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VEGETATION OF THE FLOODPLAINS AND FIRST TERRACES OF ROCK CREEK NEAR RED LODGE, MONTANA

by

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VITA

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ABSTRACT

The floodplain vegetation of Rock Creek near Red Lodge, Montana was studied with a view to learning more about the relationship between riparian vegetation and trout habitat. The major objectives of the study were to: (1) qualitatively and quantitatively describe the vegetation, (2) delineate the successional stages and relate the sequence to soil and other environmental factors, and (3) compare two adjacent sections of floodplain, one essentially undisturbed and the other heavily grazed. The vascular plants occurring on the floodplain and nearby land forms were collected. The vegetation was sampled with permanent plots within and belt transects across the floodplain. Soils were sampled at two levels and analyzed for several physical and chemical properties.

The undisturbed vegetation of the Rock Creek floodplain consists of several strata. The tree stratum is composed nearly entirely of _Populus trichocarpa_. The tall shrub stratum has the following constituents: _Cornus stolonifera_, _Salix_ sp., _Prunus virginiana_, _Alnus incana_, _Betula occidentalis_ and _Crataegus douglasii_. _Rosa acicularis_, _Symphoricarpos albus_ and _Rubus idaeus_ are the most abundant taxa in the low shrub stratum. Characteristic herbaceous species occur under the woody vegetation, depending upon soil, water, light and the degree of disturbance.

Five successional stages, from Pioneer Stage to Mature Forest, have been designated and their floristic compositions compared. Soil samples were collected and analyzed from each of these successional stages. Most soils are sandy, especially in early successional stages. There is an increase in the amount of organic matter, potassium and phosphorus with vegetational development. Conductivity and 15-atmosphere moisture retention percentage are also greater in the advanced successional stages.

The essential elimination of the two shrub strata and the marked changes in the floristic composition of the herbaceous vegetation indicate the effects of burning, clearing, grazing, flooding and stream course alteration within the floodplain.

INTRODUCTION

Statement of the Problem

The floodplain may be described as a strip of relatively smooth land bordering a stream and overflowed at time of high water (Leopold, Wolman and Miller, 1965). For millions of years flood plains have been centers of biological activity. The earliest agricultural settlements appear to have been those along tributaries of the lower Euphrates and Tigris rivers, and are now dated at around 7000 B.C. The kind of agriculture made possible by irrigation and the domestication of grasses--wheat, barley and rice--was permanent and demanded a large scale cooperation that led in turn to a closely knit social organization. The cultivation of irrigated lands that tied man to the river valleys led invariably to the development of cities with their granaries, market places, administrative centers and religious rites (Bardach, 1964). Today one finds that the centrality of rivers in human life has brought about profound conflicts of interest. Some of these interests include the preservation of an adequate water supply, the prevention of pollution, the control of floods, the continuation of high agricultural productivity and the maintenance of desirable recreational areas for a population with increasing leisure time.

The present problem, although not concerned with a large river, manifests many of the interesting aspects which are being dealt with in connection with larger rivers. The study was supported by the Montana Fish and Game Department and the Montana Cooperative Fisheries Unit with a view to learning more about the relationship of riparian vegetation to trout habitat. The primary objective was to qualitatively and quantitatively describe the vegetation. In addition, the successional stages leading to the mature flood plain forest were delineated. To as great a degree as possible the successional stages were related to environmental factors. The factors influencing succession appear to be flooding, clearing, burning, grazing and mechanical stream course alterations. The study further involved the comparison of two sections along the stream which were nearly equivalent in area. One area is heavily grazed by cattle, while the other is essentially undisturbed by grazing, clearing, burning or alteration practices. The latter will hereafter be referred to as the natural area.

Description of the Study Area

Rock Creek originates at Glacier Lake on the Beartooth Plateau of Montana and Wyoming (Figure 1). The headwaters are near the Montana-Wyoming state boundary at an elevation of approximately 8600 feet above sea level. The stream flows northeasterly 59 miles until it joins the Clark's Fork River of the Yellowstone River Drainage. Most of Rock Creek would be classified as a straight stream (Leopold _et al_., 1965)

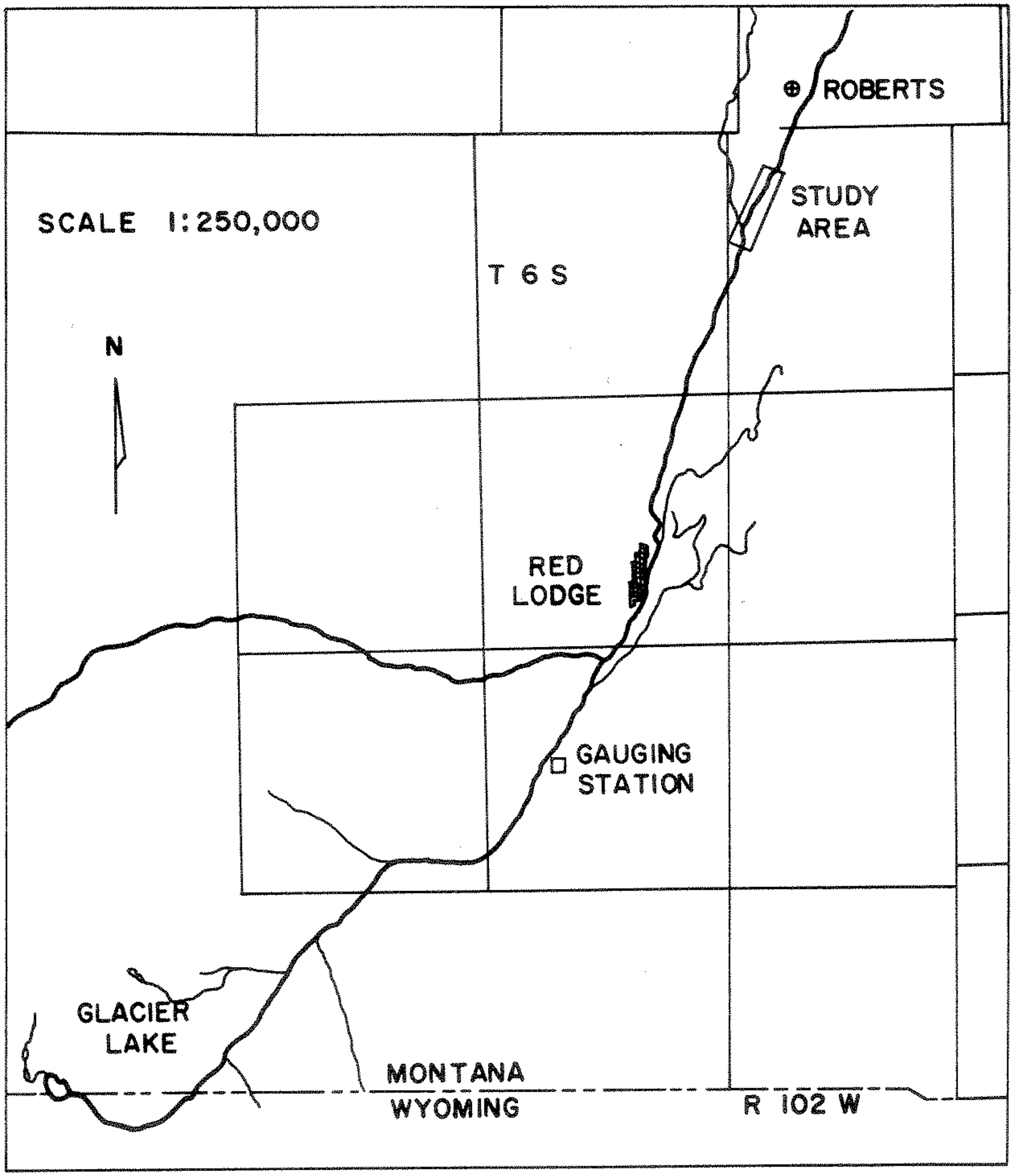

Figure 1. Map tracing the route of Rock Creek from origin at Glacier Lake to Roberts, Montana.

although in areas of heavy stream-side vegetation it may become a braided stream. The channel lacks most of the characteristics of a meandering stream (Matthes, 1941). At the United States Geological Survey recording station approximately four miles above Red Lodge, Montana, the stream has a drainage area of 124 square miles. It should be pointed out that this does not include the West Fork of Rock Creek and a few other small tributaries between the station and the study area. However, the station is also above the point at which water is diverted out of the stream for irrigation. This means that the recording station probably accurately reflects the natural discharge characteristics of Rock Creek. During late summer the volume of flow is generally less at the study area than in the upper reaches due to irrigation use. The 20 miles of stream above Red Lodge have an average gradient of 128 feet per stream mile, while the 23 miles between Red Lodge and the mouth of Red Lodge Creek have an average gradient of 66 feet.

Flood plain vegetation is probably most seriously affected by maximum discharge as opposed to either minimum discharge or average daily discharge. This is due to the fact that the maximum discharge usually occurs during flood or near flood conditions and does the most to physically alter the stream banks and flood plain. Table I presents the maximum discharge, minimum discharge and average daily discharge for the years 1951 to 1966

Table I. Maximum discharge, minimum discharge and average daily discharge (cfs) of Rock Creek near Red Lodge, for the years 1951 to 1966.

YEAR	MAXIMUM	MINIMUM	AVERAGE
1951	1460	28	199.8
1952	2590	30	182.2
1953	1300	24	148.9
1954	1570	18	149.6
1955	578	14	115.2
1956	1800	24	203.6
1957	3110	16	233.4
1958	1250	23	160.6
1959	1200	25	179.2
1960	680	27	118.7
1961	674	22	125.3
1962	912	23	174.2
1963	1120	15	180.6
1964	1330	24	156.3
1965	1450	24	214.0
1966	1230	22	154.1
Mean	1390.9	22.4	168.5

recorded at station 6-2095 of the United States Geological Survey (Rock Creek near Red Lodge, Montana) in cubic feet per second (U.S. Geological Survey, 1951-1960; 1961-1966). The maximum flow during these years has been recorded from May 15 to July 21 with the average date being June 14. The minimum discharge is more variable, occurring during the first four months of the calendar year with the average date being February 19. Figure 1 indicates the distribution of discharge over the year. The points plotted on the graph are the average daily flow for each month averaged for the years 1951 to 1966. It is easily observed that late spring and summer are the periods of highest average discharge. This is also the period when plants are most active physiologically. The results of this study will show which species and which plants have been most successful in perpetuating themselves in relation to various environmental stresses.

At its origin, the substrate of Rock Creek is Precambrian gneiss, schist, marble and associated rocks of the Cherry Creek series, pre-Cherry Creek formations and the Stillwater igneous complex. Near Mount Maurice, south of Red Lodge, the creek flows through Mississippian, Pennsylvania and Permian rocks of the Madison group and Amsden, Tensleep and Phosphoria formations. These Paleozoic formations are largely carbonates, sandstones and thin limestone. Near the point where Rock Creek emerges

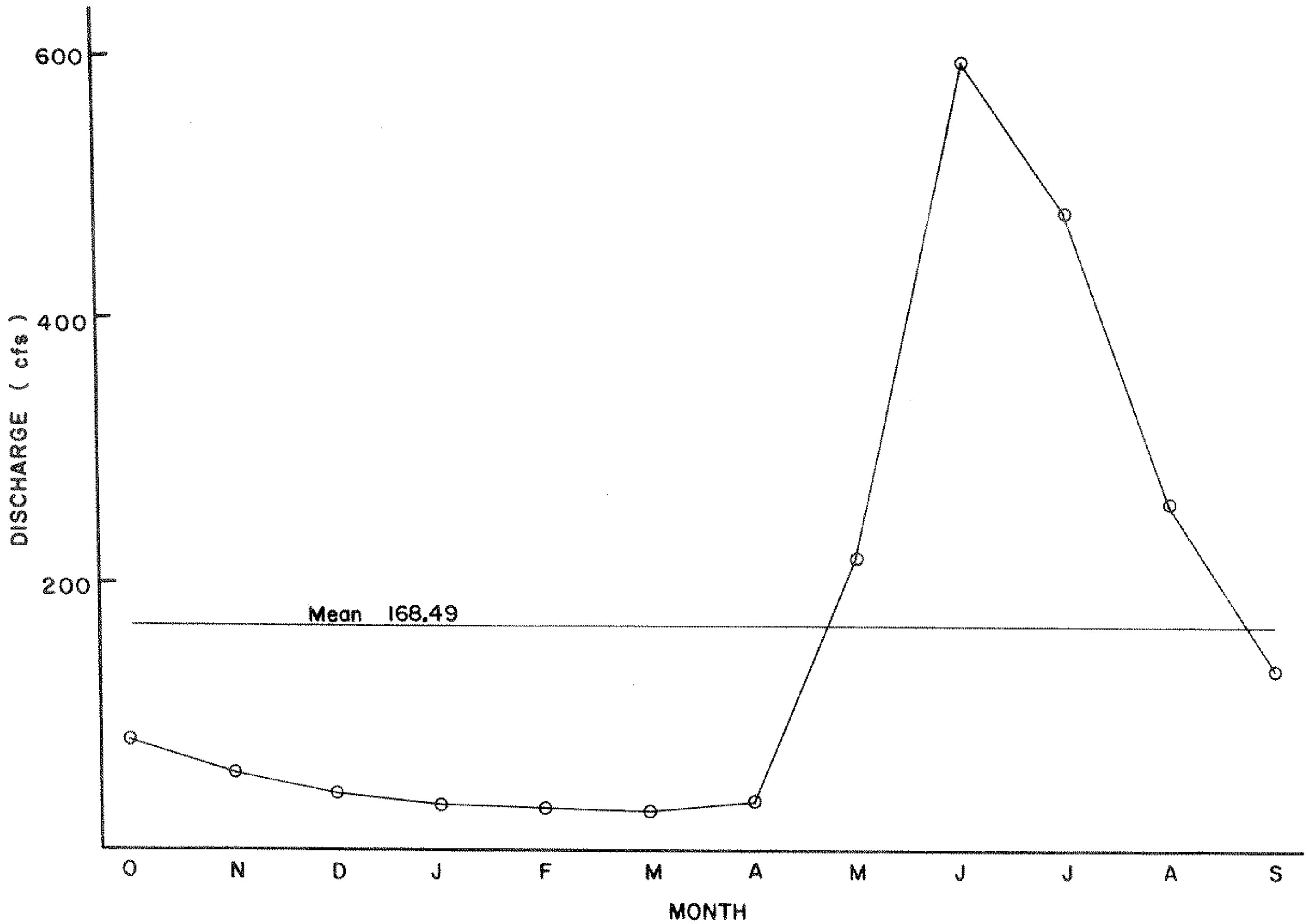

Figure 2. Average daily discharge reported monthly of Rock Creek near Red Lodge, Montana, for the years 1951 to 1966.

from the mountains several Mesozoic formations occur. These include the Lower Mesozoic Ellis group, Morrison formation, Kootenai formation, Dinwoody formation and the Chugwater formation. These formations are composed of shale, limestone and sandstone (Perry, 1962; McMannis, W. J., personal communication 1967). It is in this area that the spectacular limestone and dolomite palisades occur. Evidence (Alden, 1932) indicates that the valley north of Red Lodge through which Rock Creek flows was glaciated to a point about three miles south of Red Lodge where the creek emerges from the mountains. The first indication of a terminal moraine was found two or three miles above the canyon mouth. The glaciation of this area occurred during the Wisconsin glaciation of the Pleistocene epoch. Below Red Lodge the flood plain becomes broader and better defined. However, it is still bordered by high benches along with intermediate terraces and alluvial fans. These cut terraces and planated surfaces are mostly covered by deposits of smoothly worn nonglacial gravels derived from the mountains and in places cemented to conglomerate. Also included is some gravel probably derived from older and higher terraces. Some of the terraces and gravel are overlain by drift from the Wisconsin and Iowan or Illinoian stages of glaciation (Alden, 1932). Fort Union is the major formation which occurs below the gravel. The stream may cut into this formation of shale, sandstone and coal at various places. There are intrusive and extrusive igneous rocks composed primarily of andesites which occur along the stream. Much of the stream below Red Lodge is bordered by alluvial materials of various sorts (McMannis, personal communication 1967).

