Army Corps of Engineers, Omaha Division.

Soils Analyses. In each stand studied, mineral soil samples from the upper one dm were collected along every two meters of one of the 25 m transects. They were then combined to provide a composite sample for analysis. For each of these samples the following edaphic features were determined: mechanical analysis modified from Bouyoucos, soil reaction with a glass electrode, and organic matter by a modified Walkley and Black method (Moodie *et al*. 1963). Readily available soil nutrients other than total nitrogen were estimated using a Hellige-Truog soil testing kit. Cation exchange capacity was determined using a Hach soil testing kit. Total (Kjeldahl) nitrogen was determined by the Soil Testing Laboratory, South Dakota State University, Brookings, South Dakota.

SYNECOLOGICAL CONCEPTS PERTINENT TO THIS STUDY

Because the terminology of plant synecology is not uniformly used, some specific terms are defined here as they will be used in this paper. A biotic community is any assemblage of populations living in a prescribed area or physical habitat. The concept of a biotic community is necessary not only because plant and animal populations are interwoven everywhere, but also because there is a certain amount of conformity in their distribution over the landscape. Plant distribution is controlled primarily by the physical factors of the environment.

Although it is generally true that habitat characteristics play the basic role in determining the kind of community the latter certainly alters many characteristics of its habitat. A plant association is comprised of those groups of climax stands in which dominants of corresponding layers are essentially the same. Differences in make up of the vegetation are the result of chance dissemination or a passing historic factor rather than the result of basic ecologic differences in the stands. An important subdivision of the plant association is the union. The union consists of one, or more than one, abundant species (e.g. *Populus deltoides*) characterizing a given stratum of the community. Species are usually grouped together in a union on the basis of similarity in life-form, phenology, stature, or somewhat coextensive distribution in a local vegetation mosaic.

All the area that now supports or within recent time has supported, and presumably is still capable of supporting one plant association is called a habitat type. The unidirectional changes of the community with time are commonly referred to as biotic succession. However these changes are not without end, for eventually the community ceases to undergo measurable change in a constant direction and when this happens the last community to gain control of the area retains its supremacy. This last community is the climax community and remains in steady state with the environment. All the temporary communities in the sequence are collectively referred to as the sere. Representative areas of vegetation having essentially homogeneous characters in all layers are called stands. It is within stands that macroplots are established for sampling purposes.

The principal method used in measuring dominance is coverage. We used coverage as an expression of the percentage of ground included in a vertical projection of imaginary polygons drawn about the total spread of foliage of the individuals of a species. Frequency, the percentage of occurrence of a species in a series of samples of uniform size in a stand, provides information about the uniformity of distribution. Constancy may be defined as the percentage of occurrence of a species in samples of a uniform size scattered over the geographic range of an association. Just as the biotic community can exhibit changes in time, called succession, it can also exhibit changes in space.

Where one community comes in contact with another, the area of intergradation, whether broad or narrow, is called an *ecotone*.

RESULTS AND DISCUSSION

Riparian Vegetation and its Development

To more easily analyze our data, sites were arranged in chronologic order according to the ages of the stabilization structures that caused the substrate deposition (Table 2). The more mature communities, farther removed from the river, were arranged according to their apparent order of succession. The sites were then grouped into three broad vegetation types as determined by the dominant overstory species present. The youngest communities along the channelized portion of the Missouri River are dominated by *Salix spp*. (willows) and represent the *Salix* (willow) community. In the second community, *Populus deltoides* (cottonwood) replaces *Salix spp*. and becomes the dominant tree in the community. The mature floodplain community is characterized in part by the dominance of one or more deciduous tree species which have replaced *Populus* as the dominant overstory tree. Stratifying our data into these communities provided a convenient way to tabulate and analyze our data, and also provided a reasonably accurate successional scheme along the channelized portion of the Missouri River.

Although the sites were arranged according to the construction dates of the stabilization structures from youngest to oldest, some vegetation on "younger" substrates may be more successionally advanced than other vegetation on "older" sub-substrates. Though a good correlation exists between age of stabilization structures and stage of vegetation development, the correlation is not perfect. This may be due to a variety

Table 2. Construction dates of the stabilization structures built adjacent to the stands studied.

Site	Dike No.	Location (m from river)	Completion Dates of Construction	Age
1	577.95	5 m	10/30/73	1
2	577.95	5 m	10/30/73	1
3	602.82	6 m	11/7/67	7
4	594.25	7 m	10/12/67	7
5	573.3	5 m	5/12/67	7
6	800.75	6 m	1/10/66	8
7	576.09	10 m	8/13/65	9
8	576.01	4 m	8/11/65	9
9	605.8	8 m	6/7/63	11
10	651.8	16 m	6/10/57	17
11	651.8	20 m	6/10/57	17
12	579.3	25 m	1/9/59	15
13	572.9	10 m	2/1/52	22
14	575.8	25 m	5/16/38	36
15	575.8	35 m	5/16/38	36
16	609.2	30 m	8/11/38	36
17	570.0	20 m	8/11/38	36
18	570.0	25 m	8/11/38	36
19	570.0	20 m	8/11/38	36
20	563.0	20 m	4/12/37	37
21	563.0	30 m	4/12/37	37
22	563.0	35 m	4/12/37	37
23	563.0	15 m	4/12/37	37
24	561.5	40 m	5/11/37	37

Table 2. Continued.

Site	Dike No.	Location (m from river)	Completion Dates of Construction	Age
25	561.2	25 m	9/12/37	37
26	567.0	40 m	4/20/36	38
27	567.0	80 m	4/20/36	38
28	567.0	20 m	4/20/36	38
29	652.0	35 m	5/14/35	39
30	615.1	45 m	5/24/35	39
31	651.4	150 m	7/27/35	39
32	651.4	120 m	7/27/35	39
33	565.0	30 m	12/16/35	39
34	565.2	25 m	12/16/35	39
35	565.4	35 m	12/17/35	39
36	801.15	85 m	4/28/34	40
37	630.8	60 m	6/29/34	40
38	630.8	130 m	6/29/34	40
39[a]	605.0	50 m	8/23/34	40

[a] Sites 40 through 45 are all older stands on the Missouri River floodplain but are not between river stabilization structures.

of reasons: the time needed for deposition of sand, silt, and clay varies from one location to another, the availability of disseminules, conditions vary for germination, and the water level may be a limiting factor. However, this dating method remains an accurate and quite precise method of charting the vegetational succession, as demonstrated more fully below.

Salix-dominated communities. The _Salix_ communities are pioneer communities along the channelized portion of the Missouri River rapidly establishing themselves on newly exposed substrates. Three species of _Salix_ (willow) are among the early woody invaders along with _Populus deltoides_ (cottonwood). On the Republican River in Kansas, Bellah and Hulbert (1974) reported that _Salix spp_. and _Populus deltoides_ invaded floodplain alluvium immediately after it was above water level. We also found this to be true in our study area. The stabilization structures that resulted in deposited substrate on which sites 1 and 2 developed were built in the fall of 1973 (Table 2). Both sites were under water in May, 1974, but by June the water level had dropped to expose barren substrate. In August sites 1 and 2 were covered with vegetation. The first woody invaders were _Salix interior_ (sandbar willow), _Salix amygdaloides_ (peach-leaved willow), _Salix nigra_ (black willow), and _Populus deltoides_ (cottonwood). The time of exposure of the barren substrate above water, the proximity of nearby trees, and chance all determine which of the woody invaders becomes established; and the composition of the pioneer communities is affected by the factors listed above. There is every indication that the first species to successfully become established on the raw parent material determine the composition of the pioneer communities. Since *Populus deltoides* (cottonwood) and *Salix interior* (sandbar willow) seeds do not remain viable after 14 days (Ware and Penfound 1949), the time of seed dispersal is critical to successful germination and seedling establishment, and subsequently to the course of development that a community will take, at least during early stages of development. Some of the early herbaceous pioneers are emergent hydrophytes. *Alisma subcordatum* (water plantain) and *Sagattaria latifolia* (arrowhead) exist only a short time (1 to 2 years) before they are eliminated by the additional buildup of substrate, thus removing them from their semi-aquatic habitat. Reduced light intensity resulting from the rapid growth of the woody plants is also a factor in eliminating emergent aquatics. Neither of these plants were sampled or even seen in sites 3-8, representative of 5-10 year old communities. Other early herbaceous pioneers include *Eragrostis hypoides*, *Eragrostis frankii* (love grass), *Carex spp*. (sedge), *Bidens laevis* (bur marigold), and *Bidens frondosa* (beggar tick) (Sites 1 and 2). These species, except for *Bidens spp*. which may become tall plants and compete for the overstory with the woody pioneers, are also eliminated due to lack of light. In sites 1 and 2 the average number of trees per square meter was 421, which means that an average of 157,875 trees in each 15 X 25 m macroplot. We actually counted stems per square meter but at this young stage in their life cycle, root sprouts should be minimal and most if not all the stems are probably individual trees. Tree basal areas in *Salix* dominated stands are given in Table 3. Only the herbaceous species that can compete effectively with the dense willow population can endure this environment. In sites 3-8, successful species include Polygonum spp., Rumex mexicanus (dock), Rumex crispus (sour dock), and Phalaris arundinacea (reed canary grass). No shrub species are found in the Salix-dominated vegetation during the first 10 years of its development. Van Vechten and Buell (1959) found along the Millstone River in New Jersey that few herbs and shrubs were present in young forest stands less than 20 years old, probably the result of inadequate light. The very high density of Salix spp. and Populus deltoides in the Salix communities must result in strong competition for light and nutrients in these stands (sites 1-8). After the initial invasion of the woody species (sites 1-2), we find many trees have died in sites 3-8 as a result of intense competition. Very little light penetrates through the overstory and little or no litter was found on the ground.

Lawrey et al. (1973) found Typha augustifolia (narrow-leaved cattail) in all his pioneer stands along the unchannelized portion of the Missouri River, though this species was rarely encountered along the channelized portion of the Missouri River except in backwater areas adjacent the river. The lack of development of marsh communities may be due to the rapid formation of the substrate between adjacent stabilization structures not allowing adequate time for the development of this community. The swiftness of the current along the banks may also attribute to its lack of development. From data

Table 3. Basal area for the trees found in the *Salix* communities observed. Sites are numbered consecutively according to age of wing dikes with site 1 corresponding to the most recent wing dike. Basal areas are in m^2/ha.

Species	Site Numbers 1	2	3	4	5	6	7	8	9	10	11	12	13
Salix amygdaloides	+[a]	+	23.2	6.6	3.3	10.1	21.4	19.5	2.4	19.1	27.2	4.0	7.8
Salix interior	+	+	28.8	50.0	93.3	31.2	61.2	71.0	12.8	0.5	0.5	+	0.9
Salix nigra	+	+			+		2.7	2.5	+	2.4	0.4		
Populus deltoides	+	+	0.4	0.8	3.3	0.9	1.5	1.0	0.2	+	+	35.2	1.3
Morus alba									+	0.2	+	0.2	+
Salix eriocephala											1.8		
Ulmus rubra												+	

[a] Indicates any basal area less than 0.05 m^2/ha.

obtained in this study plus that obtained by Lawrey *et al.* (1973) it would be worthwhile to do a comparative study on a number of the backwater areas now cut off from the main river channel. It would be important to assess the vegetation development in these backwaters, the aquatic organisms, and the substrate chemistry with a view in mind of determining similarities and differences with the main channel. The backwater areas may prove to be important temporary or permanent wildlife habitats which cannot exist along the main channel. Yet their occurrence close to the main channel could provide significant diversity of biota for the channelized portion of the Missouri River basin. To our knowledge, ecologic studies have not yet been done on these backwater areas, though the importance of these areas is in no way lessened by our lack of knowledge about them.

After approximately 15 years of vegetational succession (sites 9-13), the thinning of the overstory has proceeded to the point where adequate light penetrates through the canopy that a herbaceous union develops. The new undergrowth union is dominated by *Phalaris arundinacea* (reed canary grass), *Urtica dioica* (nettle), and *Impatiens pallida* (pale touch-me-not), *Galium aparine* (beggar'sticks), *Teucrium canadense* (wood sage), *Conyza canadensis* (horseweed), and by *Rumex mexicanus* (dock) which is a constant species in the *Salix* communities. Here also occurs the first shrub species to become an important part of the community. The fast-growing vines *Menispermum canadensis* (moonseed) and *Vitis riparia* (riverbank grape) have higher average cover and are more ubiquitous in these older

Salix communities than woody shrubs such as Toxicodendron rydbergii (poison ivy) and Parthenocissus quinquefolia (Virginia creeper). Thus, the older Salix communities (sites 9-13) have a distinct herbaceous union plus the presence of a developing shrub union compared to the younger Salix communities. Undergrowth data for Salix communities are in Table 4.

The population structure of these older Salix communities (sites 9-13) shows that most of the trees are in the same size classes (Table 5). It is at this time in the development of the sere that Populus deltoides (cottonwood) begins to shade out the Salix spp. and become dominant. Shelford (1959) found in the lower Mississippi River Valley that Populus deltoides (cottonwood) becomes more vigorous than Salix spp. after 18 years of succession. In site 12, Populus deltoides has already become dominant over the Salix spp. The population structure of site 10 (Table 5) also shows that no young Populus deltoides or Salix spp. are present; only Morus alba (mulberry) and Ulmus rubra (slippery elm) were reproducing in the older Salix communities, though Ulmus was not found in site 10.

Populus-dominated communities. All the sites between 36 and 40 years of age (sites 14-39) were dominated by Populus deltoides (cottonwood), and were appropriately categorized as Populus-dominated vegetation. Populus deltoides clearly is the dominant tree in all the sites except site 15 in which Platanus occidentalis (sycamore) is competing with Populus for the overstory. In none of the 26 sites representative of the Populus community did we find any Salix spp; they had been completely eliminated from the floodplain. The dominance of

Table 4. Average percent cover (C) and average percent frequency (F) for the shrub and herbaceous species occurring in the *Salix* communities.

Species	Site Numbers 1 C/F	2 C/F	3 C/F	4 C/F	5 C/F	6 C/F	7 C/F	8 C/F	9 C/F	10 C/F	11 C/F	12 C/F	13 C/F
Shrubs:													
Vitis riparia									2.5/28	1.1/12	0.7/6	5.1/30	1.0/8
Menispermum canadense									3.4/34	5.0/50	0.1/2	2.1/6	1.2/8
Toxicodendron rydbergii									6.0/54	0.8/12		0.8/10	0.2/6
Parthenocissus quinquefolia									1.2/1[illegible]	1.6/12		0.1/2	
Ampelamus albidus									0.2/8	[illegible]	0.2/6		
Cornus stolonifera									[illegible]/17	0.1/[illegible]		+/+	
Sambucus canadensis									[illegible]/24				
Smilax hispida										0.2/10		+/+	

Table 4. Continued.

Species	1 C/F	2 C/F	3 C/F	4 C/F	5 C/F	6 C/F	7 C/F	8 C/F	9 C/F	10 C/F	11 C/F	12 C/F	13 C/F
	Site Numbers												
Herbaceous:													
Alisma subcordatum	0.3/2												
Lindernia dubia	1.9/56												
Ammannia coccinea	0.7/8												
Sagittaria latifolia	0.1/2												
Eragrostis frankii	0.2/8	0.2/6			0.4/6								
Eragrostis hypnoides	2.7/38	0.2/8			+/+								
Carex spp.	3.0/48	1.3/42											
Bidens laevis		7.6/70	5.6/32		0.3/12		1.4/10	1.0/10	0.4/4				
Bidens frondosa		1.2/10	0.1/4	0.4/4	1.1/14			0.7/16	5.2/46	0.3/2		+/+	

Table 4. Continued.

Species	1 C/F	2 C/F	3 C/F	4 C/F	5 C/F	6 C/F	7 C/F	8 C/F	9 C/F	10 C/F	11 C/F	12 C/F	13 C/F
Polygonum spp.			43.7/90	0.4/4	23.6/80	10.4/54	24.1/82	10.0/50	8.1/58				
Rumex mexicanus			2.2/10					0.1/2	0.1/4	2.1/26	0.1/2	0.1/2	0.1/4
Phalaris arundinacea			0.7/6	0.2/8				0.2/8	8.5/36	3.6/16	88.4/100	2.3/16	13.2/18
Solidago spp.			1.3/2			15.2/46		0.1/2		+/+		0.9/8	
Rorripa islandica			1.6/4		1.7/5			0.7/6					
Chenopodium album			0.3/2							0.1/2			
Rumex crispus			2.0/4			1.1/4	1.6/4						
Urtica dioica			0.8/2						[illegible]/16	2.1/14	0.7/8	1.6/12	1.1/6
Ambrosia trifida				0.3/2					[illegible]	+/+		3.9/22	

Table 4. Continued.

Species	Site Numbers 1 C/F	2 C/F	3 C/F	4 C/F	5 C/F	6 C/F	7 C/F	8 C/F	9 C/F	10 C/F	11 C/F	12 C/F	13 C/F
Xanthium strumarium					+/+			0.4/4					
Typha angustafolia					0.1/2								
Apocynum cannabinum						0.6/4							
Festuca obtusa						0.5/18							
Polygonum punctatum								5.1/22					
Impatiens pallida									30.7/32	3.3/22		5.1/[illegible]	[illegible].7/3[illegible]
Lycopus americanus									0.4/4				
Galium aparine									4.1/28	12.[illegible]/70	0.6/14	23.3/96	[illegible].1/36
Mentha arvensis									0.3/2				

Table 4. Continued.

Species	Site Numbers 1	2	3	4	5	6	7	8	9	10	11	12	13
	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F
Conyza canadensis									6.6/36	5.0/54	0.1/2		0.2/8
Sanicula canadensis									0.4/6				
Erigeron ramosus									0.1/2			+/+	
Elymus virginicus									+/+				
Phyla lanceolata									+/+				
Muhlenbergia sylvatica										16.3/44		1.6/34	
Geum canadense										1.6/16		1.7/5	
Chenopodium leptophyllum										1.0/8			
Lappula echinata										0.3/2		0.3/2	

Table 4. Continued.