The soils of Carbon County have not been surveyed as yet and only a provisional description is available. The main soils along Rock Creek are shallow, gravelly soils. They have the following profile characteristics:

0 to 3 inches	Dark gray heavy loam with weak fine granular structure, non-calcareous, pH 6.0.
3 to 17 inches	Dark brown clay loam with prismatic to blocky structure, non-calcareous, pH 6.0.
17 plus inches	Brown gravelly clay loam. Rocks are of mixed origin but primarily granite, quartz and argulite, non-calcareous, pH 6.0.

There are areas of deep, dark colored alluvial soils that have a mollic epipedon for 12 inches over a stratified substratum for 10 to 30 inches (Brunsvold, personal communication 1967).

The major study area (Figure 3) is located approximately 8 miles north of Red Lodge, Montana. The natural area is called the Water Birch Fishing Access and the grazed area is part of the holdings of the Ruiter brothers who graze cattle and produce hay in the area. Three other fishing access sites owned by the Montana Fish and Game Department and located between Red Lodge

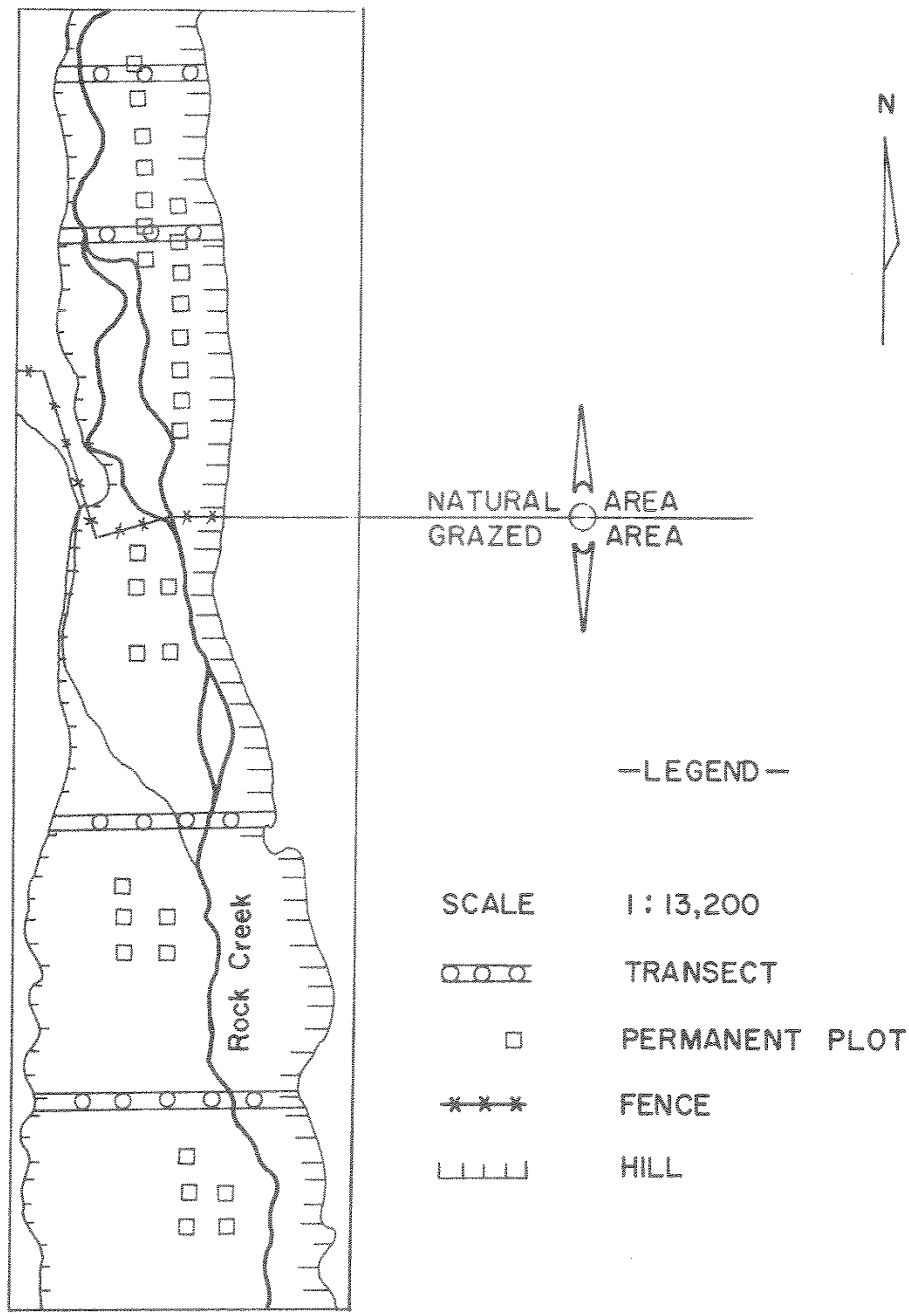

Figure 3. Map of the major study area near Red Lodge, Montana.

and the major study area were also investigated. Horsethief Fishing Access is closest to Red Lodge being about four miles north. The next site known as Beaver Lodge Fishing Access is six miles north of Red Lodge near the hamlet of Fox, Montana.

Climatic records (U.S. Weather Bureau, 1930; U. S. Department of Commerce, 1964-1966) have been kept at Red Lodge and precipitation records have been kept at Roberts, Montana since 1951. Figures 4 and 5 present graphically the temperature and precipitation data which is thought to be most representative of the experimental areas. The temperature data at Red Lodge (Figure 4) is probably comparable to that which could be collected at the study area. In addition to the temperatures shown on the graph it can be noted that the maximum temperature of 110°F. was recorded in June and the minimum temperature of -40°F. was recorded in February. It is thought that the maximum of 110°F. in June may be anomalous, since both July and August consistently have both higher average temperatures and higher average maximum temperatures. The average number of days from frost in the spring to killing frost in the fall is 95 days with the average critical dates being June 6 and September 9. It may be noted that nearly half of the average annual precipitation comes during the months of April, May and June, with only the winter months falling well below the monthly average of 1.34 inches. At Red Lodge the average annual snow-

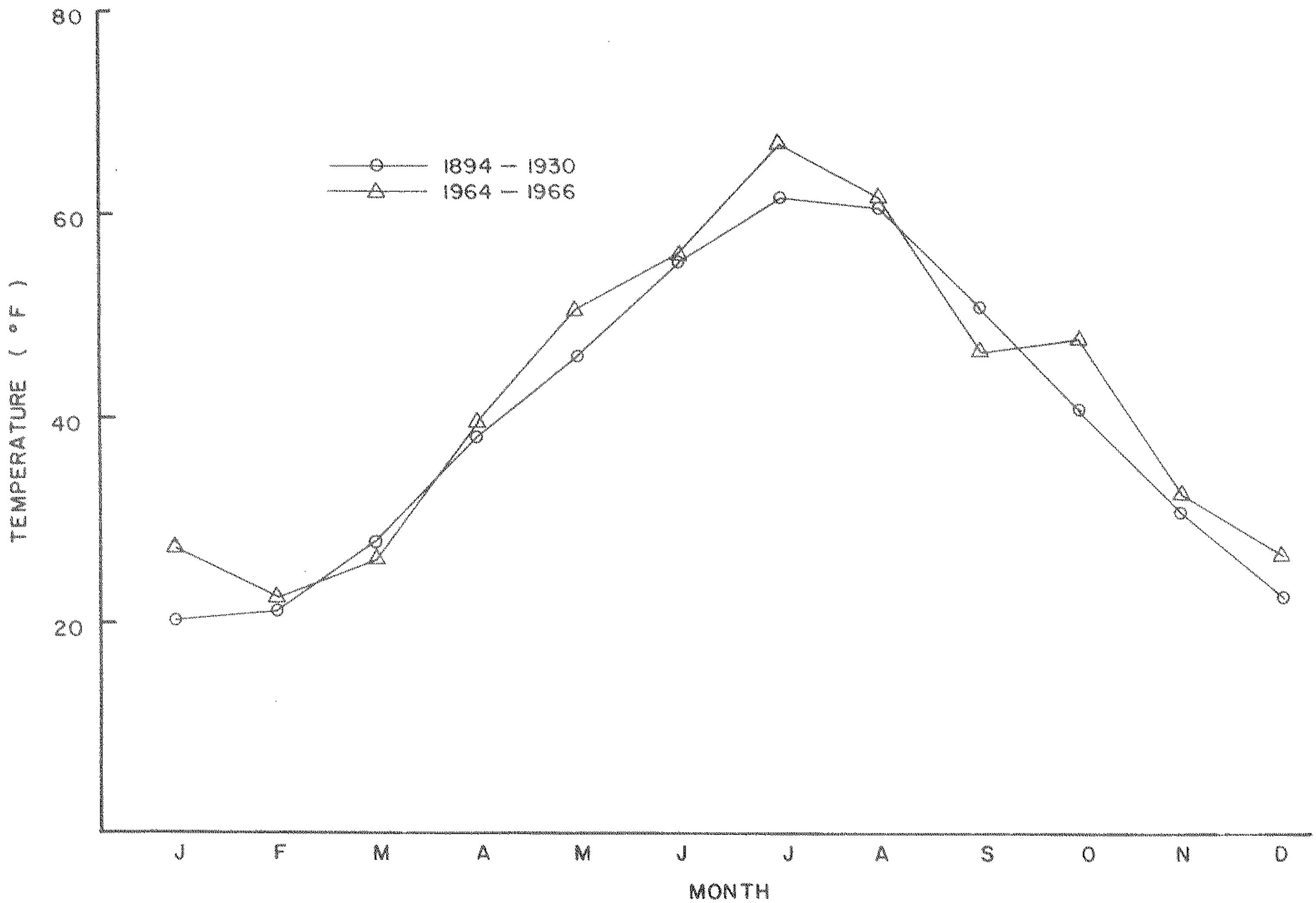

Figure 4. Average monthly temperatures at Red Lodge, Montana.

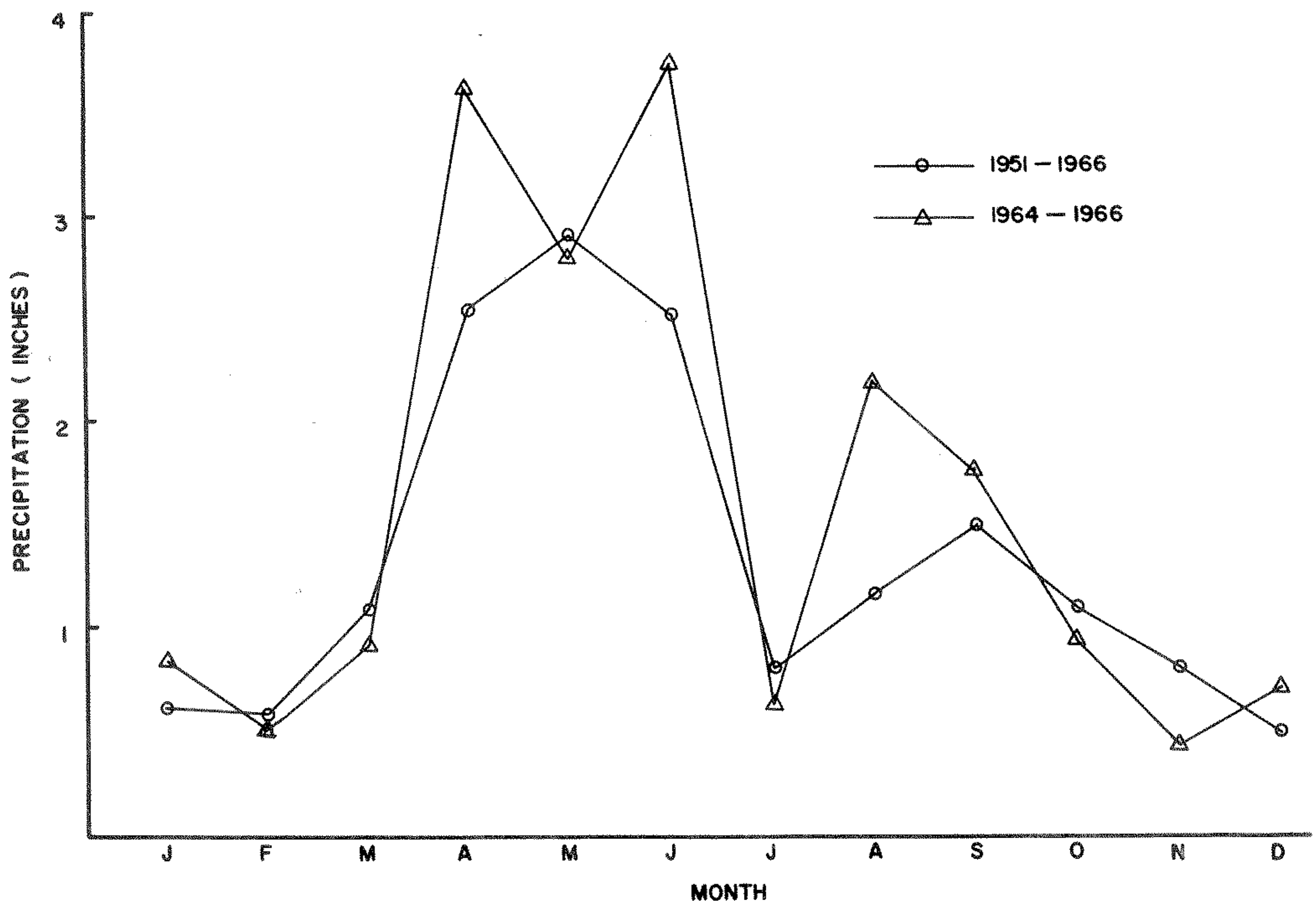

Figure 5. Average monthly precipitation at Roberts, Montana.

fall is 107.50 inches which is equivalent to about 10.75 inches of precipitation. This is over half of the annual precipitation of 19.82 inches at Red Lodge. Significant snowfall occurs in each month except June, July, August and September. Although these climatic data are valuable in assessing the overall climate of the study areas, some caution in interpreting them should be exercised. Flood plain vegetation is apparently more dependent upon the quality, quantity, periodicity and distribution of ground water than upon precipitation _per se_.

The flood plain and terraces of Rock Creek have been subjected to considerable domestic activity, especially since the closing of coal mines near Red Lodge in about 1930. This activity has taken the form of clearing, burning, grazing and mechanical alteration of the stream course. The natural area was purchased by the Montana Fish and Game Department about 1962. Prior to that time it was quite undisturbed except that two horses belonging to the former owner occasionally visited the area. The adjoining grazed property is currently grazed by about 40 head of mature cows for seven months of the year. In addition the calves born in the spring graze the area until sold in the fall. The history of the other sites owned by the Montana Fish and Game Department is variable, but none has been as heavily grazed as the Ruiter property nor as undisturbed as the natural area.

Some areas below Fox, Montana have been treated under the Agricultural Conservation Program (ACP) F-3 practice. The F-3 practice approved for federal cost-shares with specifications for work on Rock Creek below Fox, Montana is as follows:

> Removal of trees and debris from stream channels as well as minor realignment made necessary because of unusual flood conditions. This practice is applicable in those cases where stream channels have been blocked by trees and debris which have been cast into the main stream and potential damage to adjoining farm and crop land and irrigation diversion works. Cost-sharing will be allowed in those cases where removal of such debris is necessary for protection of farm and crop land. Cost-sharing will be allowed for the removal of debris from the channel such as trees, brush, stumps and log jams which may cause erosion or channel change. Also, cost-sharing will be allowed for minor channel realignment for the improvement of existing channels for the protection of stream banks from erosion. This work is limited to removal of gravel, stumps and sediment bars within the present banks of the stream. (Nelson, 1958)

One of the critical points concerning the management of flood plain areas appears to be the assessment of damage. That is, there is a rather broad latitude of opinion as to whether unusual erosion (that above normal erosion and meandering) is due to the occurence of abnormally high flows as in 1957, or to excessive use of the flood plain so that important understory shrubs are eliminated making the banks more easily eroded. Fisheries biologists (Nelson, 1958; Nelson and Hill, 1960) think that the basic problems concerning the multiple use of flood plains are not being solved by present programs.

DISCUSSION OF THE LITERATURE

Geomophology of Floodplains

The physiographical features of a floodplain may be of greater significance than they are in some other kinds of vegetation. The general trends of floodplain vegetational development have been found to be closely related to the nature of the alluvial substrate and to water levels.

A recent book (Leopold *et al*., 1965) reviews very adequately the literature associated with fluvial processes in geomorphology. This work also summarizes previous papers by Wolman and Leopold which are especially pertinent to the present study (Leopold and Wolman, 1957, 1960; Wolman and Leopold, 1957). Major features of river floodplains have frequently been described in the literature. There is general agreement on the designation of these features, although the origins of some of them remain in doubt. A floodplain would include river channel, oxbows, meander scrolls, sloughs, natural levees, backswamp deposits and sand splays. On larger rivers such as the Mississippi, the Sacramento, or the Mikong, the majority of these features are distinctly displayed in what might be called the classic model. On smaller streams, however, many of them may be hard to distinquish as the floodplain deposits are subject to rapid removal and alteration (Leopold *et al*., 1965)

Two related processes are probably responsible for the formation of most of the floodplains of the great rivers of the world. The first type is the point bar deposit; the second is the overbank deposit. The two types of deposits may respectively be described as deposits of lateral and vertical accretion. Despite the distinction between the two in the literature, it is often difficult to distinguish between them in the field. The modes of deposition are, nevertheless, different. Basically overbank deposits consist of material deposited from high water flowing or standing outside of the channel. Point bars originate within the confines of the channel. Despite the difficulty involved in distinguishing between them, for purposes of discussion the distinction continues to be a useful one. The relative amounts of channel deposits or point bars and overbank deposits vary, but on the average, the proportion of overbank material is small. This conclusion is supported by the uniform frequency of flooding and by the small amount of deposition observed in great floods. Lateral migration, relatively high velocities which can occur in overbank flows, and the decrease in sediment concentration at high flows contribute to this result. Frequency studies indicate that many floodplains are subject to flooding at approximately yearly intervals (Wolman and Leopold, 1957).

The floodplain can be transformed into a terrace by some tectonic, climatic or man-induced change which alters the regimen of the river, causing it to intrench itself below its established bed and associated floodplain. Lateral migration of a stream across its floodplain takes place with almost no change in channel width. The volume of material deposited tends to be about equal to the volume eroded and only when the stream erodes laterally into terraces or hillsides higher than the floodplain does the volume eroded exceed the volume deposited (Wolman and Leopold, 1957).

Vegetation of Floodplains

Shelford (1963) observes that the constant shifting of channels, islands and bars in the floodplains of rivers provides continuous new ground for the initiation of succession. The resulting seres often stop short of the climax of the region due to the regular flooding that occurs. This makes the river floodplains as important as sand areas for the study of community development patterns. The early stages of seral development are similar throughout most of North America north of 28° latitude (north). The important sand bar willow (Salix interior), black willow (Salix nigra), cottonwood (Populus deltoides) are widely distributed. On the basis of Shelford's work and that of others, zonation of vegetation is probably the most widespread observation concerning floodplain vegetation.

Lindsey et al. (1961) state:

> As Dansereau (1957 wrote, "Our first clue to the process of seral movement is in the relative spatial positions of belts or zones, for a contact always makes a transition, an invasion or a replacement possible." Zonation in the flood plain habitat is a clear and often striking phenomenon. Theoretically, all such zones can be placed along a physiographic gradient from the main stream channel to the most mesic site of the floodplain proper. One may thus envisage a gently sloping bank where each respective seral stage occurs in ascending order, with space representing time in the successional sequence. Both allogenic (physical) and autogenic (biotic) processes of succession are involved.

The work of several investigators indicates the importance of vegetational zonation, the relationships of organisms to environmental gradients and the many specific differences found in different geographical areas. Lindsey et al. (1961) found that the riparian vegetation of both the Tippecanoe and Wabash Rivers of Indiana occurred over eight clearly defined physiognomic zones. In another important study Wistendahl (1958) has investigated the floodplain of the Raritan River, New Jersey. He found that in general, recognizing the differences in vegetation along the length of the river, there are four physiographic communities on the Raritan River floodplain. The floodplain of the Mississippi River, especially in northwestern Tennessee, has been studied by several investigators (Putnam, 1932; Fisk, 1944; Shelford, 1954) and is reviewed by Shelford (1963). Eight successional stages have been found from an initial sand bar willow (*Salix interior*) to the mature oak-hickory forest composed of several species of both *Quercus* and *Carya*. Dietz (1952) has found that well developed stream-bend gravel bars present an example of spatial succession, similar to that observed in such places as the dunes region of lower Lake Michigan. Seven seral stages were found on the Mill Creek floodplain near Nashville, Tennessee, by Shaver and Dennison (1928). Goff (1952) has described six stages of succession along the Sangamon River in Illinois. In Oklahoma, Hefley (1937) discovered that even on streams with practically no floodplain there is a distinct series of seral stages in the form of narrow bands or zones and that the wider the floodplain and the older the river the more complex the initial and mid-seral stages in the sere become. Ware and Penfound (1949) studied the lower levels of the floodplain of the South Canadian River in central Oklahoma with special reference to the responses of important species to the floodplain environment. Weaver (1960) has made a long-term study of the origin and development of streams in prairie and of the woodland vegetation which often borders them. He has described the vegetation and soils of several flood-plain habitats, primarily near the Missouri River. Zonation is a product of the dynamics of both vegetational change and stream action. The size of the stream would certainly affect the floodplain communities. For example, a large mature river would probably have a broad floodplain with many taxa and relatively well-defined communities. A younger, smaller stream would not have altered the floodplain to such an extent and communities would not be as well defined.

It should be pointed out that floodplains would not inherently be expected to exhibit vegetational zonation. In fact, a recent study by Campbell and Dick-Peddie (1964) of phreatophyte communities has not shown a distinct zonation of vegetation. These investigators found that in general no distinct breaks or ecotones occurred in the composition of the narrow band of river vegetation; it formed a continuum with gradual and almost imperceptible changes between dominant and subdominant species as one moved (north or south). This lack of zonation would be more characteristic of ephemeral streams and streams with lower discharges than of the large rivers of the eastern United States.

In addition to studies of floodplain zonation and associated problems several other aspects of floodplain vegetation have been investigated. Several studies have been undertaken with a view to elucidating successional phenomena in floodplains. McVaugh (1947, 1957) has studied the establishment of vegetation on sand flats along the Hudson River, New York, and Bliss and Cantlon (1957 have studied succession on river alluvium in northern Alaska.

Other studies have directed attention primarily toward the forests which occur on floodplains. Lee (1945) conducted an ecological study of the floodplain forest along the White River system in Indiana. Hosner and Minckler (1963) have emphasized the regeneration and succession of bottomland hardwood forests of southern Illinois. Rice (1965) investigated the vegetation and edaphic factors associated with the bottomland forests of north-central Oklahoma.

The Floodplain Ecosystem

The floodplain ecosystem varies according to such factors as the nature of the stream, nature of the substrates, elevational differences, regional climatic differences and regional vegetational differences. The volume of flow of a stream is and has been important in determining the physiographic nature of the floodplain. Floodplain soils have not been intensively studied probably because of the constant erosion and deposition which occurs. However, investigators have found that the soil factor may be more uniform than other important floodplain habitat factors (Lindsey *et al.*, 1961). Alluvial soils are often high in important nutrients (Weaver, 1960) and it has been concluded by Wistenuahl (1958) that differences in soil profiles are explicable on the basis of stream velocity, distance from the channel and the consequent types of deposition. With time and deposition relatively small elevational differences within the floodplain may be closely associated with characteristic vegetation. The floodplain ecosystem is influenced primarily by the ground water supply and precipitation affects the vegetation largely as it contributes to ground water. However, the regional and local temperatures are of importance and plants are attuned to these temperatures. The vegetation of floodplains may be thought of as occupying a compensating habitat in the sense that it is dependent on ground water to a greater or lesser degree. In general floodplain vegetation occupies sites that are wetter than the climax vegetation of a given region. As with most ecosystems these points indicate that the floodplain is the product of a multiplicity of factors operating in a heterogeneous environment. In this ecological system the variables are changing in rate, duration and extreme values.

METHODS

Collection of Plant Specimens

Plant speciments were collected during ecological reconnaissance of the experimental areas, primarily during the summer of 1964. Some additions were made during the summers of 1965 and 1966. A total of 182 species of vascular plants representing 44 families were collected. The authority for plant names is Flora of Montana: Parts I and II (Booth, 1950; Booth and Wright, 1959). Voucher specimens of the plant species collected have been placed in the Montana State University Herbarium, Bozeman, Montana.

Vegetational Sampling

Two methods were used to sample the vegetation of the experimental areas: (1) permanent plots located in grazed and natural areas, and (2) belt transects across the entire floodplain. Within the sampling units of these two methods several characteristics of the vegetation were recorded.

Fifteen permanent plots were located in the natural area and 15 were located in the grazed area. These plots were placed in areas thought to represent the vegetation most prevalent in each area. In the natural area all 15 plots were located at 60 meter intervals along two parallel north-south compass lines. In the grazed area the plots were also placed along two parallel north-south compass lines, but the grazed area naturally divided into three different stands and five permanent plots were located in each of these stands in the manner described previously. The plot system consisted of 0.5 x 2.0 meter plots and 1.0 x 4.0 meter plots nested within a 5 x 20 meter plot. The 5 x 20 meter plot was oriented with the long axis perpendicular to the east of the north-south compass line. The southwest corner of each 5 x 20 meter plot was marked by a two-foot cement post placed deeply enough below the ground surface so that approximately four inches was exposed.

Within the 5 x 20 meter plots the trees were counted by size classes with the classes being:

0-1 decimeters in diameter at breast height
    less than 1 meter tall
    greater than 1 meter tall
1-2 decimeters in diameter at breast height
2-3 decimeters in diameter at breast height
3-4 decimeters in diameter at breast height
4-5 decimeters in diameter at breast height
5-6 decimeters in diameter at breast height

In addition, the heights of the trees in the plot were measured with a clinometer, the diameters at breast height were measured with a diameter tape and an increment core sample of each tree in the plot was taken at ground level. The end of the 1 x 4 meter plot was located at a point five meters east of the marker post. At this point, designated as the center, the plot was oriented parallel to the north-south compass line for a distance of four meters to the north. Within the 1 x 4 meter plot all shrubs were counted. The cover of the shrubs was determined along a 25 meter line which constituted the west and south sides of the 5 x 20 meter plot (Canfield, 1941). The center point of the 0.5 x 2.0 meter plot was located at the same point as the 1 x 4 meter plot, and the plot was oriented with the long axis parallel to the north-south compass line. Within the 0.5 x 2.0 meter plot the number of herbs was counted and an estimation of cover was made. The cover of litter, bare ground, rock, mosses, and lichens and water was also estimated. At each permanent plot marker an estimation of canopy cover was obtained using a Model A Spherical Densiometer designed by Paul E. Lemon (1956). Within the permanent plots of both areas an estimation of productivity was obtained. For shrubs a volume estimate was used as an indication of the volume of production. This amounted to multiplying together radius squared, pi and height (Cook, 1960). To estimate production of herbs all 0.5 x 2.0 plots in the natural area were clipped. In the grazed area the grazing animals were used to calculate an estimation of herb production.

Transects are noted for usefulness in indicating transitions in vegetation (Can and Castro, 1959; Phillips, 1959) and have been found to be very satisfying as a method for the study of floodplain vegetation in at least one instance (Weaver, Hanson, and Aikman, 1925). A total of seven transects were analyzed in this study. Two were located in the natural area, two in the grazed area and one in each of the other three study areas.

Those located in the natural and grazed areas extended from the first major terrace on the west of the floodplain to the high bench on the east of the floodplain. The other three transects only included the floodplain proper. Transects were spaced so as to be as far from each other and from the boundaries of the study areas as possible. In some cases the transects could not be ideally located because of buildings or agricultural fields. The transect was initiated at the west end and an east-west compass line was used as the direction. The transects may be thought of as a series of nested plots. Each 10 meter section became a plot. Trees were counted one meter on each side of the line. Shrubs were counted one-half meter on each side of the line. At five meter intervals along the line a 2 x 5 decimeter plot was analyzed (Daubenmire, 1959) for number and cover class of herbaceous species. The line intercept (Canfield, 1941) was used along the entire length of the line to determine shrub cover. Trees occurring in the 2 x 10 meter plots were also measured for diameter at breast height. Thus for the transects there resulted a series of nested plots which were 2 x 10 meters in size for trees, and 1 x 10 meters for shrubs with two 2 x 5 decimeter herb plots per nest (Wistendahl, 1958).

It should also be pointed out that 2 x 5 decimeter plots were analyzed in areas thought to be successional stages. The plots were placed along lines at five meter intervals and since the areas sampled were generally long and narrow, one, or at most two, lines of various lengths were analyzed.

Approximately 250 tree cores were extracted from *Populus trichocarpa* and *Populus tremuloides*. These increment core samples were examined and the growth rings counted. Age was related to height and diameter of the tree. The ages of trees were used to make inferences about the successional sequence.

Soil Sample Collection and Analyses

The objective in observing soil profiles and collecting soil samples was primarily to relate the vegetation development pattern to soil characteristics. Thus, two soil pits were dug in areas which represented each of the five major successional stages. Soil samples were taken from these pits at appropriate levels for laboratory analysis. Field determinations of horizon depth and thickness, texture, structure, consistency and boundaries, and dry and moist color were made where appropriate. Texture, structure, consistency and boundaries were recorded on data sheets designed after those of the Soil Survey Staff (1951). Colors were determined using the Munsell color notation (Soil Survey Staff, 1951).

Samples collected from each representative profile were analyzed by the Plant and Soil Science Department, Montana State

University. The samples were analyzed for organic matter (Jackson, 1958), available potassium (Anonymous, 1954), available phosphorus (Olsen, Cole, Watanabe and Dean, 1954), pH of saturation paste and conductivity of saturation extract (U.S. Salinity Laboratory Staff, 1954). In addition the 15-atmosphere moisture retention percentage test (U.S. Salinity Laboratory Staff, 1954) was performed and the samples were subjected to mechanical analysis (Bouyoucos, 1936).