Species	1 C/F	2 C/F	3 C/F	4 C/F	5 C/F	6 C/F	7 C/F	8 C/F	9 C/F	10 C/F	11 C/F	12 C/F	13 C/F
							Site Numbers						
Teucrium canadense										0.6/4		4.5/32	0.1/4
Laportea canadensis										0.4/4			
Verbena urticiflora										0.3/10	0.3/2		
Equisetum arvense										0.1/2			
Carex amphibola										+/+	0.1/4	0.1/4	0.1/2
Leonurus cardiaca												1.5/6	
Oxalis stricta												0.4/4	

[a] Indicates species occurred in macroplot but not in the 2 X 5 dm plots.

Table 5. Population structure of the tree species in a representative *Salix* forest along the Missouri River near Omaha, Nebraska.

Species	Site 10 Size Class (dbh)[a] 0-0.5 <1m tall	0-0.5 >1m tall	0.5-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8+
Salix amygdaloides				21	7						
Salix nigra				5							
Salix interior				1							
Morus alba		7.5	1								

[a] Diameter at breast height is measured in dm.

Salix on the floodplain lasts for only 15-20 yrs. Although Populus deltoides (cottonwood) is clearly the dominant tree species in these sites (even though several other tree species do occur) it was never found to be reproducing in any of the sites. This is due to the fact that Populus deltoides (cottonwood) dominated communities in our area become established by the simultaneous germination of thousands of cottonwood seeds. Once established, very little further germination in cottonwood occurred. Thus the cottonwood community is one of a unique nature, the development and duration of which depends primarily on the life cycle of the dominant species. Many other tree species were present in the understory and give an indication on the future course of succession. Morus alba (mulberry) was reproducing in all the Populus communities. Ulmus rubra (slippery elm), Celtis occidentalis (hackberry), and Acer negundo (boxelder) were reproducing in at least 50% of the stands. In the older cottonwood communities along the Mississippi River, Shelford (1954) found Acer negundo (boxelder), Acer rubrum (red maple), Platanus occidentalis (sycamore), Ulmus americana (American elm), and Celtis occidentalis (hackberry) to be the most abundant seedlings. Other tree species encountered on the floodplain in our study were Juglans nigra (black walnut), Gymnocladus dioica (Kentucky coffeetree), Quercus macrocarpa (bur oak), and Gleditsia triacanthos (honey locust) all more representative of the more mature floodplain forests of the eastern deciduous forests. The fact that they were found reproducing in at least one site after only

40 years of succession certainly indicates the rapid change that is occurring in these communities.

The population structure in the *Populus* communities is more complex and interesting than that of the *Salix* community. *Populus deltoides* (cottonwood) is the only species occupying the overstory canopy for the reason stated above. However, unlike the *Salix* communities, the *Populus* community has species in the other size classes. In site 35 (Table 6), *Ulmus rubra* (slippery elm), *Fraxinus pennsylvanica* (green ash), *Celtis occidentalis* (hackberry), and *Morus alba* (mulberry) have been reproducing and represent the smaller size classes. The significance of population age structure in tree species as implied from Tables 5, 6 , and 10 is that the course of vegetation development can best be determined from it. The stratification of our tree sampling into individuals of different sizes (ages) is the only way in which to learn about population dynamics in given species. Again we do not find *Populus deltoides* reproducing. Tree basal areas of *Populus* stands are in Table 7.

In the *Populus* communities there is a distinct shrub union. In most of our study area this union is dominated by *Cornus stolonifera* (red osier dogwood). Although some *Cornus* occurred in the *Salix* communities, it was never sufficiently mature or abundant to be recognized as a union. In some of the *Populus* dominated sites, nos. 24, 31, 38, *Cornus stolonifera* (red osier dogwood) had a frequency of over 50%.

Other shrub species are well represented in these sites. Bellah and Hulbert (1974) found that *Toxicodendron rydbergii*

Table 6. Population structure of the tree species in a representative *Populus* forest along the Missouri River near Brownville, Nebraska.

Species	Site 35 Size Class (dbh)[a] 0-0.5 <1m tall	0-0.5 >1m tall	0.5-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8+
Populus deltoides						4	2				
Ulmus rubra	37.5	15	11	5	2						
Fraxinus pennsylvanica		7.5	1								
Celtis occidentalis		7.5	1								
Morus alba			1								

[a] Diameter at breast height is measured in dm.

Table 6. Population structure of the tree species in a representative *Populus* forest along the Missouri River near Brownville, Nebraska.

Species	Site 35 Size Class (dbh)[a]										
	0-0.5 <1m tall	0-0.5 >1m tall	0.5-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8+
Populus deltoides						4	2				
Ulmus rubra	37.5	15	11	5	2						
Fraxinus pennsylvanica		7.5	1								
Celtis occidentalis		7.5	1								
Morus alba			1								

[a] Diameter at breast height is measured in dm.

Table 7. Basal area for the trees found in the *Populus* communities observed. Sites are numbered consecutively according to age of wing dikes with site 14 corresponding to the most recent wing dike. Basal areas are in m^2/ha.

Species	Site Numbers 14	15	16	17	18	19	20	21	22	23	24	25	26
Populus deltoides	56.8	11.4	48.2	61.3	54.1	52.2	43.7	42.4	43.2	39.7	65.5	31.9	46.7
Morus alba	5.3	1.3	2.8	5.2	2.9	3.2	3.6	2.9	4.3	2.5	3.2	3.9	4.8
Ulmus rubra	1.1	2.5		3.1			0.3	0.5		0.9		0.1	1.1
Platanus occidentalis	0.5	12.7	0.1				0.5	0.9	0.6		0.1	1.1	
Acer saccharinum	0.5												
Celtis occidentalis	*	2.6		*	0.9	0.8	*	*	0.3	0.2		0.3	0.1
Acer negundo			6.4		*	0.1			0.2	*	0.1		0.7
Ulmus americana			0.5					0.1				2.6	
Fraxinus pennsylvanica			*					0.1	0.6				
Juglans nigra													1.9
Catalpa speciosa													0.1
Gymnocladus dioica													
Quercus macrocarpa													
Gleditsia triacanthos													

Species	27	28	29	30	31	32	33	34	35	36	37	38	39
Populus deltoides	46.9	37.7	22.5	34.1	23.5	23.4	28.7	54.5	18.7	9.3	27.2	39.3	33.6
Morus alba	5.1	2.2	3.8	1.3	5.0	2.1	2.5	3.0	0.1	*	4.2	3.2	4.6
Ulmus rubra	*	0.5		0.1			0.5	1.5	0.5	*	0.2	0.4	*
Platanus occidentalis	0.5	6.6		0.1				1.1					
Acer saccharinum			6.8										
Celtis occidentalis	*	*			0.1		0.2	*	0.2			0.1	
Acer negundo	3.3	0.1	0.5			5.9		0.1			0.1	0.9	
Ulmus americana		*	*					2.0					
Fraxinus pennsylvanica			0.1	0.2				0.5	0.2			0.1	
Juglans nigra													
Catalpa speciosa													
Gymnocladus dioica	0.1												
Quercus macrocarpa	*	*											
Gleditsia triacanthos		*											

* Indicates any basal area less than 0.05 m^2/ha.

(poison ivy) and Parthenocissus quinquefolia (Virginia creeper) were never important shrub species in young sites along the Republican River in Kansas but were important in the older stands. In our study area, Toxicodendron rydbergii (poison ivy) was found in all 26 sites representative of Populus dominated vegetation. Parthenocissus quinquefolia (Virginia creeper) was found in 23 of the 26 sites studied. Other shrub species having high constancy in the Populus dominated vegetation were Menispermum canadense (moonseed) 69%, Symphoricarpos occidentalis (wolfberry) 50%, and Sambucus canadensis (elderberry) 54%. Vitis riparia (riverbank grape) and Menispermum canadense (moonseed) were less abundant in Populus-dominated vegetation than in the oldest Salix-dominated sites. The number of shrub species increased from 8 in the Salix-dominated vegetation to 14 in the Populus dominated vegetation.

The herbaceous vegetation in these sites was characterized by Galium aparine (rough bedstraw) and Laportea canadensis (wood nettle), with Geum canadensis (white avens), Parietaria pennsylvanica (pellitory), and Viola spp. (violets) as additional important species. In several of the sites the subordinate unions had additional important members. For example Impatiens pallida (pale touch-me-not) was found in sites 15, 16, and 26. Osmorhiza claytonii (sweet cicely) was found in site 16. In sites 21 and 24, Sanicula canadense (snakeroot) was an important member of the community. Urtica dioica (nettle) was an important member in sites 22, 24, 26, 31 and 32.

Teucrium canadense (wood sage) had the second highest cover in site 30 surpassed only by Galium aparine (rough bedstraw). Site 36, the northernmost site studied in the Populus vegetation, had a subordinate union dominated by Conyza canadensis (horseweed) and Solidago spp. (goldenrod). Poa pratensis (Kentucky blue grass) was also an important member of this site (Table 8).

Topography within Populus-dominated communities was somewhat more irregular than in the nearly flat topography of the Salix sites. This is probably due to the development of drainage patterns in these older Populus communities. The Populus sites were also higher above the water table, and they had a distinct litter layer not found in Salix communities.