RESULTS

Qualitative Description of the Vegetation

The undisturbed vegetation of the study areas, at the present time, is composed of four physiognomic strata (Figure 6). The tree stratum is essentially entirely Populus trichocarpa. These trees have a maximum height of about 40 meters in the study area. The average height of trees measured is about 20 meters. Populus tremuloides occurs along the west terrace of the floodplain and in some other areas. Isolated individuals of Pseudotsuga menziesii, Pinus contorta and Pinus ponderosa were observed in the floodplain but all appeared to be lacking in vigor. The tall shrub stratum is composed of the following important species: Cornus stolonifera, Salix sp., Prunus virginiana, Alnus incana and Betula occidentalis. Populus trichocarpa saplings are also very important. These shrubs occupy the space from two to six meters above the ground. The important low shrubs include Rosa acicularis, Symphoricarpos albus and Rubus idaeus. These shrubs are, in general, less than one meter tall. The field layer of plants is composed of the following important taxa: Calamogrostis canadensis, Agrostis alba, Poa pratensis, Rudbeckia laciniata, Carex sp., Smilicina stellata, Solidago occidentalis, Aster canescens and Equisetum arvense. Mosses and lichens occurred in nearly 5 percent of the plots and covered about 1 percent of the ground surface.

The areas which have been cleared and grazed would possess, in some degree, all of these strata (Figure 7). However, the two shrub strata become largely eliminated, and *Crataegus douglasii* becomes very important in the heavily grazed areas. The field layer becomes radically altered in species composition under heavy grazing. One species, *Poa pratensis*, becomes the dominant taxon and species not present in the natural areas become important. The important herbaceous plant taxa in grazed areas include *Taraxicum officinale*, *Trifolium dubium*, *Plantago major*, *Trifolium repens*, *Cirsium vulgare* and *Cerastium viscosum*.

A successional sequence has been determined from examination of the study areas, and the successional stages will be considered later.

Quantitative Description of the Vegetation

The quantitative analysis of the vegetation of Rock Creek is based upon data derived from the permanent plots located in the natural area and the grazed area, and also from transects across the floodplain in the study areas.

Table II is a comparison of average density, cover and frequency values of trees and shrubs based upon data recorded in permanent plots in natural and grazed areas. As stated previously, the only tree which occurs in the floodplain in

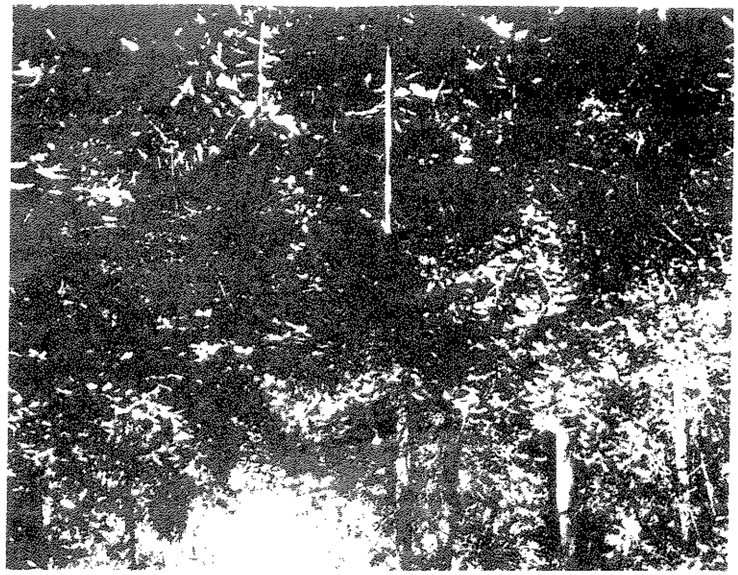

Figure 6. Photograph of vegetation in the natural area.

Figure 7. Photograph of vegetation in the grazed area.

Table II. Comparison of average density, cover and frequency values of trees and shrubs for permanent plots in the natural and grazed areas

	NATURAL		GRAZED	
	D1	F	DL	D
TREES				
Populus tremuloides	---	----	0.2	13.3
Populus trichocarpa		86.7		73.5
dbh: 0 - 1 dm.				
ht: 1 m.	1.0	40.0	2.3	60.0
ht: 1 m.	0.7	40.0	---	----
dbh: 1 - 2 dm.	0.3	13.3	0.7	40.0
dbh: 2 - 3 dm.	0.5	26.7	0.5	33.3
dbh: 3 - 4 dm.	0.5	33.3	0.4	26.7
dbh: 4 - 5 dm.	0.2	13.3	---	----
dbh: 5 - 6 dm.	0.2	20.0	---	----

	NATURAL			GRAZED		
	D2#	RC	F	D2	RC	F
TALL SHRUBS						
Alnus incana	0.7/1.6	30.4	26.7	0.2/0.2	30.0	6.7
Amelanchier alnifolia	0.7/0.3	0.1	26.7	0.1/---	----	13.3
Betula occidentalis	-------	3.0	----	-------	2.6	----
Cornus stolonifera	2.7/2.2	17.9	73.3	-------	----	----
Crategus douglasii	0.4/0.3	0.7	20.0	0.1/---	24.9	13.3
Prunus virginiana	1.5/0.3	6.9	40.0	0.1/---	0.5	13.3
Saxis amygdaloides	-------	1.3	----	---/0.5	21.6	13.3
Salix sp.	0.5/1.0	13.7	33.3	-------	9.8	----
LOW SHRUBS						
Juniperus communis	-------	0.3	----	0.1/---	1.6	6.7
Juniperus horizontalia	0.3/---	----	6.7	-------	1.6	----
Ribes sp.	0.2/---	0.7	13.3	-------	----	----
Rosa acicularis	7.9/0.3	8.6	80.0	1.8/---	3.6	40.0
Rubus idaeus	1.2/---	0.7	33.3	-------	----	----
Shepherdia canadenis	0.1/---	1.0	6.7	-------	----	----
Symphoricarpos albus	14.8/---	5.8	73.3	-------	0.7	----

SYMBOLS

D1 - number per 100 square meters
D2 - number per 4 square meters
F - frequency (percent)
RC - relative cover

- numerator indicates number less than 1 meter tall and denominator indicates number greater than 1 meter tall.

important numbers is Populus trichocarpa. The upper portion of Table II indicates that there are important differences in the distribution of size classes of trees between the two areas. All size classes are represented in the natural area while several are missing in the grazed area. Of most significance is the difference between the two areas with regard to saplings in the 0-1 dm. dbh class and greater than 1 meter tall. This size class is completely missing in the grazed area due to the fact that cattle browse the saplings heavily and do not allow them to grow.

The average basal area coverage of Populus trichocarpa in the natural area is 5733.18 square centimeters per 100 square meters, and that in the grazed area is 3690.29 square centimeters. The average canopy cover in the natural area is 71.53 percent and in the grazed area it is 66.20 percent. However, the difference between means is not significant by the t-test or by the sign test of nonparametric statistics. From data to be presented later it would appear that the absence of trees in the two largest size classes is not significant but merely reflects the placement of plots.

The tall shrub stratum is also of very different composition in the two areas. No tall shrub except Salix amygdaloides increases significantly in importance when the grazed area is compared to the natural area. Crataegus douglasii decreases in density and frequency but becomes much more important with regard to cover in the grazed area. The increase in the importance of Crataegus douglasii will be more evident when transects in various areas are compared. The most frequently occurring low shrubs are all either eliminated or much less important in the grazed area.

The species composition and quantitative measures recorded are also quite different in the two areas with regard to the field layer plants (Table III). There are only five species of plants common to both areas (Poa prateusis, Rudbeckia laciniata, Taraxicum officinale, Aster canescens, Phleum prateuse), indicating the differences in composition. It should also be noted that the grazed area is dominated by a single species, Poa pratensis, while the natural area has several species with comparitively high importance values. This indicates that the plant communities in the natural area are more diverse. The species which are common to the two areas have also changed their position of importance.

The permanent plots were also used as the areal basis for an estimation of the production of shrubs and herbs. A volume estimate of shrub production indicated that in the natural area shrubs occupied an average volume of 85.30 cubic meters above each square meter of ground surface. In the grazed area shrubs occupied 6.67 cubic meters above each square meter of

Table III. Comparison of density, cover, frequency and importance value for important herbaceous speices occurring in permanent plots in the natural and grazed areas.

NATURAL	Density 1/	Cover 2/	Frequency 3/	I.V. 4/
Calamorgrastis canadensis	4.12	3.52	60.0	58.70
Poa pratensis	1.40	1.92	40.0	28.49
Rudbeckia laciniata	3.52	0.27	33.3	24.99
Carex sp.	1.38	1.39	46.7	24.77
Smilicina stellata	0.78	0.35	80.0	17.13
Taraxacum officinale	0.85	0.53	53.3	15.62
Solidago occidentalis	0.60	0.38	46.7	12.22
Aster canescens	0.85	0.45	26.7	11.59
Cirsium arvense	0.63	0.21	46.7	10.96
Equisetum arvense	0.42	0.21	40.0	9.01
Geranium reichardsonii	0.45	0.31	20.0	7.48
Geum strictum	0.42	0.14	26.7	6.79
Gragaria vesca	0.43	0.30	13.3	6.45
Agropyron subsecundum	0.18	0.29	20.0	5.90
Phleum pratense	0.25	0.23	20.0	5.76
GRAZED				
Poa pratensis	17.82	17.31	100.0	130.85
Taraxacum officinale	3.28	1.34	86.7	25.92
Trifolium dubium	1.48	1.17	66.7	17.25
Pleum pratense	1.21	1.23	33.3	12.42
Aster canescens	0.96	0.62	46.7	11.10
Plantago major	0.96	0.51	40.0	9.86
Tribolium repens	0.57	0.47	46.7	9.36
Agrostis alba	0.55	0.85	26.7	8.17
Bromus inermis	0.70	0.89	20.0	7.92
Cirsium vulgare	0.38	0.13	26.7	5.01
Viola sp.	0.25	0.12	26.7	4.57
Cerastium viscosum	0.28	0.25	20.0	4.28
Linaria vulgaris	0.40	0.37	13.3	4.26
Antennaria dimorpha	0.86	0.14	6.7	4.00
Rudbeckia laciniata	0.33	0.06	20.0	3.75

1/ average number per 0.5 x 2.0 meter plot
2/ average percent cover estimated in 0.5 x 2.0 meter plot
3/ percent occurrence in 15 plots
4/ sum of relative density, relative cover and relative frequency

ground surface. On this basis the shrub production is approximately 13 times greater in the natural area than in the grazed area. This supports other evidence indicating that the shrub strata are the most important components of the vegetation to be eliminated with clearing and continued heavy grazing.

To estimate production in the field layer two techniques were employed. All of the 0.5 x 2 meter plots in the natural area were clipped near the end of the summer. The material was dried and weighed. It was found that the average production of dry matter in the field layer of the natural area was 31.1 grams per square meter. The estimation of production in the grazed area was made by using the requirements of the grazing animals as a basis. Records indicate that an average of 40 mature cows, 2 mature bulls and 35 calves are grazed on the area and thus the number of animal units is 63.5 (Brown, 1954). The animals are generally grazed in other fields for about four to six weeks immediately following the harvest of hay in the late summer. In addition, the animals are fed hay for about four months in the winter. There are thus approximately 444.5 (7 x 63.5) cow-months of use during the year. The area in which the cattle graze is about 120 acres. If the number of acres is divided by the number of cow-months it is found that 0.27 acres are required per cow-month (Brown, 1954). According to the <u>Handbook of Biological Data</u> (Spector, 1956), a mature cow consumes 9.4 kilograms of hay per day. Hay has been dried and it is probably similar to the amount of dry matter which a cow would ingest during grazing. By multiplying together the number of cow-days and the number of kilograms ingested per day it is found that 125,349 kilograms are consumed by cattle during the grazing season. If this figure is divided by area grazed in square meters (487,296) it is found that 257.2 grams per square meter of dry matter are produced. Although this estimate and the estimate based upon clipped plots are not obtained by the same process, it is thought that these estimates give the magnitude of the difference in production between the two areas. It should be pointed out that the estimate in the grazed area is probably low since the area upon which it is based includes much cobble and also the area of the stream surface. Conversely, all of the clipped plots were purposely located on areas thought to be most representative of natural floodplain vegetation. In the present case, estimates in the grazed area may be low because it is not known to what extent the cattle utilize the available forage.

More extensive data was collected from the transects across the floodplain. The data used in the analysis of the transects was restricted to the floodplain proper except in the profile diagrams where the entire transect is considered. These data have been analyzed and are presented in the following pages.

Tables IV is a matrix which makes all possible comparisons between the seven transects based upon frequencies of taxa. These comparisons are based upon what has been termed the Coefficient of Community (Jaccard, 1912; Gleason, 1920) or the Index of Similarity (Bray and Curtis, 1957; Curtis, 1959):

$$C = \frac{w}{a + b} \times 100$$

where a = the sum of frequency values from transect A

b = the sum of frequency values from transect B

w = the sum of the lower of the frequency values for all species common to both A and B.

This particular expression was proposed by Kulczynski (1927) and has been widely used in ecology. The resulting index may vary from zero for transects which have no measurement in common to 100.00 for two quantitatively identical transects.

Scrutiny of Table IV reveals that transects N1, N2, BS, BL, and HS are quite similar to each other. The lowest Indices of Similarity among these occur when BS is compared to the other transects. All other comparisons are above 60. The table also indicates that transects G1 and G2 are quite similar, although not as similar as the undisturbed transects are to each other. The previously discussed transect BS is more similar to the undisturbed transects than to the grazed transects and on this basis there are two groups of transects: (1) G1 and G2, and

Table IV. Matrix of similarities of flood plain transects based upon frequencies of taxa.

	G1	G2	N1	N2	BS	BL	HS
G1	100.00	53.19	33.92	28.82	36.08	41.52	29.35
G2		100.00	34.19	35.02	42.44	39.58	40.07
N1			100.00	63.44	64.48	61.25	65.81
N2				100.00	54.46	57.29	67.70
BS					100.00	62.56	67.40
BL						100.00	67.94
HS							100.00

SYMBOLS:

G1	Grazed Area
G2	Grazed Area
N1	Natural Area
N2	Natural Area
BS	Bull Springs
BL	Beaver Lodge
HS	Horsethief Station

(2) N1, N2, BS, BL, and HS. These comparisons lend quantitative credence to the floristic differences observed between disturbed and undisturbed areas of floodplain.

The availability of a detailed map (scale 1 inch = 60 feet) of the study area made it possible to construct four profile diagrams across the floodplain. These profile diagrams (Figs. 8, 9, 10, 11) correspond to transects N1, N2, G1, and G2. Elevational changes can be shown because of the two foot contours drawn on the map. The elevational changes shown are somewhat exaggerated due to the differences in scale chosen for the horizontal and vertical axes. The map was made by the Montana Highway Department and was constructed from aerial photos (scale 1 inch = 250 feet) and land survey data using a Kelsh plotter.

The floodplain of Rock Creek is bordered on the west by a major terrace about 10 feet above the water level and on the east by a high bench about 120 feet above the water level. This topography can be visualized from Figure 8 and the remaining profile diagrams. Figure 8 shows the distribution of important trees, shrubs and herbs across the floodplain. Populus trichocarpa appears to be largely restricted to the floodplain proper with an isolated occurrence on the steep hillside shown in Figure 9. On the steep hillside Pseudotsuga menziessii begins to replace Populus trichocarpa. At the top of the hill Pinus

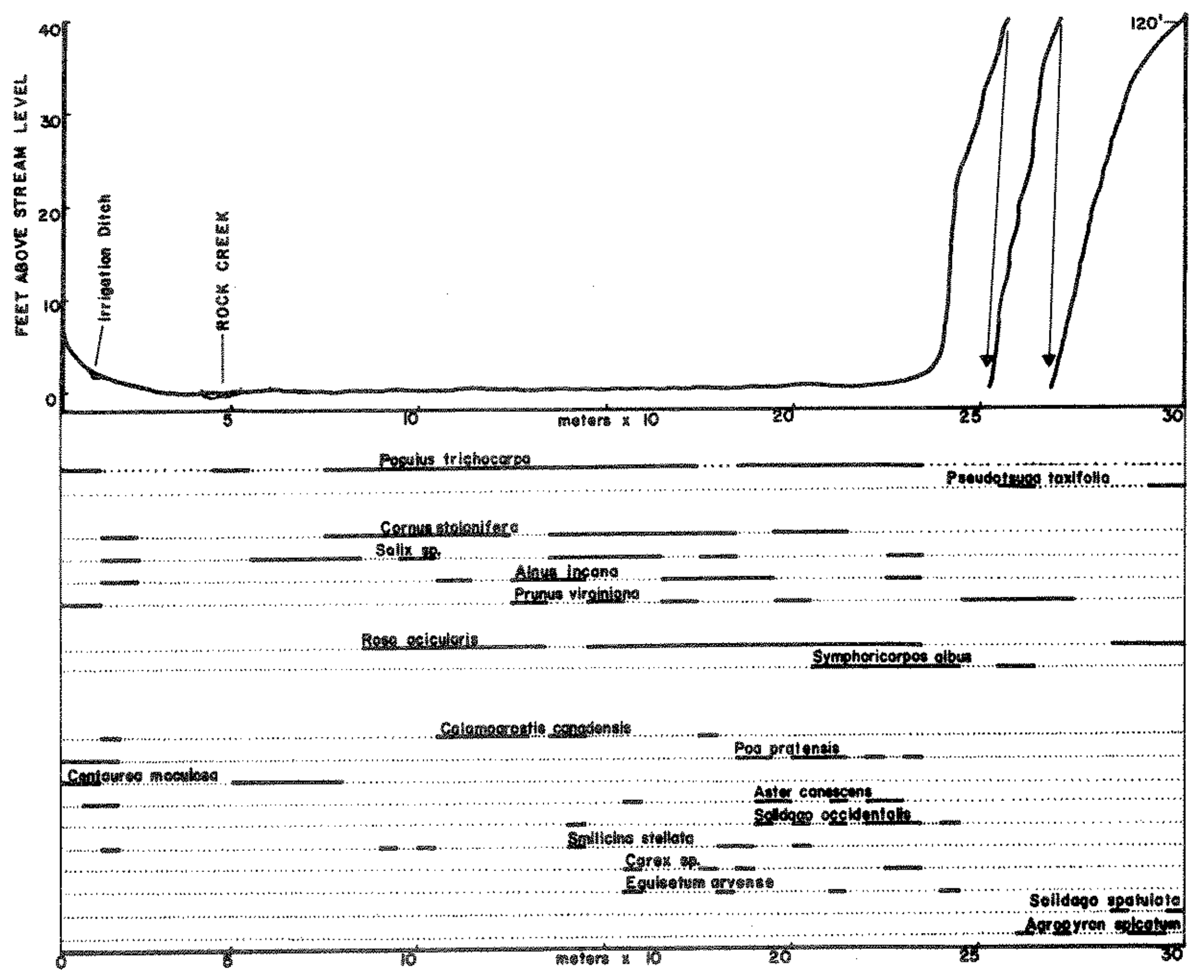

Figure 8. Profile diagram across the lower end of the natural area showing the occurrence of important trees, shrubs and herbs.

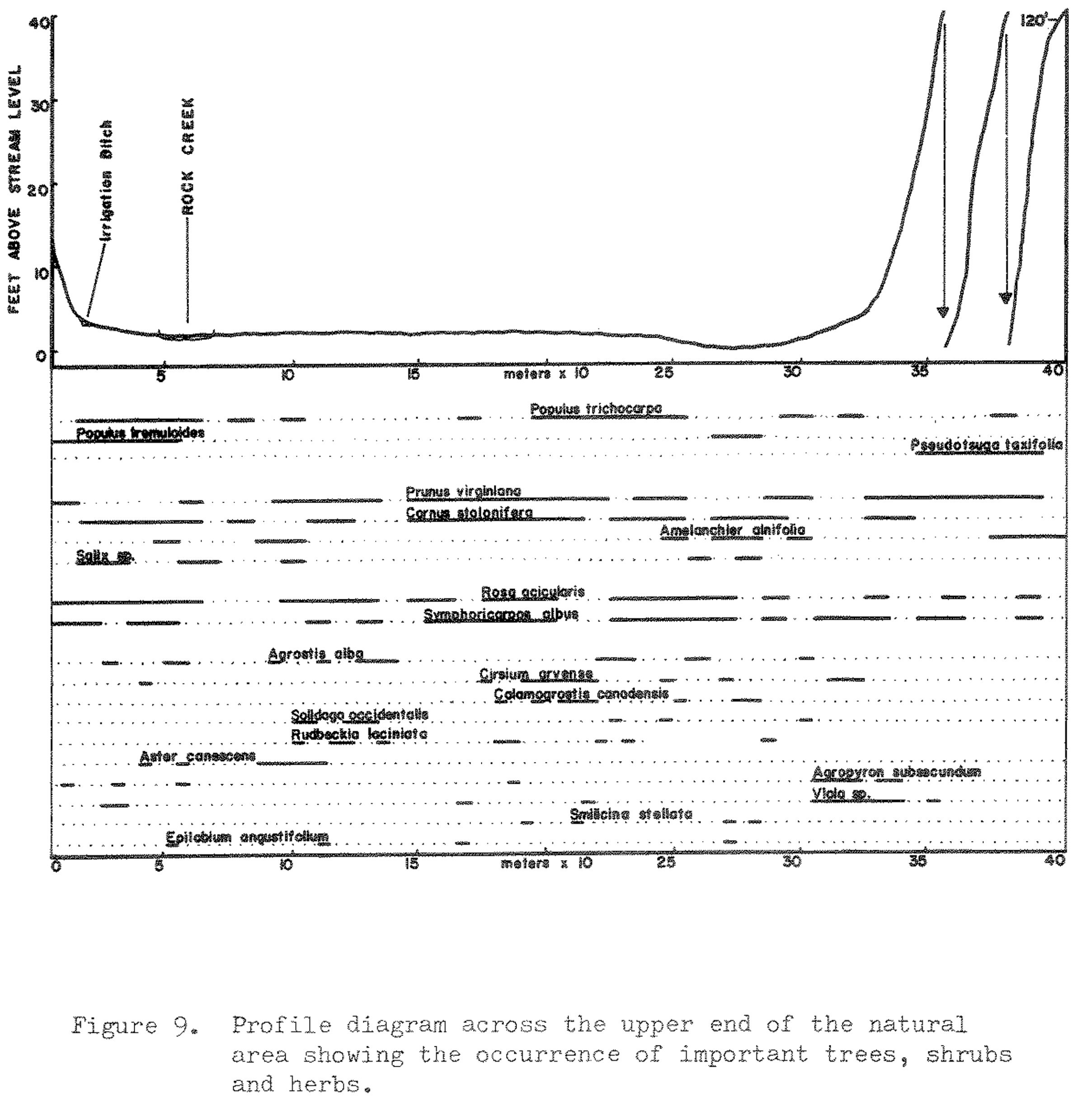

Figure 9. Profile diagram across the upper end of the natural area showing the occurrence of important trees, shrubs and herbs.

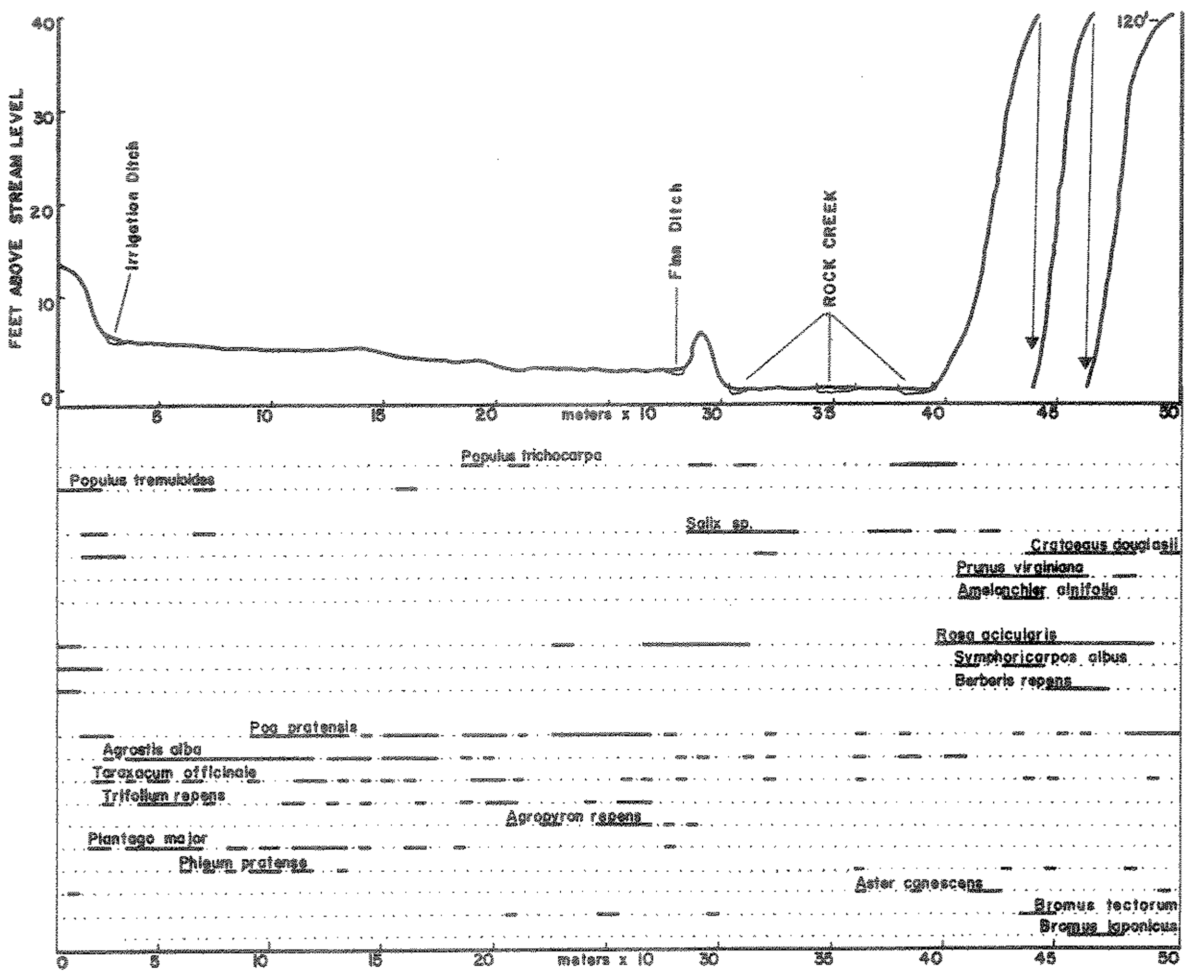

Figure 10. Profile diagram across the lower end of the grazed area showing the occurrence of important trees, shrubs and herbs.

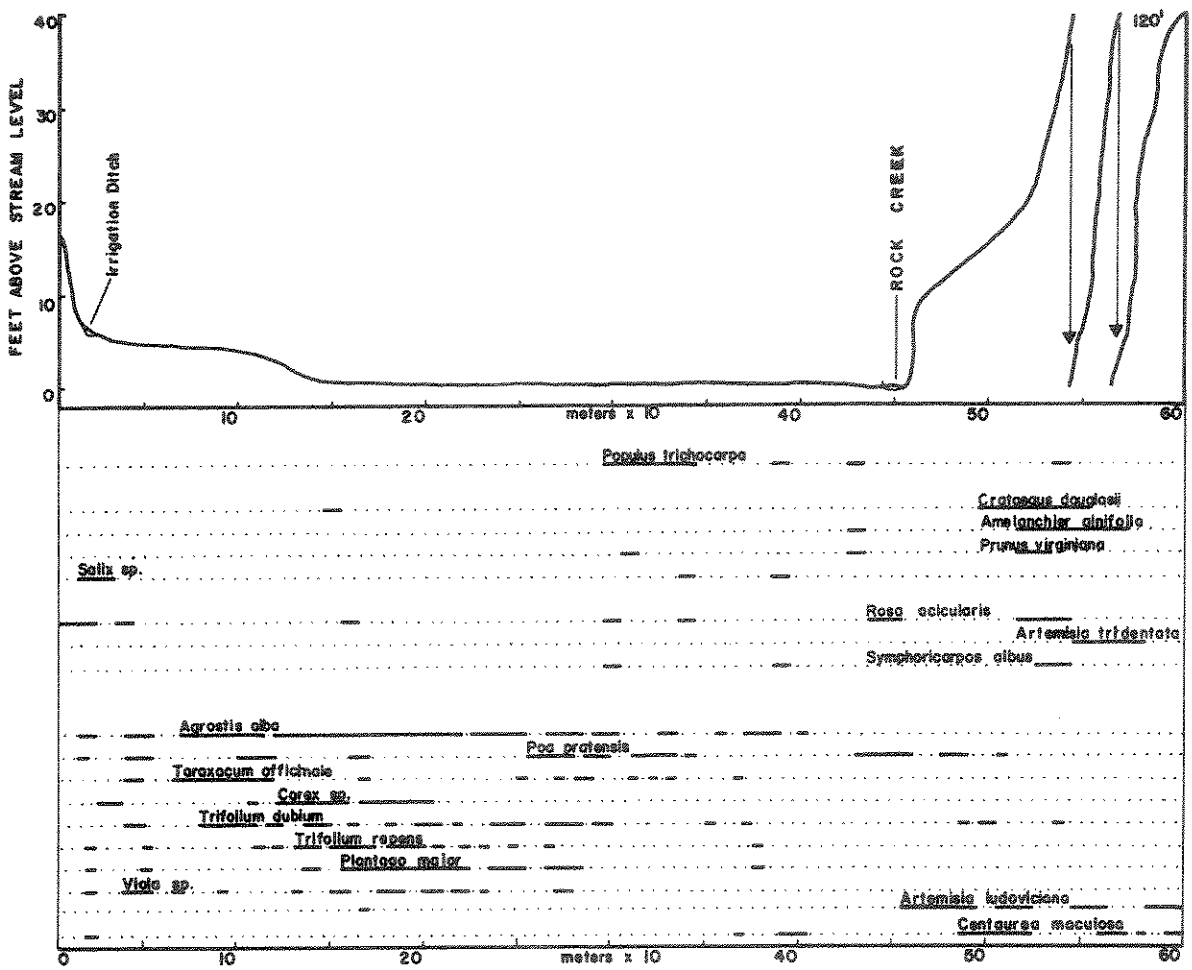

Figure 11. Profile diagram across the upper end of the grazed area showing the occurrence of important trees, shrubs and herbs.

flexilis occurs in small numbers. *Populus tremuloides* also also occurs (Figure 9) near the west terrace and at one low site on the floodplain.

In the tall shrub stratum *Cornus stolonifera*, *Salix* sp. and *Alnus incana* are restricted to the floodplain, while *Prunus virginiana* and *Amelanchier alnifolia* occur on the hillside. The low shrubs doe not appear to be dependent on ground water and grow far up on the hillside.

The herbaceous species shown in Figures 8 and 9 are the most important taxa occurring in each transect. Most of the important species occur in the floodplain proper. However, such species as *Agropyron spicatum* and *Solidago spatulata* become important on the relatively sparsely vegetated hillside.

If one compares the profile diagrams shown in Figure 10 and 11 with the previous two profile diagrams, several contrasts are evident. The tree stratum is composed of the same species, *Populus trichocarpa* but the west side of the floodplain has been cleared to provide pasture for cattle and few trees are present. Figure 10 shows small groves of *Populus tremuloides* occurring on the west terrace and between the terrace and the stream. The occurrence of conifers on the hillsides is noticeably absent in the grazed area. It is not known if this is a cause-and-effect relationship or whether some other phenomenon will explain it. There is evidence that a large landslide occurred in the vicinity of transect G2 (Figure 11).