Since construction began on the Missouri River Stabilization and Navigation Project in the early 1930's, the oldest communities between the stabilization structures are only 40 years old. Shelford (1954) found that at least 1-2 centuries were needed for the development of the climax community on floodplains in the lower Mississippi River Valley. In our study area, the succession has not had time to attain climax status in 40 years. To determine the later stages in the sere, we sampled more mature floodplain communities located behind the wing dikes. These data helped us in predicting the course of biotic succession.

Platanus-Ulmus dominated communities. After Populus has been removed from dominance in the floodplain communities along the channelized portion of the Missouri River, Platanus occidentalis (sycamore) and Ulmus rubra (slippery elm) take over as the dominant trees in the overstory. Tree basal areas of

Table 8. Average percent cover (C) and average percent frequency (F) for the shrub and herbaceous species occurring in the *Populus* communities.

Species	14 C/F	15 C/F	16 C/F	17 C/F	18 C/F	19 C/F	20 C/F	21 C/F	22 C/F	23 C/F	24 C/F	25 C/F	26 C/F	27 C/F	28 C/F	29 C/F	30 C/F	31 C/F	32 C/F	33 C/F	34 C/F	35 C/F	36 C/F	37 C/F	38 C/F	39 C/F
Shrubs:																										
Toxicodendron rydbergii	13.2/58	7.6/50	7.1/32	11.5/54	10.3/52	9.9/66	4.9/22	3.1/18	4.2/14	12.7/50	14.2/60	14.1/58	8.7/66	0.8/10	1.2/8	0.1/4	0.8/2	0.4/8	6.2/50	5.9/60	0.1/4	2.0/22	0.8/12	14.8/52	3.7/26	1.0/8
Parthenocissus quinquefolia	6.6/50	4.1/36	2.7/36	2.0/20	6.3/36	11.2/60	4.9/36	2.0/30	17.6/66	14.3/68	2.0/12	12.5/60	5.0/66	5.0/64	6.3/56	2.7/12		0.9/26	0.4/16	3.1/10	4.4/56	1.9/36		4.2/58	3.8/72	
Cornus stolonifera	1.1/8	5.1/12	7.9/12	0.6/26	2.9/16	1.0/8	11.2/26	10.1/30	9.0/18	4.1/18	27.7/50	3.9/26	2.1/6	0.3/8	3.0/12	+	0.6/10	25.0/54	0.8/6	2.4/26	1.6/8	0.8/6		2.2/18	23.4/52	
Asimina triloba	1.1/2																									
Symphoricarpos occidentalis	1.1/8			0.1/2	1.1/4	1.6/6	0.2/6	+	7.7/22		+				+			+			+	1.1/6			+	
Menispermum canadense	1.1/12		0.1/2	0.8/6	2.1/14	0.4/6	5.8/36	8.2/52	7.1/50	6.8/62		2.4/22	0.8/10	+		0.7/16	1.5/18			1.0/8	0.4/6			2.1/14		+
Vitis riparia	+	0.1/2		0.2/6	0.1/2	0.1/2				1.8/16	0.1/2	0.4/6	0.8/6		0.1/2	0.1/2	1.0/12	0.4/6	0.5/8	0.6/6	0.1/2	+	2.2/12	0.1/4	0.1/2	+
Smilax hispida	+	0.1/2		+				+			0.1/4		0.2/6	+		+	+				0.1/2	1.1/16		0.1/2	0.1/2	+
Sambucus canadensis		0.4/4		+	+	1.4/6	+	0.8/4		0.1/2	+	+		0.1/2	0.1/2		+				+					+
Cercis canadensis									7.7/12																	
Rubus occidentalis									0.1/2				+	1.1/4												
Zanthoxylum americanum											1.7/2				0.1/2											
Rhus glabra																		0.1/2								
Ampelopsis albidum																					0.1/2					
Herbaceous species:																										
Galium aparine	0.9/6		0.7/6		5.2/60	14.4/82	2.6/18	0.8/20	1.2/20	2.9/26	2.8/50		9.5/98	14.1/68	1.7/30	20.1/62	28.5/100	2.9/30	+	14.8/84	13.3/96	7.6/90		7.4/98	2.9/84	13.4/100
Chenopodium album	0.1/6								2.0/18	0.1/2					+			0.4/6	0.1/2		0.1/4	0.5/10		0.1/2	0.1/2	
Parietaria pennsylvanica	0.1/4	0.5/8	4.1/36	5.6/76	+	0.1/6	0.3/10	0.1/2	0.1/4	6.7/34		0.4/6	+	+		1.1/22			0.4/6	0.3/10		0.2/6				
Viola spp.	0.1/2	3.4/54	4.5/60	3.3/62			0.1/2	0.2/8		0.1/2			0.1/2	1.0/10		0.4/16		0.2/6			0.4/4	0.9/24	0.2/6	0.2/6		
Chenopodium hybridum	+								+												+					
Tovara virginiana	+																	0.1/2								
Impatiens pallida		0.5/70	4.4/22	0.4/6							0.1/2		2.8/32	0.1/2		0.7/6	+									+
Carex spp.		1.5/12		0.1/4	0.2/6		+	+				0.1/2	0.2/6				1.0/20		+	0.2/6	0.1/4	0.2/8			0.8/10	+

Table 8. Continued.

Species	14 C/F	15 C/F	16 C/F	17 C/F	18 C/F	19 C/F	20 C/F	21 C/F	22 C/F	23 C/F	24 C/F	25 C/F	26 C/F	27 C/F	28 C/F	29 C/F	30 C/F	31 C/F	32 C/F	33 C/F	34 C/F	35 C/F	36 C/F	37 C/F	38 C/F	39 C/F
Equisetum arvense		0.9/30		0.1/4	0.8/30	0.3/10	0.2/6			0.4/15		0.7/26							0.5/10	0.6/20			0.7/6			
Laportea canadensis		0.7/15	1.0/10	0.4/6	2.4/26	0.9/6	2.5/26	1.3/30	0.7/6	+			0.2/6	6.8/30	5.6/22		5.1/10	0.9/16	0.1/2	1.6/8		+		0.3/2	4.7/24	0.2/6
Osmorhiza claytonii			1.7/16													+										
Smilacina racemosa			0.1/2																							
Geum canadense				1.2/8	0.7/8		1.1/8		+		0.1/2			11.8/62	2.1/14		0.3/2	10.6/76	0.3/2	+		1.6/14		+	0.3/2	0.1/2
Muhlenbergia sylvatica				0.5/8	0.1/2		0.2/6	0.2/8	0.2/6		+	0.1/2	0.6/14	0.1/2			1.7/10	7.1/76	0.5/8	0.1/4		0.2/6		+	0.1/4	0.4/4
Anemone canadensis				0.2/6													0.5/8	0.2/6					0.2/6			
[illegible] americana				0.1/2			+	0.8/4	+	0.1/2			0.4/6									+			0.1/2	
Sanicula canadensis				+	0.4/6		0.6/4	1.5/10	+	0.1/2	1.7/8	0.1/7	0.1/4	0.1/2	0.5/8				0.1/2	+	+			0.1/2		
Chenopodium leptophyllum						0.5/10												0.1/4	0.9/6							
Campanula americana								0.3/2																		
Lappula echinata								0.1/2										0.1/2								
Cannabis sativa								+	0.1/2	+						0.3/2		+	0.1/2			+				
Desmodium grandiflorum								+	0.6/4							0.1/2					0.4/6	0.1/2				
Urtica dioica									2.8/16		1.9/16		2.0/4			+	1.1/4	3.8/34	3.8/34					0.3/2		0.6/4
Pilea pumila									0.1/2						0.7/6											
Oenothera biennis									+																	0.3/2
Oxalis stricta										0.7/6			+	0.1/2	0.1/2				+							
Solidago spp.											0.1/2						1.4/16	0.1/2				0.3/2	8.0/52			
Teucrium canadense													+				15.1/66							0.3/2		2.9/34
Circaea quadrisulcata														1.1/12												
Phryma leptostachya															1.9/6							0.7/6				

Table 8. Continued.

Species	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F	C/F
Leonurus cardiaca																	1.4/6							+/+		
Phalaris arundinacea																	0.4/6									+/+
Ambrosia trifida																	0.3/2									
Apocynum cannabinum																	0.1/2									
Verbena urticifolia																	0.3/2						0.3/2			
Convolvulus spp.																	0.1/2						0.8/10			
Sicyos angulata																		1.9/14								
Solanum nigrum																					0.1/4			+/+		
Bidens frondosa																					+/+					
Elymus virginicus																						0.2/6				
Conyza canadensis																							1.4/26			
Poa pratensis																							1.1/54			
Cassia fasiculata																							1.4/26			
Polygonum spp.																							0.9/6			

+ Indicates species occurred in macroplot but not in the 2 X 5 dm plots.

old floodplain stands are recorded in Table 9. Site 40 represents the transitional stage between these two communities. One large _Populus deltoides_ (cottonwood) (12+ dbh) still remained in the site but _Platanus occidentalis_ (sycamore) and _Ulmus rubra_ (slippery elm) were located in the overstory in the other parts of the site and upon the death of the last _Populus_ tree, would be the dominants of the community. The presence of the old _Populus_ tree in site 40 shows the importance that _Populus_ has in the floodplain communities and the long period of time that this importance persists. _Celtis occidentalis_ (hackberry) was another important tree species in the area although it was not located in the macroplot. The _Cornus_ union was well developed. The herbaceous union was similar to some of the _Populus_ communities. _Laportea canadensis_ (wood nettle), _Galium aparine_ (rough bedstraw), _Geum canadensis_ (white avens), _Sanicula canadense_ (snakeroot), and _Viola spp._ (violets) were important members of the herbaceous union.