While the pattern of tree distribution has been altered to a great extent, the change in the shrub strata is even more evident. A comparison of Figures 8 and 9 with 10 and 11 shows the almost complete elimination of the shrub strata. Species such as Crataegus douglasii and Rosa acicularis are not palatable to cattle and thus remain as components of their respective strata, although even these taxa are of low frequency. Cornus stolonifera, an important constituent of the vegetation in the natural area is completely eliminated in the grazed area. The profile diagrams in the grazed area also indicate that while trees are not important on the hillside, there are rather heavy thickets of shrubs. These are composed primarily of Crataegus douglasii, Amelanchier alnifolia, Prunus virginiana, and Rosa acieularis. In some areas near the top of the hill Artemisia tridentata and Berberis repens occur.

The herbaceous species of importance in the grazed transects are quite different than those in the natural transects. The species that occur in the grazed areas also appear to have more amplitude and are not restricted so exclusively to the floodplain. For example, important species such as Poa pratensis, Taraxacum officinale, Phleum pratense, Bromus tectorum and Centaurea maculosa occur not only on the floodplain, but also on the hillside.

Frequency and presence values of the size classes of *Populus trichocarpa* show important differences when the transects in different areas are compared (Table V). The observations made about the permanent plots are here confirmed, namely that saplings in the 0-1 dm dbh class and greater than one meter tall are noticeably missing in grazed areas. There is also a more complete representation of size classes in the natural areas. The average basal area coverage of Populus *trichocarpa* in the natural transects is 298.26 square centimeters and in the grazed transects it is 48.78 square centimeters per 20 square meters. When comparing these averages it should be kept in mind that considerable clearings of trees has taken place with the difference between the two averages indicating the approximate amount of clearing.

In Table VI the plant species occurring in the shrub strata are arranged in order of descending importance value as calculated from transects in natural areas. This order is changed for tall shrubs in grazed areas. *Populus trichocarpa* saplings continue to be the most important member, but essentially all of the individuals are less than one meter tall. This is also the case for species of *Salix*. The elimination of these two species leaves *Crataegus douglasii* as the only significant component of the tall shrub stratum, although some individuals of *Alnus incana* and *Betula occidentalis* also occur. The low shrub

Table V. Frequency and presence values of size classes of Populus trichocarpa occurring in floodplain transects.

Size Classes		G1	G2	N1	N2	BS	BL	HS	Presence
dbh:	0-1 dm.								
height:	1 m.	8.6	46.2	50.0	28.0	64.0	66.6	46.2	100.0
height:	1 m.	0.0	0.0	54.5	40.0	48.0	61.1	46.2	71.4
dbh:	1-2 dm.	0.0	7.7	4.5	12.0	24.0	0.0	23.1	71.4
dbh:	2-3 dm.	5.7	15.4	27.2	12.0	24.0	16.7	11.5	85.7
dbh:	3-4 dm.	2.8	0.0	13.6	8.0	16.0	0.0	3.8	71.4
dbh:	4-5 dm.	0.0	0.0	4.5	8.0	0.0	16.7	3.8	57.1
dbh:	5-6 dm.	0.0	0.0	0.0	4.0	0.0	0.0	0.0	14.3

SYMBOLS:

G1 Grazed Area
G2 Grazed Area
N1 Natural Area
N2 Natural Area
BS Bull Springs
BL Beaver Lodge
HS Horsethief Station

Table VI. Importance values of plant species occurring in the shrub layer of floodplain transects.

Tall Shrubs	G1	G2	N1	N2	BS	BL	HS
Populus trichocarpa	7.22	191.13	37.06	19.72	66.51	65.65	43.38
Cornus stolonifera	-----	1.92	63.95	63.28	24.76	26.23	36.42
Salix sp.	57.73	30.93	43.55	19.41	44.47	62.76	38.55
Prunus virginiana	36.00	9.06	9.54	29.20	12.08	31.14	36.89
Alnus incana	16.50	-----	50.03	32.39	16.57	11.78	3.68
Betula occidentalis	-----	9.06	13.00	3.07	35.93	5.79	18.50
Crataegus douglasii	61.58	-----	-----	13.02	3.24	8.39	4.92
Amelanchier alnifolia	16.09	7.14	3.35	10.32	1.63	-----	1.03
Low Shrubs							
Rosa acicularis	79.68	8.92	37.42	33.39	41.10	77.69	50.21
Symphoricarpos albus	11.19	9.06	10.71	37.39	32.92	3.12	44.79
Rubus idaeus	2.23	32.74	-----	22.07	7.57	5.54	17.10
Shepherdia canadensis	3.52	-----	19.19	-----	-----	-----	-----
Ribe sp.	-----	-----	-----	7.42	3.72	1.90	1.13
Juniperus communis	-----	-----	10.19	-----	3.86	-----	-----
Berberis repens	2.47	-----	-----	9.26	-----	-----	3.31
Juniperus horizontalis	-----	-----	2.01	-----	-----	-----	-----

stratum does not change in composition to a great extent except that Rubus idaeus becomes more important in grazed areas, probably because of its impalatability to cattle.

The phytosociological relationships among the herbaceous taxa occurring in natural area transects have been analyzed using the index of joint occurrence technique of Swindale and Curtis (1957). Seventeen taxa remained for consideration after disregarding those of low frequency in the transects. Those taxa occurring in less than 4 percent of the 232 total 2 x 5 decimeter plots were disregarded. An index of joint occurrence was then calculated. It was the number of plots in which two species occurred together expressed as a percentage of the number of quadrats of occurrence of the less common species.

Species of pairs with zero joint occurrence were placed at opposite ends of a list, and species of pairs with high joint occurrence were placed near each other (Guinochet, 1955; from Swindale and Curtis, 1957). Eventually an order was obtained which is considered to be a reflection of the reactions of these taxa to the complex of environmental factors. The taxa were then divided into four groups (Table VII), in order of their positions in the joint occurrence list. The number of the joint occurrence group to which each species belonged was used to weight the species' relative frequency in each transect. The products of relative frequency and joint-occurrence

Table VII. Joint-occurrence groups of herbaceous species occurring in ungrazed floodplain transects.

1

Poa pratensis
Aster canescens
Solidago occidentalis
Equisetum arvenso

2

Agropyron subsecundum
Agrostis alba
Taraxacum officinale
Viola sp.
Pyrola chlorantha

3

Smilicina stellata
Epilobium angustifolium
Carex sp.
Galium boreale

4

Rudbeckia laciniata
Cirsium arvense
Calemagrostis canadensis

number for each species were summed to provide a compositional index for each transect.

The compositional indices ranged from 128.25 for transect BS to 215.52 for transect HS. In Figure 12 the species in joint-occurrence groups one and four are included and the relative frequency of each species is plotted against the compositional index. The two groups are widely separated at the lowest compositional index, but at the higher compositional indices the species considered appear to be distributed with much less variance. Although Solidago occidentalis appears to respond somewhat ambiguously to the environment, the other species are more predictable. In general, those species placed in group four are of low relative frequency at low compositional indices and vice versa. The species in group one are at their highest relative frequencies at the low compositional index and tend to decrease at higher indices.

The extreme differences noted at low compositional indices are again noted when the sums of relative frequencies of all species in each of the four joint occurrence groups is plotted against the compositional index (Figure 13). It is also notable that all species seem to be responding similarly at high compositional indices. Figure 13 also shows that different joint occurrence groups tend to peak at different compositional indices. Group 1 shows a peak at the lowest compositional index

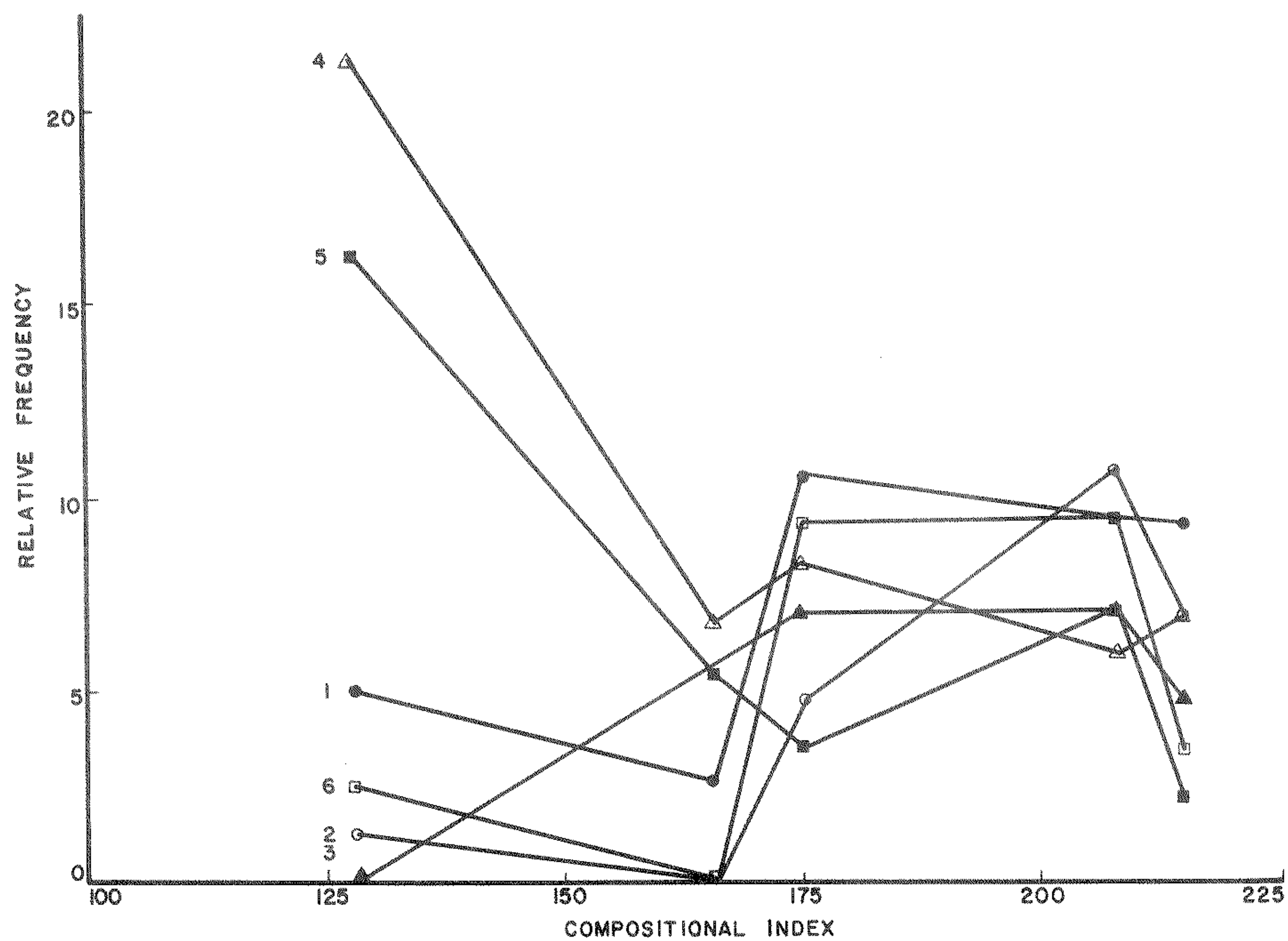

Figure 12. Relative frequency of taxa in joint-occurrence groups one and four plotted against compositional index: 1. Calamogrostis canadensis, 2. Cirsium arvense, 3. Rudbeckia laciniata, 4. Poa pratensis, 5. Equisetum arvense, 6. Solidago occidentalis.

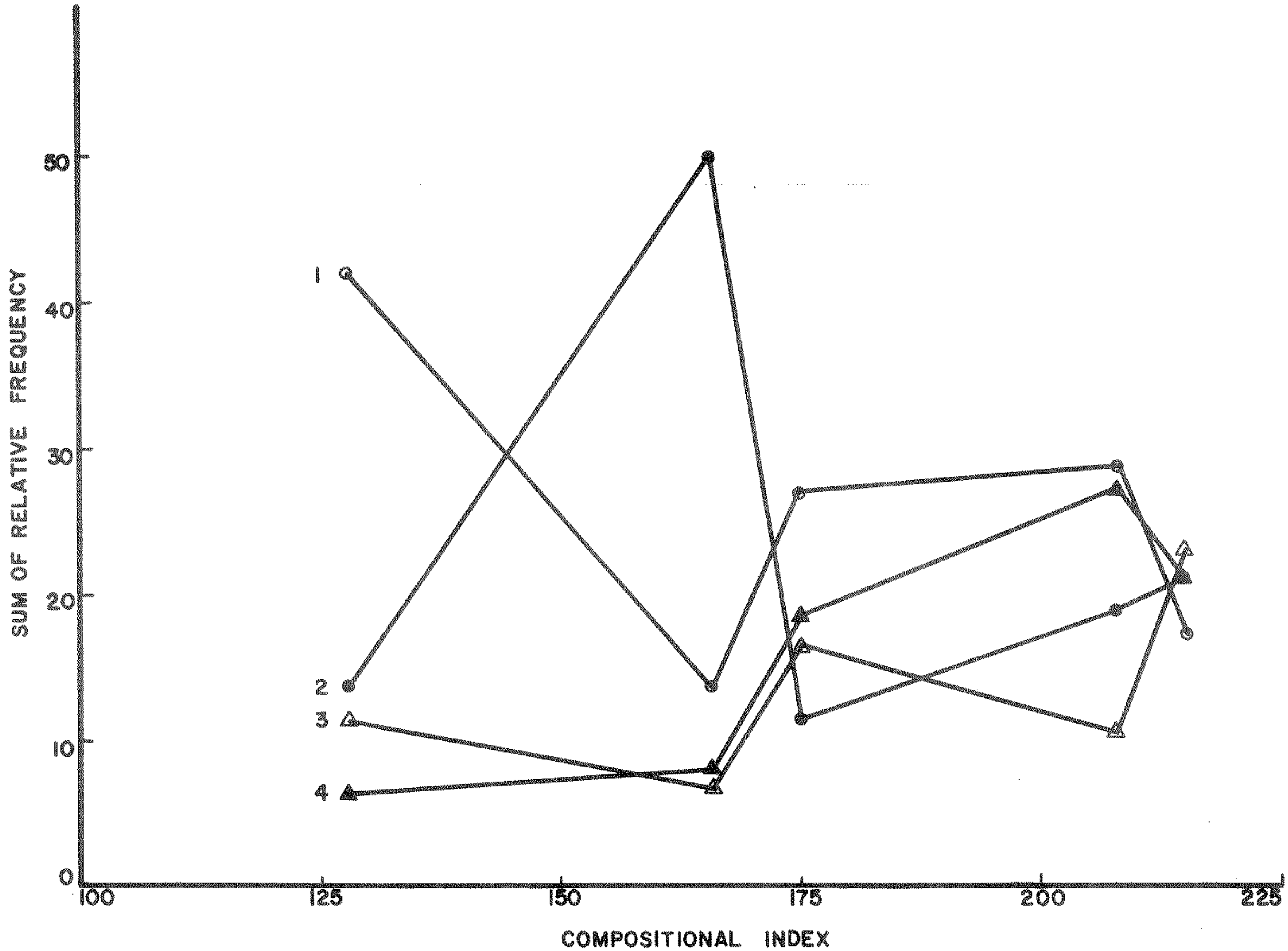

Figure 13. Sums of the relative frequencies of all the species in each of the four joint-occurrence groups plotted against the compositional index.

(128.25) and group 2 definitely peaks at the second compositional index (166.16). The species composing group 3 do not appear to significantly change in relative frequency as the compositional index changes. The species in group 4 show a definite trend in that the relative frequencies increase as the compositional index increases.

Successional Relationships

A successional sequence has been arrived at from observations in the field and analysis and inference from data collected (Figure 14). The mature floodplain forest has been described previously along with some of its variations in response to grazing and other disturbances. As shown in the successional diagram the initial stage of succession has been called the pioneer stage. Table VII shows the species found in 2 x 5 dm. plots spaced at five meter intervals and analyzed in several places where the pioneer stage existed. Some of these taxa occurred in areas sampled in connection with the permanent plots or transects. However, the following species appear to be largely restricted to the pioneer stage: *Agrostis scabra*, *Lychnis alba*, *Chenopodium album*, *Veronica americana*, *Verbascum thapsus*, *Silene cucubalus*, and *Barbarea orthoceras*. The information concerning substratum types is also valuable in discerning the severe nature of the habitats

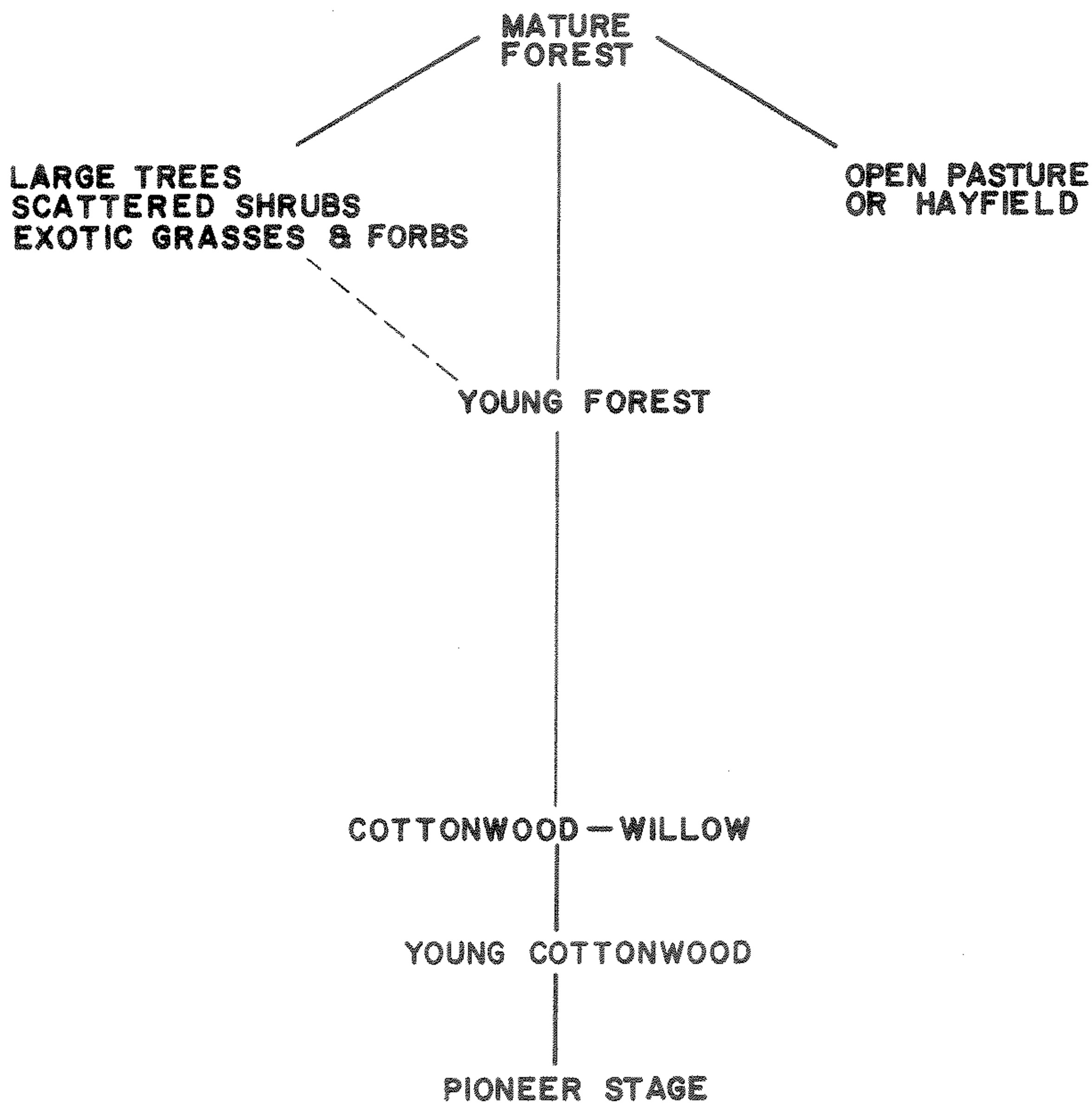

Figure 14. Diagram showing the successional sequence of the Rock Creek floodplain.

Table VIII. Density, cover, frequency and importance value of plant species occurring in the pioneer state along with frequency and cover of ground cover types.

Species	Density 1/	Cover 2/	Frequency 3/	I.V. 4/
Agrostis alba	0.79	1.58	29.0	74.65
Epilobium sp.	0.39	0.92	17.0	41.02
Agrostis scabra	0.27	0.72	14.0	31.37
Centaurea maculosa	0.34	0.90	7.0	30.83
Rumex crispus	0.08	0.50	5.0	14.05
Linaria vulgaris	0.16	0.30	2.0	11.71
Taraxacum officinale	0.07	0.18	7.0	10.75
Cerastium nutans	0.10	0.32	3.0	10.61
Lychnis alba	0.05	0.25	5.0	9.40
Chinopodium album	0.06	0.22	4.0	8.53
Artemisia michauxiana	0.04	0.08	3.0	5.02
Veronica americana	0.02	0.18	2.0	4.90
Polygonum bistortoides	0.02	0.18	2.0	4.90
Verbascum thapsus	0.03	0.08	3.0	4.65
Juncus sp.	0.03	0.08	3.0	4.65
Cirsium vulgare	0.03	0.08	3.0	4.65
Silene cucubalus	0.04	0.15	1.0	4.40
Agrostis variabilis	0.07	0.02	1.0	3.64
Stellaria media	0.02	0.05	2.0	3.05
Barbarea orthoceras	0.02	0.05	2.0	3.05
Trifolium repens	0.02	0.05	2.0	3.05
Trifolium dubium	0.02	0.05	2.0	3.05
Mentha arvensis	0.02	0.02	1.0	1.82
Mimulus lewisii	0.02	0.02	1.0	1.82
Aster canescens	0.01	0.02	1.0	1.32
Plantage major	0.01	0.02	1.0	1.31
Oenothera rydbergii	0.01	0.02	1.0	1.31
Litter		2.10	25.0	
Bare Ground		25.62	74.0	
Rock		62.50	90.0	
Mosses and Lichens		0.50	6.0	
Water		3.60	6.0	

1/ number per 0.1 square meter
2/ average percent cover in 2 x 5 dm. plots
3/ percent occurrence in 100 plots
4/ sum of relative density, relative cover and relative frequency

of early successional stages. Rock is the primary type of substratum and the only other substratum of importance is sand (bare ground).

Populus trichocarpa is the first woody species to invade bare of sparsely vegetated areas. The second stage of succession is called Young Cottonwood. The saplings growing at this stage are generally less than two meters tall and widely spaced. No other woody species invades at this point, possibly because conditions are generally dry. The important herbaceous species occurring at this stage are: Centaurea maculosa, Linaria vulgaris, Lychnis alba, Cirsium vulgare, Anaphalis margaritaceae, Verbascum thapsus, Solidago nana, and Artemisia michauxiana. The Cottonwood-Willow stage is somewhat more mesic than the Young Cottonwood stage although considerable intergrading of the two stages occurs. Along with the continued presence and development of Populus trichocarpa, one finds Salix interior becoming an important component of the Cottonwood-Willow stage. The herbaceous flora is richer in this stage probably due to the increased moisture. Many taxa characteristic of the field layer of both grazed and ungrazed areas are represented. Some species which occur in this stage more frequently than in other areas would include Salvia reflexa, Mimulus guttatus, Myosotis sylvatica, Fragaria vesca, and Mentha arvensis. Grass species are the major components of these sites, however, with Argrostis alba being very important.

The foregoing three stages are closely related to one another in regard to time and space, although development is very slow with the poor substrate. The Young Forest stage is generally not sequentially related to the aforementioned stages. It is thought to develop at higher levels above the stream. The sites are generally dry and appear to have been recent channels which were left dry by a change in the stream course. These areas are often bordered by dense forest and are not as severe environmentally as previous stages. The channels which once flowed over these areas apparently were not large channels, since some fine textured soil materials have remained. The upper five centimeters of the soil profile is augmented by litter from surrounding trees making a comparitively hospitable soil for the invasion of plant species. It should not be assumed, however, that any recognizable soil profile has developed, since cobble is at the surface and continues down for several feet, although some stratified materials may be present from stream depositions. The flora of the mature forest is almost completely represented. However, most trees are in the smaller size classes. The areas may be quite variable and some possess trees as large as three to four dm. dbh. The tall shrubs represented in this stage of succession are Prunus virginiana, Crataegus douglasii, and Amelanchier *alnifolia*, with the remaining species becoming important in lower and wetter sites. The low shrubs are *Rosa acicularis* and *Symphoricarpos albus* primarily, with latter generally of the greatest importance. The herbaceous vegetation is generally characteristic of drier sites within the mature forest. *Poa pratensis*, *Centaurea maculosa*, *Aster canescens*, *Solidago accidentalis*, *Glycyrrhiza lepidota*, *Lupinus lepidus*, *Antennaria rosea* and *Danthonia spicata* are some of the important species.

The successional diagram also shows that the mature forest can be altered so that either grazing or haying are practiced. Grazed areas have been discussed previously with regard to their physiognomy and composition. Table IX is a listing of species designated as decreasers, increasers, or invaders, on the basis of comparison between permanent plots and transects in grazed and ungrazed areas. The species shown on this list are thought to be representative of their designations since all conflicts which occurred between permanent plot and transect occurrences have been eliminated. Decreasers were designated on the basis that they did not occur in the grazed area or they decreased in importance value in the grazed area as compared with the natural areas. Invaders are species which did not occur in the natural areas, and increasers are those taxa which increased in importance value when subjected to grazing

Table IX. Decreasers, increasers and invaders (approximately in order of decreasing importance value) determined from permanent plot and transect data in natural and disturbed areas.

DECREASERS	INVADERS
Calamogrostis canadensis	Trifolium repens
Rudbeckia laciniata	Trifolium dubium
Carex sp.	Cerastium nutans
Solidago occidentalis	Artemisia michauxiana
Agropyron subsecundum	Capsella bursa-pastoris
Smilicina stellata	Agropyron repens
Galium boreale	Bromus tectorum
Equisetum arvense	Arctium lappa
Pyrola chlorantha	Juncus effusus
Epilobium angustifolium	Eleocharis sp.
Geranium viscosissimum	Bromus inermis
Geranium richardsonii	Cerastium viscosum
Glycyrrhiza lepidota	Antennaria dimorpha
Thalictrum sparsiflorum	Antennaria rosea
Geum strictum	Stellaria media
Viola sp.	Salvia reflexa
Monarda fistulosa	Astragalus sp.
Rorippa nasturtium-aquaticum	Campanula parryi
Heracleum lanatum	Chenopodium album
Agrimonia striata	Rumex crispus
Carex nebraskaensis	Rumex venosus
Stellaria longifolia	Tragopogon dubius
Smilicina racemosa	
Habenaria hyperborea	
Scutellaria galericulata	

INCREASERS
Poa pratensis
Taraxacum officinale
Centaurea maculosa
Agrostis alba

pressure. Although conflicts occurring between the natural and grazed areas have been resolved, there is some discord with regard to native and exotic plant species included in the lists. All of the taxa designated as increasers would be designated as invaders if the dichotomy between native and exotic species was the only consideration. These taxa represent the results of changing environmental conditions with respect to grazing pressure, soil compaction, and light conditions, among others.

In relation to successional considerations it is also instructive to consider the changes in substratum types with regard to changing vegetation (Table X).

Table X. Comparison of average frequency (%) and average cover (%) of various types of ground cover in three floodplain habitats.

	PIONEER		GRAZED		NATURAL	
Cover Type	Frequency	Cover	Frequency	Cover	Frequency	Cover
Litter	25.00	2.10	64.58	16.32	79.74	63.22
Bare Ground	74.00	25.62	68.75	31.71	31.46	7.61
Rock	90.00	62.50	23.95	12.47	17.24	6.88
Mosses and Lichens	6.00	0.50	8.33	1.92	4.74	0.89
Water	6.00	3.60	16.67	14.27	15.08	11.79

It has already been pointed out that rock is by far the most commonly recorded substratum type in pioneer areas. The amount of litter increases in both frequency and cover as the more advanced successional stages are encountered. Bare ground and rock are the most important types of substratum in early successional stages, but are decreased at the more mature stages. Mosses and lichens are not important in any successional stage and there appears to be no significant difference between natural and grazed areas. The amount of area covered by water is probably only comparable in the natural and grazed areas, due to similar sampling technique. The frequency of water cover is similar in the two areas, but the cover is less in natural areas than in grazed areas.

Populus trichocarpa is an important constituent of each successional stage except the initial one. It germinates well in moist floodplain situations and grows very rapidly for the first few years. Figure 15 is a photograph of a growth of *Populus trichocarpa* and *Populus tremuloides* which invaded the pictured corner three years previous to the time of the photograph. The site was previously part of a hay field and would be considered a favorable site from many standpoints. The two tree species have responded similarly to this opportunity and the tallest saplings are more than two meters tall after three years growth.

Table XI is a summary of the measurements taken from *Populus trichocarpa* trees during the course of the study. Diameters of

Figure 15. Photograph of *Populus* saplings invading a recently fenced area.

Table XI. Average diameter at breast height, average height, average age and diameter/age ratio for decimeter size-classes of Populus trichocarpa trees in the natural and grazed areas.

Size Class	dbh (inches)		height (feet)		age (years)		ratio (diameter/age)	
	N	G	N	G	N	G	N	G
1 - 2	6.21	5.90	47.07	35.05	29.35	37.17	.2114	.1588
2 - 3	10.16	10.31	60.00	46.80	48.64	51.60	.2089	.1997
3 - 4	14.24	13.21	77.75	67.12	63.00	48.12	.2260	.2745
4 - 5	18.08	18.42	101.00	79.62	67.33	57.50	.2685	.3203
5 - 6	22.62		118.25		84.25		.2724	

SYMBOLS:

N Natural Area

G Grazed Area

trees selected vary only slightly while other measurements show wide variation. For example, the height of trees in all size classes is greater in the natural area than in the grazed area. However, when the ages of the trees are compared it is found that in the two smallest size classes trees in the natural area are younger, while in the remaining size classes trees in the grazed area are younger. The diameter/age ratio evidences a comparable relationship. In the two smallest size classes the natural area trees grow faster than those in the grazed area, but the larger trees grow faster in the grazed area than they do in the natural area.

Although successional interrelations will be discussed more fully, it can be pointed out here that it would require approximately 50 years to establish trees in the 2 - 3 decimeter size class.

Soil-Vegetation Relationships

Floodplain soils have been studied in an attempt to relate vegetational changes to changes in the physical and chemical properties of the soil.