In site 41 _Populus deltoides_ had been replaced by _Platanus occidentalis_ (sycamore). Four old _Salix amygdaloides_ (peach-leaved willow) trees remained in this site; however, none of them were vigorous. Along with _Ulmus rubra_ (slippery elm), _Acer negundo_ (boxelder) was another important overstory species. _Toxicodendron rydbergii_ (poison ivy) and _Parthenocissus quinquefolia_ were important shrub species. _Galium aparine_ (rough bedstraw) had the highest cover of the herbs.

Site 42, the southernmost site studied, was also a member of the _Platanus-Ulmus_ community. However other tree species of the eastern deciduous forest formation were part of the

Table 9. Basal area for the trees found in the mature communities observed. Sites are numbered consecutively according to age of wing dikes with site 40 corresponding to the most recent wing dike. Basal areas are in m^2/ha.

	Site Numbers					
Species	40	41	42	43	44	45
Populus deltoides	17.0					
Ulmus rubra	4.5	2.6	4.3	5.7	1.0	4.5
Platanus occidentalis	4.2	23.5	15.2			
Morus alba	2.3	2.2		0.6		
Celtis occidentalis	+[a]	+		0.8		0.4
Salix amygdaloides		10.2				
Acer negundo		6.4		0.1	0.1	0.3
Juglans nigra			6.5			
Gymnocladus dioica			4.0	4.1		

Table 9. Continued.

Species	Site Numbers 40	41	42	43	44	45
Tilia americana			1.3	35.2	4.3	0.1
Fraxinus pennsylvanica			1.2			
Quercus rubra				2.6		
Ulmus americana					0.2	
Quercus macrocarpa					31.4	17.0
Carya ovata					1.4	21.3

[a] Indicates any basal area less than 0.05 m^2/ha.

community. Juglans nigra (black walnut), Gymnocladus dioica (Kentucky coffee-tree), and Tilia americana (basswood) were present in the site, giving more diversity to the tree population structure. The Cornus union was replaced by a well developed Asimina triloba (papaw) union which at this site may have reached its northernmost extension along the Missouri River. Geum canadense (white avens) and Viola spp. were the dominant herbaceous species.

Tilia-Quercus dominated community. We found two communities which probably are two distinct climax communities on the floodplain of the Missouri River. One of these, represented by site 43, is the more mesic Tilia americana (basswood)-Quercus rubra (red oak) community. In New Jersey, Buell and Wistendahl (1955) reported more mesic floodplain terraces can support an Acer-Tilia (maple-basswood) community instead of a Quercus-Carya (oak-hickory) community. Ulmus rubra (slippery elm) and Gymnocladus dioica (Kentucky coffee-tree) were subdominant species in the overstory. The population structure of site 43 (Table 10) had species representation over all the size classes. The shrub union was dominated by Cornus stolonifera (red osier dogwood), and Cercis canadensis (redbud) which is characteristic of a more mesic habitat. Symphoricarpos occidentalis (wolfberry) was an important shrub species in site 43 and was part of the formation of a new shrub union, along with Ribes missouriense (gooseberry). In this mesic habitat, Laportea canadensis (wood nettle) was clearly the most important herb, with Galium aparine (rough bedstraw) and Osmorhiza claytonii (sweet cicely) as the next important herbs.

Table 10. Population structure of the tree species in a representative mature floodplain forest along the Missouri River near Nebraska City, Nebraska.

	Site 43										
	Size Class (dbh)[a]										
Species	0-0.5 <1m tall	0-0.5 >1m tall	0.5-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8+
Tilia americana		22.5	2	3		2	5	1			
Ulmus rubra				3			1				
Gymnocladus dioica	7.5	15			1	1					
Quercus rubra						1					
Morus alba		7.5		1							
Celtis occidentalis	60	52.5	1								
Ulmus americana		15									
Acer negundo		7.5									

[a] Diameter at breast height is measured in dm.

Quercus-Carya dominated community. Sites 44 and 45 were located in an old Quercus macrocarpa (bur oak) and Carya ovata (shagbark hickory) community, 5 km south of Hamburg, Iowa, and approximately 1 km from an old channel of the Missouri River. This is the second of the two probable climax communities on the Missouri River floodplain. Both sites contained an 8+ dbh Quercus macrocarpa (bur oak) tree indicative of the very old age of the community. These were the only two sites encountered on the floodplain in which Carya ovata (shagbark hickory) was found. Ulmus rubra (slippery elm) and Tilia americana (basswood) were important tree species. Cornus stolonifera (red osier dogwood) had a well-developed union in site 45. The shorter Symphoricarpos-Ribes union was more developed in the Quercus-Carya community than in the Tilia-Quercus community. Parthenocissus quinquefolia (Virginia creeper) was another important shrub species in this community. In the last two communities, dominated by Tilia-Quercus and by Quercus-Carya, there was a significant reduction in the cover of Toxicodendron rydbergii (poison ivy). Laportea canadensis (wood nettle) was not found in either of the sites representative of the Quercus-Carya dominated vegetation. Galium aparine (rough bedstraw) and Circea cuadrisulcata (enchanter's nightshade) were the dominant herbaceous plants in the two sites (Table 11).

Two of the study sites, no. 6 and 36, sampled were in the northern portion of the study area. The sites exhibited few differences in their overstory vegetation compared to similarly aged sites in the southern areas. However, the

Table 11. Average percent cover (C) and average percent frequency (F) for the shrub and herbaceous species occurring in the mature communities.

Species	40 C/F	41 C/F	42 C/F	43 C/F	44 C/F	45 C/F
Shrubs:						
Cornus stolonifera	18.2/44	3.2/12	+[a]/+	2.5/14	+/+	22.0/44
Toxicodendron rydbergii	4.0/34	9.5/38	0.4/14	+/+	1.0/8	1.8/14
Parthenocissus quinquefolia	2.3/20	7.4/44	1.6/14	13.1/64	25.6/78	17.9/80
Smilax hispida	0.5/10	0.3/2	+/+	0.7/8	1.6/14	0.3/2
Menispermum canadense	0.4/6	+/+	0.2/6	1.6/14	+/+	5.8/46
Sambucus canadensis	0.3/2					0.1/2
Vitis riparia	+/+	+/+	0.5/2		1.4/16	2.1/16
Symphoricarpos occidentalis	+/+		6.8/42	1.6/16	10.4/42	6.5/26

Table 11. Continued.

Species	Site Numbers 40 C/F	41 C/F	42 C/F	43 C/F	44 C/F	45 C/F
Asimina triloba			46.5/88			
Xanthoxylum americanum			0.3/2			
Cercis canadensis			+/+	10.5/28		
Ribes missouriense			+/+	+/+	17.7/46	5.1/20
Rubus occidentalis					1.9/8	
Campsis radicans						+/+
Herbaceous species						
Laportea canadensis	9.6/22			23.1/74		
Galium aparine	4.4/58	6.7/46		7.7/78	13.2/72	0.6/4

Table 11. Continued.

Species	Site 40 C/F	Site 41 C/F	Site 42 C/F	Site 43 C/F	Site 44 C/F	Site 45 C/F
Geum canadense	2.3/24		3.0/58			
Sanicula canadense	1.9/26	+/+	0.2/8	0.3/2	1.4/16	
Viola spp.	1.6/32		4.0/80	2.6/54	0.2/6	0.1/2
Parietaria pennsylvanica	0.5/8	0.7/8			0.3/2	
Phalaris arundinaceae	0.1/2					
Chenopodium album	+/+	+/+				
Oxalis stricta	+/+					
Phytolacca americana		0.4/6	1.6/24			
Tovara virginianum		+/+		1.2/8		1.3/2

Table 11. Continued.

Species	Site Numbers 40 C/F	41 C/F	42 C/F	43 C/F	44 C/F	45 C/F
Ambrosia trifida		+/+	0.3/2			
Conyza canadensis			2.7/28			
Phryma leptostachya			1.1/6	0.4/6	2.5/20	
Circaea quadrisulcata			0.8/10		4.2/24	11.9/70
Apocynum cannabinum			0.4/16			
Carex spp.			0.4/15	4.3/90		
Botrychium virginianum			0.1/4			
Cassia fasiculata			0.1/2	0.1/4		
Osmorhiza claytonii				5.8/46		

Table 11. Continued.

Species	Site Numbers 40 C/F	41 C/F	42 C/F	43 C/F	44 C/F	45 C/F
Desmodium grandiflorum				0.6/4		
Smilacina racemosa				0.2/6		
Viola canadensis				0.1/4		
Impatiens pallida				+/+		
Anemone canadensis				+/+		
Arisaema dracontium				+/+		0.3/2
Teucrium canadense					1.1/6	
Helianthus annuus					0.3/2	
Galium obtusum					0.1/4	0.9/14

Table 11. Continued.

	Site Numbers					
	40	41	42	43	44	45
Species	C/F	C/F	C/F	C/F	C/F	C/F
Cryptotaena canadensis						0.1/2

[a] Indicates species occurred in macroplot but not in 2 X 5 dm plots.

understory was dominated by Solidago spp. (goldenrod) and Conyza canadensis (horseweed) which is distinct from the Galium-Laportea herbaceous union in the other sites. These differences could be the basis for distinguishing a different vegetation type; however we decided to keep the northern Populus-dominated communities with the bulk of the Populus-dominated communities until further data warrant a separation.

We made some other observations relating to a north-south gradient. Platanus occidentalis (sycamore) was not seen north of Omaha, Nebraska. Asimina triloba (papaw) was seen only in the southernmost sites. Campsis radicans (trumpet creeper) was encountered south of Nebraska City, Nebraska.

The method that we used in our study to determine a time-scale of vegetational development along the channelized portion of the Missouri River proved to be efficient and rather precise. Although we do not know how long it takes for substrate deposition to reach the water level, or just above, we found that newly exposed substrates in 1974 were almost immediately covered by young willows and some cottonwoods. The results reported above portray an accurate view of succession along the Missouri River. Not only did the youngest wing dike areas have the youngest vegetation development, but stabilization structures of approximately equal age and located in the same region had similar overstory and understory vegetation. The fact that many stabilization structures were built in the 1930's and all the sites adjacent these structures were dominated by Populus deltoides (cottonwood) and all these communities had completely eliminated

Salix spp. (willows) from the overstory attests to the validity of this dating technique. Additionally, by this time, the short period at the beginning for substrate deposition becomes somewhat less important. The *Populus*-dominated community maintains its identity for quite a long period of time. This technique was so precise on the floodplain of the Missouri River that we could immediately determine the approximate age of the stabilization structures upon entering the community and noting its development. A study of this nature has the benefit of relating vegetation development to date of wing dike construction. Even though some precision is lost by the fact we could not measure rates of substrate deposition this is less important than it might first appear.

One of the problems encountered in the study was that the construction of stabilization structures along the Missouri River was not done continuously from beginning to end. Rather there were periods of active construction alternating with periods of no construction. Thus not all the successional history of the vegetational development could be followed. However the information lost proved to be minimal in the vegetational development of the communities. Another problem with the study was the fact that the oldest stabilization structures were only 40 years old and succession had not yet obtained the climax condition; but older communities were found and studied though not with the precise time-scale accuracy. It is usually possible to date the age of vegetation, even if approximately, by taking tree cores and counting growth rings. But in our oldest sites the largest trees were far too large to be cored, so we can only estimate the age of these sites to be well over 100 years.

Channelizing the Missouri River has created a situation of conflicting interests, at least to some degree. These conflicts stem mainly from the problem of land use. The effective control of the Missouri River though a system of reservoirs above the study area and the construction of stabilization structures along the study area has created more land that can be used for farming. A former practice of farmers along the Missouri River was to leave a tree zone between the river and their land to reduce the river's current during times of high water. This buffer zone protected the farm land from erosion and also provided an area for vegetational succession. But with more control over the river and the high price for arable farm land these stands are being eliminated.

The technique of dating used in our study could possibly be related to sedimentation studies along the Missouri River. The rate of sedimentation as well as the texture of the material in the Missouri River could be determined and compared to previous sedimentation along the river. A relationship could be worked out among sedimentation rates, textural properties of sediment, and vegetation development.

The older communities that still exist and were studied on the floodplain are invaluable. These remnants of the eastern deciduous forest formation have a variety of plant species that are not encountered in any other community on the floodplain. These are highly diverse and stable communities. They represent a record of natural vegetation which if removed will never again be attained. The value of these mature biotic communities transcends levels of economic thinking. Fortunately these areas are apparently to remain as they are, undisturbed. They will provide for future generations the opportunity to seek answers to basic questions current investigators have not yet thought to ask. They will also provide, as they do now, the opportunity for persons to visit and enjoy the environment of a mature floodplain forest.

There are a variety of wildlife habitats along this portion of the Missouri River. An assessment of the wildlife could be made in the context of the vegetation types described in this study. Those vegetation types providing the best combination of cover and food for the wildlife can be maintained by management based on ecologic knowledge of the vegetation.

Diversity

We were especially interested in interpreting changes in species diversity, both successionally and geographically. Theoretically, diversity increases with an increase in succession, resulting in a greater community stability (Odum 1967). Since a relatively large diversity may indicate not only a large number of species, but also a relative evenness in individual species importance values, we expected the more mature communities, *Platanus-Ulmus*, *Tilia-Quercus*, and *Quercus-Carya*, to exhibit greater diversity values than the younger *Salix* and *Populus* communities.

We computed mean diversity for the tree, shrub, and herbaceous unions using the Shannon-Wiener index of diversity:

$$D = \sum_{i=1}^{m} \left(\frac{n_i}{N} \mathrm{Log}_2 \frac{n_i}{N}\right)$$

where n_i is the importance (coverage) value of the ith species, m is the number of species, and N is the total importance (coverage) value for the site. We then averaged these values for each community type to show general trends (Table 12). The diversity values of the tree unions are low in the *Salix* and *Populus* dominated communities. In the *Populus* community this was due to the overwhelming dominance of *Populus deltoides* in the tree union of most of the stands studied. The more mature floodplain tree unions had substantially higher values than the younger communities. The shrub union had approximately equal values for the *Salix* and *Populus* communities. The *Platanus-Ulmus* had the lowest value in the shrub union. The two climax communities, *Tilia-Quercus* and *Quercus-Carya*, had the highest diversity values in the shrub union. In the herbaceous union all the communities except the *Tilia-Quercus* community had approximately the same values. The *Tilia-Quercus* community had a high value in its herbaceous union.

Lawrey *et al*. (1973) found herbaceous species diversity to be greater in young northern stands than in young southern stands. This was attributed to the greater variety of habitat conditions in the northern unchannelized part of their study area. However, as succession advances, diversity of herbaceous species becomes greater in the southern stands where more species are part of the herbaceous undergrowth of older stands.

Table 12. Mean diversity, $\bar{D}$, and standard errors were calculated for tree, shrub, and herbaceous unions in each of the five vegetation types occurring in the study region. The Shannon-Wiener Index was used.

Dominant Member of the Community	$\bar{D}$ Tree Union	Shrub Union	Herbaceous Union
Salix	0.79 ± .07[a]	1.69 ± .26[b]	1.67 ± .22
Populus	0.72 ± .07	1.53 ± .11	1.76 ± .12
Platanus-Ulmus	1.83 ± .15	1.28 ± .19	1.90 ± .63
Tilia-Quercus	1.42 ± .00	1.93 ± .00	2.25 ± .00
Quercus-Carya	1.23 ± .27	2.19 ± .18	1.59 ± .37

[a] Includes *Salix* sites 3-13. No measurable trees in sites 1-2.

[b] Includes *Salix* sites 9-13. No shrubs in sites 1-8.

<u>Similarity Indexes and their use in Vegetation Descriptions</u>.

In order to further analyze our data, we determined stand similarity between each pair of the 45 stands. This was done by using the following coefficient of similarity (Oosting 1956): C= 200w/(a+b). We used percent basal area or percent coverage data for each species in each stand in determining similarity. For species occurring in both sites being compared, the lower coverage percentages of all such species were summed (w) and doubled to represent the degree of similarity between the two sites. This value was then taken as a percentage of the sum of all coverage or basal area percentage values of both sites (a+b). A site similarity coefficent was calculated for each of the 45 sites paired with each of the remaining sites.

By using the tree values (Table 13), the coefficient of similarity verifies that five communities can be identified. The first community, the <u>Salix</u>, consist of sites 3-11, and 13. Sites 1 and 2 had no measureable basal areas and did not have any values for comparison. Site 12 which is approximately the same age as 11 and 13, had essentially no <u>Salix</u> <u>spp.</u> left in the community, and therefore the similarity of trees was more closely related to the <u>Populus</u> community. The <u>Populus</u> community, sites 14-39, were similar to each other due to the dominance of <u>Populus</u> <u>deltoides</u> in the overstory. Although some variations do exist between some of the stands, they clearly show a relationship between each other. Sites 40, 41, and 42 represent the <u>Platanus</u>-<u>Ulmus</u> community. Site 40

COEFFICIENT OF SIMILARITY

2	0																																										
3	0	0																																									
4	0	0	68																																								
5	0	0	43	69																																							
6	0	0	83	80	50																																						
7	0	0	73	91	71	65																																					
8	0	0	67	77	73	62	93																																				
9	0	0	45	41	27	53	40	28																																			
10	0	0	53	22	6	33	40	38	15																																		
11	0	0	58	20	6	29	36	33	13	77																																	
12	0	0	10	10	9	12	0	7	9	14	12																																
13	0	0	29	27	10	37	21	19	28	52	42	21																															
14	0	0	1	1	4	2	2	1	1	0	0	68	4																														
15	0	0	1	2	5	2	3	2	1	1	0	33	6	30																													
16	0	0	1	1	4	2	2	1	1	0	0	73	4	84	29																												
17	0	0	1	1	4	2	2	1	0	0	0	65	3	94	30	80																											
18	0	0	1	1	4	2	2	1	1	0	0	73	4	93	31	88	80																										
19	0	0	1	1	4	2	2	1	1	1	0	74	4	92	31	89	98	99																									
20	0	0	1	1	4	2	2	1	1	1	0	81	4	86	34	88	81	88	99																								
21	0	0	1	2	4	2	2	1	1	1	0	82	5	83	36	87	79	86	98	97																							
22	0	0	1	1	4	2	2	1	1	1	0	80	4	85	34	86	80	87	89	97	96																						
23	0	0	1	2	5	2	2	1	1	1	0	86	5	80	37	83	76	84	85	93	95	92																					
24	0	0	1	1	4	2	2	1	0	0	0	65	3	90	26	81	93	90	89	80	78	79	75																				
25	0	0	1	2	5	2	2	1	1	1	0	81	5	70	40	72	66	72	74	82	83	82	83	65																			
26	0	0	1	1	4	2	2	1	1	1	0	75	4	88	32	89	84	88	90	92	90	91	88	80	76																		
27	0	0	1	1	4	2	2	1	1	1	0	74	4	87	31	93	83	88	89	92	89	92	85	81	76	94																	
28	0	0	1	1	4	2	2	1	1	1	0	80	4	76	50	79	71	78	80	88	90	87	92	71	79	81	81																
29	0	0	1	2	5	2	2	2	1	1	0	62	6	55	40	56	51	55	57	64	63	64	65	50	71	60	60	60															
30	0	0	1	2	5	2	2	2	1	1	0	91	6	71	39	76	67	76	77	85	86	84	90	68	88	78	77	84	69														
31	0	0	1	2	5	3	3	2	1	1	0	70	7	61	43	61	58	61	63	71	70	72	73	55	80	68	67	66	64	77													
32	0	0	1	2	5	2	3	2	1	1	0	67	6	53	41	70	50	57	59	64	65	64	68	51	72	60	66	64	77	74	85												
33	0	0	1	2	5	2	3	2	1	1	0	81	6	66	43	69	62	70	71	79	80	77	85	62	88	73	71	78	76	89	86	81											
34	0	0	1	1	4	2	2	1	1	0	0	69	4	93	33	96	89	95	93	95	96	85	81	88	74	86	85	78	53	73	58	54	67										
35	0	0	1	2	5	3	3	2	1	0	0	58	7	44	51	45	46	45	45	52	53	51	58	40	58	49	46	52	64	62	70	66	68	46									
36	0	0	1	2	6	3	3	2	2	0	0	38	13	25	47	28	24	28	23	32	33	32	35	24	38	29	29	32	43	41	49	46	45	26	53								
37	0	0	1	2	5	2	3	2	1	1	0	77	6	66	41	67	62	57	69	78	77	78	80	61	87	73	72	74	81	85	92	81	94	65	66	45							
38	0	0	1	2	5	2	2	1	1	1	0	85	5	79	35	84	76	83	85	93	94	92	97	75	84	88	87	90	68	89	74	70	84	80	56	35	81						
39	0	0	1	2	5	2	2	2	1	1	0	87	5	75	37	76	71	76	78	86	86	87	89	69	92	82	81	82	73	94	84	73	89	73	59	39	90	90					
40	0	0	1	2	5	3	3	2	1	1	0	51	7	45	66	45	46	45	46	53	55	52	57	40	60	49	47	62	63	58	68	64	66	48	80	50	65	55	58				
41	0	0	21	16	5	23	15	15	8	31	27	10	23	7	44	17	3	4	5	5	8	6	7	4	8	8	12	20	7	4	6	21	7	9	8	0	7	8	5	25			
42	0	0	0	0	0	0	0	0	0	0	0	0	0	3	48	0	6	0	0	2	4	3	2	0	3	7	1	17	0	1	0	0	2	7	15	0	1	1	0	28	46		
43	0	0	0	0	0	0	0	0	0	1	0	0	0	3	10	1	6	3	3	2	2	2	2	4	1	2	4	2	2	2	2	2	2	3	4	16	0	2	3	1	13	7	24	
44	0	0	0	0	0	0	0	0	0	0	0	0	0	2	8	1	5	1	1	1	1	1	3	0	1	3	1	1	1	0	0	1	2	3	14	0	1	2	0	13	7	12	11
45	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	1	2	0	0	1	1	0	2	0	1	2	0	1	0	0	0	0	1	3	3	0	1	1	0	3	3	6	12	48
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44

SITE NUMBER

with its one _Populus_ _deltoides_ (cottonwood) tree remaining, shows a strong index of similarity with the _Populus_ community. Site 41 with its four old _Salix_ trees showed some relationship with the _Salix_ community. All three sites showed a considerable similarity with site 15 which was dominated by _Platanus occidentalis_ (sycamore). The _Tilia_-_Quercus_ community represented by site 43 was not closely related to any other site in the tree union. The two sites, 44 and 45, located in the _Quercus_-_Carya_ community had a high index of similarity which one would expect.

In the shrub and herbaceous unions (Table 14) not many clear differences in similarity occur as in the tree unions. The young _Salix_ communities, sites 1-8, are somewhat similar to each other but are not related to any of the other sites. Although no other clear breaks may be discerned, some other interesting data are shown in these coefficients of similarity. For example, sites 6 and 36, the two northernmost sites are most closely related to each other. Also the two southernmost sites in the _Populus_ community, sites 24 and 25, had their highest index of similarity between each other.

Soils Characteristics

The soils in our study area are similar to those identified by Weaver (1960). The Albaton series consists of moderately dark colored, poorly drained soils that formed from alluvium along the river. These soils are clayey and stratified and occur as broad, level areas at low elevation. The available moisture capacity is medium. The soils descriptions provided by Worster _et al_. (1972) include terms like "medium",

COEFFICIENT OF SIMILARITY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
2	17																																											
3	0	17																																										
4	0	7	2																																									
5	1	8	63	6																																								
6	0	0	30	[illegible]	38																																							
7	0	7	61	1	68	42																																						
8	0	12	32	10	51	44	49																																					
9	0	3	13	1	16	13	14	17																																				
10	0	1	6	2	1	[illegible]	0	1	20																																			
11	0	0	2	0	0	0	0	1	12	8																																		
12	0	0	4	2	0	2	0	1	20	46	6																																	
13	0	0	4	1	0	0	0	1	35	37	26	40																																
14	0	0	0	0	0	0	0	0	18	10	1	7	8																															
15	7	6	0	0	0	0	0	0	30	14	0	14	17	44																														
16	0	0	0	0	0	0	0	0	22	15	1	14	16	41	70																													
17	0	0	0	0	0	0	0	0	16	11	0	8	5	53	57	73																												
18	1	1	0	0	0	0	0	0	25	24	1	21	22	73	49	44	51																											
19	0	0	0	0	0	0	0	0	21	30	1	32	19	58	37	33	36	66																										
20	0	0	0	0	0	0	0	0	22	24	1	15	12	44	44	50	54	62	33																									
21	0	0	0	0	0	0	0	0	17	17	1	9	7	26	32	41	43	39	22	75																								
22	0	0	2	0	0	0	0	0	19	19	2	10	8	36	30	35	34	40	43	54	46																							
23	0	0	0	0	0	0	0	0	24	20	2	15	13	59	40	45	56	60	59	52	38	56																						
24	0	0	1	0	0	0	0	0	16	10	2	8	8	30	26	39	39	32	25	39	42	25	32																					
25	0	0	0	0	0	0	0	0	15	9	1	6	4	45	33	28	36	45	43	32	22	36	55	67																				
26	1	1	2	0	0	0	0	0	30	41	3	39	40	53	49	45	36	62	62	44	25	32	42	26	29																			
27	0	0	0	0	0	0	0	0	11	31	1	34	17	21	19	17	15	39	49	32	20	16	20	10	12	44																		
28	0	0	0	0	0	0	0	0	11	14	1	11	8	39	35	32	29	55	34	52	38	31	36	18	25	34	47																	
29	0	0	0	0	0	0	0	0	11	34	1	54	28	18	15	20	15	30	50	21	12	11	20	9	8	49	48	18																
30	2	2	4	1	0	3	0	1	15	30	3	62	20	8	15	20	21	26	31	31	27	21	18	18	10	29	36	25	43															
31	0	0	2	0	0	0	0	0	14	30	2	16	11	9	17	24	29	20	13	42	46	27	17	45	9	20	33	25	10	26														
32	0	0	2	0	0	0	0	0	21	19	2	11	8	39	35	32	34	36	30	29	18	23	27	20	21	47	8	18	5	10	20													
33	1	1	5	0	0	0	3	0	23	36	2	41	27	41	39	40	37	62	69	46	32	26	38	23	26	68	51	34	65	43	19	39												
34	1	1	0	0	0	0	0	0	13	34	2	35	26	30	30	27	23	47	57	37	23	24	31	16	19	60	55	41	69	37	20	8	70											
35	1	1	2	0	0	1	0	1	16	29	1	28	26	34	25	27	29	48	45	35	23	21	25	17	13	55	41	35	44	22	20	28	55	52										
36	0	0	5	3	4	35	4	3	14	15	2	10	5	4	7	3	5	6	4	4	3	2	8	2	4	6	3	4	2	11	3	10	8	2	6									
37	0	0	1	0	0	0	0	0	25	27	2	25	26	69	45	42	52	77	61	49	32	33	60	40	47	67	35	37	38	26	18	34	61	55	50	4								
38	3	3	0	0	0	0	0	0	14	12	1	9	9	27	36	40	40	41	23	63	64	35	31	56	21	33	29	44	16	31	51	19	35	31	28	3	35							
39	0	0	2	0	0	0	0	0	10	36	2	49	30	8	4	7	5	26	46	15	8	8	11	9	3	47	45	14	59	41	12	13	61	63	46	4	36	13						
40	0	0	0	0	0	0	0	0	17	18	1	15	14	25	37	45	45	44	30	66	70	33	30	45	19	34	41	50	22	34	51	20	40	33	40	3	37	70	18					
41	0	0	0	0	0	0	0	0	21	21	1	13	22	69	50	46	49	78	68	43	28	36	60	32	42	68	36	47	37	21	18	36	60	57	52	3	77	37	33	40				
42	1	1	0	1	0	1	0	0	7	10	1	5	2	10	12	12	14	9	7	7	6	14	5	4	4	7	12	12	5	3	8	4	6	5	14	8	5	5	1	11	5			
43	7	3	0	0	0	0	0	0	10	17	1	14	14	22	21	21	15	36	41	26	18	42	32	10	23	29	35	33	23	24	11	3	28	32	28	1	30	24	17	35	32	10		
44	0	0	0	0	0	0	0	0	9	23	1	24	13	19	11	8	6	24	46	16	9	38	31	9	19	29	37	21	30	21	7	5	31	34	27	5	23	13	30	16	28	15	30	
45	0	0	0	0	0	0	0	0	13	13	2	9	6	25	22	24	26	28	31	47	49	60	46	33	29	19	17	24	8	18	37	8	16	19	14	6	22	46	3	39	25	14	27	47

SITE NUMBER

phorus, and available potassium are low. The surface layer is neutral to moderately alkaline. The rooting zone is deep.

Most of the edaphic characteristics of the soils in our study area bear no striking relationship either to successional status of the vegetation or geographic location (Table 15). The mature floodplain stands did show a higher total available nitrogen and organic matter content than stands representing either the _Populus_ or _Salix_ communities. Soils with a high sand content usually had a low percent organic matter and available nitrogen. All soils, except for stand 44, had pH values greater than 7.0.

Lawrey _et al_. (1973) found that soils of the younger communities had a higher sand content but we did not find this to be the case in our study area. The amount of sand, silt, and clay had no apparent correlation with the age of the community, at least in the younger stages of succession. Lawrey _et al_. (1973) found as we did, that N and organic matter increased with vegetational succession.

The probable reason for the general lack of relationship between age of vegetation (oldest stands excluded, numbers 42, 43, 44, and 45), and edaphic characteristics is the manner of substrate deposition and the maturity of the soils themselves. Substrate deposition along the Missouri River has never been uniform in terms of particle size distribution of the mineral soil, rates of deposition, or origin of deposited material. All the substrates have adequate supplies of certain nutrients such

Table 15, Continued.

Stand No.	Mechanical Analysis Sand %	Silt %	Clay %	Soil Name	Nutrients, ppm P	K	Ca	Mg	%N	%Organic Matter	pH	C.E.C.[a] meq/100 g	Base Saturation
31	20	56	24	Silt Loam	200	320	4000	2000	.06	0.6	7.5	12	.67
32	85	13	2	Loamy Sand	200	320	4000	2000	.08	0.5	7.6	8	.63
33	30	64	6	Silt Loam	200	320	4000	2000	.10	0.8	7.5	15	.60
34	48	40	12	Loam	200	320	4000	3000	.17	0.8	7.5	18	.67
35	31	54	15	Silt Loam	200	320	6000	2000	.09	2.2	7.9	13	.77
36	92	5	3	Sand	125	240	4000	2000	.09	1.7	7.4	11	.73
37	31	59	10	Silt Loam	200	160	4000	2000	.11	0.9	7.7	12	.63
38	45	36	19	Loam	125	320	4000	2000	.17	1.7	7.1	14	.72
39	46	41	13	Loam	200	320	4000	2000	.10	1.3	7.6	15	.67
40	32	40	28	Loam	125	320	6000	2000	.22	3.5	7.5	20	.50
41	78	17	5	Loamy Sand	200	320	6000	2000	.14	1.2	7.4	9	.67
42	14	34	52	Clay	125	320	4000	2000	.34	5.4	7.1	28	.79
43	36	48	16	Loam	200	320	4000	2000	.34	5.9	7.2	15	.67
44	16	54	30	Silt Clay Loam	200	320	4000	2000	.33	5.7	6.9	28	.56
45	15	55	30	Silt Clay Loam	200	320	4000	2000	.37	5.8	7.6	18	.67

[a] Cation exchange capacity

[b] Indicates percent organic matter content less than 0.01.

Table 15. Soils characteristics of the upper dm of mineral soil in each stand studied.

Stand No.	Mechanical Analysis: Sand %	Silt %	Clay %	Soil Name	Nutrients, ppm: P	K	Ca	Mg	%N	%Organic Matter	pH	C.E.C.[a] $\frac{meq}{100\ g}$	Base Saturation
1	10	74	16	Silt Loam	125	320	4000	2000	.06	1.6	7.9	16	.61
2	12	66	22	Silt Loam	75	320	4000	1000	.15	1.7	7.6	15	.80
3	12	69	19	Silt Loam	200	240	2000	2000	.12	3.8	7.6	17	.82
4	12	63	25	Silt Loam	125	240	4000	2000	.15	2.6	7.7	24	.83
5	18	65	17	Silt Loam	125	240	6000	2000	.11	2.4	7.5	15	.93
6	82	12	6	Loamy Sand	50	240	4000	3000	.16	0.5	7.4	15	.87
7	15	66	19	Silt Loam	200	320	4000	2000	.13	2.1	7.5	15	.80
8	33	58	9	Silt Loam	200	320	2000	1000	.07	+[b]	7.7	7	1.00
9	13	68	19	Silt Loam	125	160	4000	2000	.13	2.1	7.8	17	.71
10	16	64	20	Silt Loam	200	160	6000	3000	.14	1.3	7.9	22	.62
11	31	57	12	Silt Loam	200	240	2000	2000	.10	0.6	7.6	16	.57
12	14	51	35	Silty Clay Loam	75	320	4000	3000	.25	2.0	[illegible]	20	.85
13	55	30	15	Sandy Loam	125	320	4000	2000	.14	1.3	7.5	14	.79
14	74	22	4	Sandy Loam	200	320	4000	2000	.09	2.0	7.5	13	.62
15	20	64	16	Silt Loam	200	240	2000	2000	.15	1.0	7.9	11	.73

as Ca and Mg; all have relatively high pH. Potassium, nitrogen, phosphor and organic matter are quite variable except in the oldest stands. Immature soils of alluvium origin can not be expected to show distinct correlations with the biotic communities they support. Only several hundred years will permit a more distinct correlation. But it is nonetheless important to have documented edaphic characteristics for the purpose of our study as well as for future reference.

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Appendix 1. Scientific names and their associated common names of the plants occurring along the channelized portion of the Missouri River floodplain from Sioux City, Iowa, to Rulo, Nebraska.

TREES

Scientific Name	Common Name
Acer negundo	Box Elder
Acer saccharinum	Silver Maple
*Carya ovata	Shag-Bark Hickory
Catalpa speciosa	Catalpa
Celtis occidentalis	Hackberry
Fraxinus pennsylvanica	Green Ash
Gleditsia triacanthos	Honey Locust
Gymnocladus dioica	Kentucky Coffee-tree
Juglans nigra	Black Walnut
Morus alba	Mulberry
Platanus occidentalis	Sycamore
Populus deltoides	Cottonwood
Quercus macrocarpa	Bur Oak
Quercus rubra	Red Oak
Salix amygdaloides	Peach-leaved Willow
Salix eriocephala	Diamond Willow
Salix interior	Sandbar Willow
Salix nigra	Black Willow
Tilia americana	Basswood
Ulmus americana	American Elm
Ulmus rubra	Slippery Elm

SHRUBS

Ampelamus albidus	Sand Vine
Asimina triloba	Papaw
Campsis radicans	Trumpet Creeper
Cercis canadensis	Red Bud
Cornus stolonifera	Red Osier Dogwood
Menispermum canadense	Moonseed
Parthenocissus quinquefolia	Virginia Creeper
Rhus glabra	Smooth Sumac
Ribes missouriense	Gooseberry
Rubus occidentalis	Black Raspberry
Sambucus canadensis	Elderberry
Smilax hispida	Greenbriar
Symphoricarpos occidentalis	Wolfberry
Toxicodendron rydbergii	Poison Ivy
Vitis riparia	Riverbank Grape
Xanthoxylum americanum	Prickly Ash

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