A general description of the soil profile was given in the Introduction. Figures 16 and 17 are photographs of soil profiles taken in the study area. Figure 16 shows a soil profile which often occurs under the Young Forest. The profile has

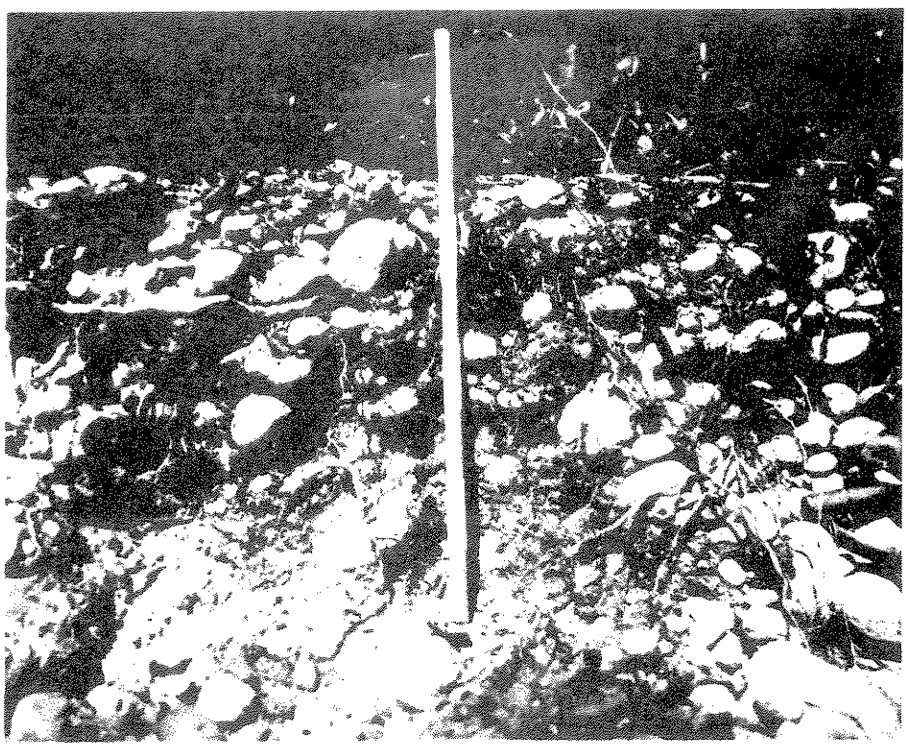

Figure 16. Immature forest soil profile.

Figure 17. Mature forest soil profile.

cobble distributed throughout and the majority of true soil is located in the top 5 cm. with the remainder being largely sand. The Mature Forest has a much better developed soil profile (Figure 17). The cobble in the profile pictured begins at a level about 50 cm. below the surface. There are clearly two horizons evident on the basis of color and other characteristics to be discussed. The soil profiles in the first three successional stages are very similar and there is very little differentiation at different depths below the ground surface.

As stated previously two soil pits were dug in each of the five major successional areas. Each of these profiles was sampled at levels where a detectable difference occurred. Upon collection of all samples (Table XII, Appendix), they were compared with regard to physical and chemical characteristics above and below 20 cm. below the ground surface. The results of these comparisons are in Figures 18 and 19. All plotted points are the average values of the two soil pits.

The major textural component of all floodplain soils in the study area is sand (Figure 18). There is very little change in the clay content of soils even at the most advanced successional stages. However, in the Young Forest and the Mature Forest there is a decrease in the sand content and an increase in the silt content, especially in the upper 20 cm. of soil. The similarity of the first three stages with regard to all

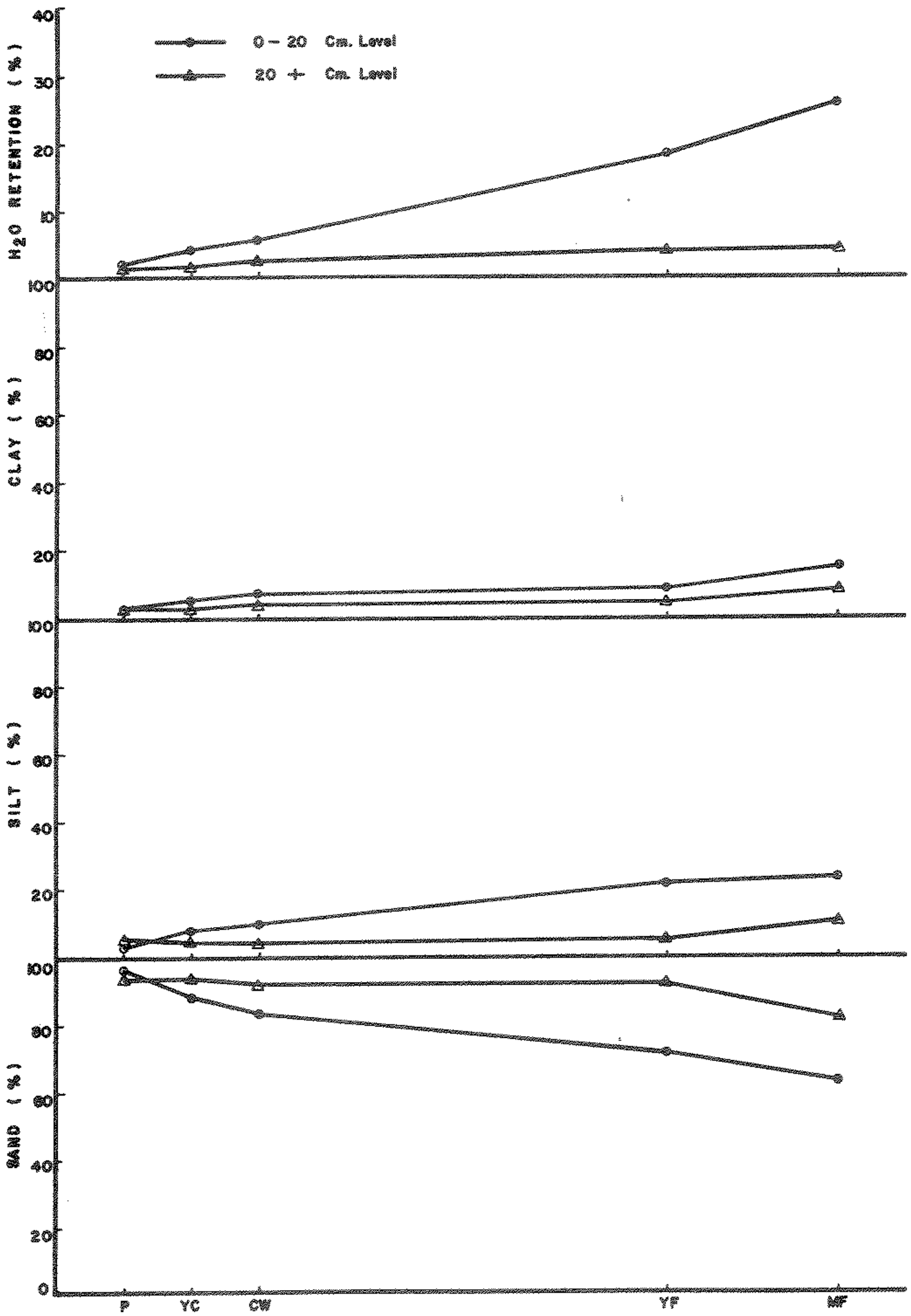

Figure 18. Changes in physical properties of the soil accompanying vegetational development.

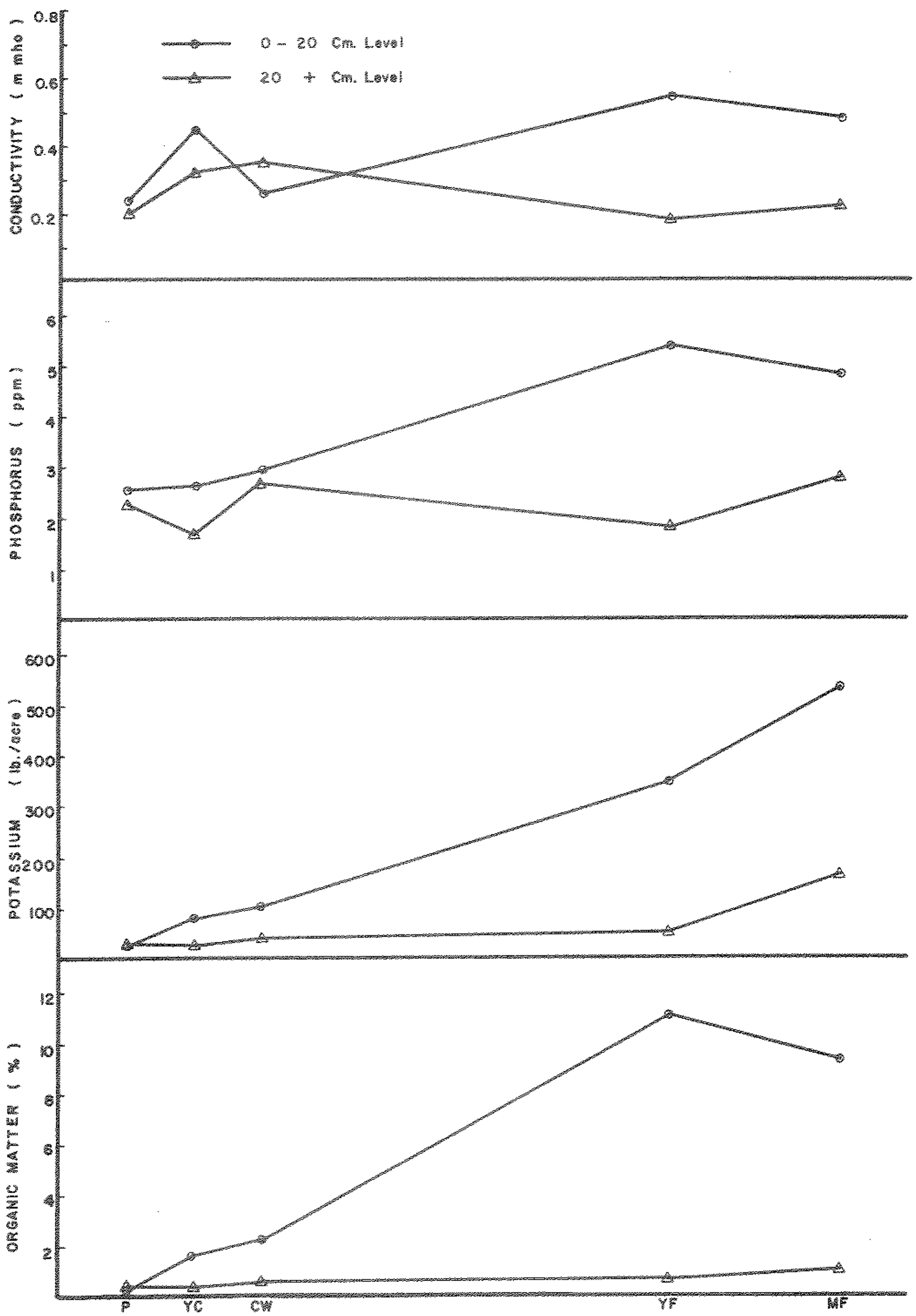

Figure 19. Changes in chemical properties of the soil accompanying vegetational development.

characteristics should also be noted. The first three stages of succession are essentially sand and cobble with little or no differentiation of horizons. The improvement of the soil in its ability to hold water is also very evident in the last two successional stages. The upper 20 cm. of soil in the last two stages shows remarkable improvement in water retention capability, but the soil below 20 cm. shows no significant change.

The chemical properties of the soils examined are even more explicit in enunciating soil differences at the two levels (Figure 19). For all measurements there is still a lack of variation in the initial three successional stages. However, at the Young Forest stage the values for all soil properties measured are divergent, and at the Mature Forest stage there is no question about the differences in the upper and lower levels of soil. The pH of all soils analyzed is near neutrality with most samples being in the range 6.4 to 7.0.

DISCUSSION

Vegetation Classification

A broad range of opinion continues to exist concerning the classification of vegetation units. In general, there are two extremes: (1) the Braun-Blanquet school (Braun-Blanquet, 1932, Daubenmire, 1952) which erects a series of units, or associations, which can be classified in an hierarchical system, and are distinct, recognizable and definable entities, and (2) the Curtis school (Cottam, 1949; Curtis and McIntosh, 1950, 1951; Whittaker, 1951) which regards vegetation as a multidimentional continuum, no two stands being the same (Kershaw, 1964). The Braun-Blanquet school and the Curtis school also differ in that the former uses a subjective choice of samples, while the latter chooses samples randomly (Kershaw, 1964). In spite of the tendency to polarity of ecological viewpoints with regard to classification of vegetation, investigators are cautioned to choose a sampling technique suitable to information required, time available, area to be studied, and possibly some other more specific factors (Cain and Castro, 1959; Hanson and Churchill, 1961; Kershaw, 1964). Hanson and Churchill (1961) list the following criteria which have been widely used in the classification of plant communities: (1) floristic or species composition, (2) ecological relations or habitat, (3) successional status, (4) physiognomy, (5) geographical characteristics.

Most vegetational studies have employed one or more of these in analyzing vegetation. The first criterion is probably of greatest importance since it segregates vegetation on the basis of the inherent nature of each unit (Hanson and Churchill, 1961).

The present study has involved many of the problems encountered in other studies in an attempt to develop an understandable picture of a vegetational complex. The successional stages have been delineated largely on the basis of reconnaissance of the study areas along the stream. The primary criteria used in determining these stages would be successional status, floristic or species composition and physiognomy. Geographical characteristics have not been considered important in delineating the stages, since a small area is considered. The use of the "ecological relation or habitat" criterion has also not been considered basic to the separation of successional stages, although it should be realized that there is considerable overlap among all of these criteria.

Regardless of the subjective classification system used initially, a comprehensive ecological study requires that detailed quantitative information be extracted from the vegetation. In this study, it was decided to use permanent plots and transects across the floodplain to obtain these data. The measures of the vegetation, such as density, cover and frequency, give quantitative support to the visual observations of the investigator. The tree stratum was generally analyzed by separation of the existing trees into decimeter size-classes. This use of size classes makes possible the relation of various sampling areas to each other in regard to succession and size composition. Since only one tree species was important in the floodplain, no comparisons with other tree species were possible in regard to importance. Several species of shrubs were present, however, and these occurred in different sampling areas. The importance value of the Curtis school (Phillips, 1959) was used to rate these species in the transects, which represented various stages of development and/or disturbance. The herbaceous vegetation data was subjected to the most phytosociological analysis. This involved use of the method of Curtis and Swindale (1957). The presence of certain species in a given joint-occurrence group is thought to reflect the response of these species to the environmental complex.

Succession

Succession may occur in areas where the habitat conditions have been altered by the plants themselves (autogenic) or in areas where the habitat conditions have been altered by external environmental factors (allogenic) (Hanson and Churchill, 1961). However, as pointed out by Odum (1959), succession is largely a characteristic of the community itself and is directed by climate. Habitats for the initiation of primary succession in the floodplain are largely caused by flooding and are generally near the stream course. Thus these habitats are initally allogenic, but are autogenic in the succeeding states. Primary succession has also been initiated on the Rock Creek floodplain by practices intended to straighten or otherwise alter the stream course. Secondary succession is usually initiated by the activities of man along the creek, namely burning, clearing, and grazing.

If succession is considered as a progressive development from a simple to a more complex community it usually involves changes in one or more of the following: diversity, stability, productivity, self-maintenance, uniformity within and between stands, and soil maturity (Hanson and Churchill, 1961). Those changes characteristic of succession on the Rock Creek Floodplain will be incorporated in this discussion.

Analysis of increment core data (Table XI) indicate that at least 30 years would be required so that trees in the 1-2 dm. size class could be established. This estimate is based entirely on ages of trees in this size class and does not consider the amount of time required for initial establishment of tree seedlings. However, it is known (Smith, 1957) that the seed of *Populus trichocarpa* is highly viable, but under natural conditions its germinative capacity is retained for only a brief period. Other evidence (Garman, 1953) indicates that if the seed falls on a moist seedbed high germination results. *Populus trichocarpa* seeds germinate best on wet river bottoms, but moist, bare, humus or sandy soils of streambanks and bottom lands are also good (Fowells, 1965). With this evidence of the high germination and initial rapid growth rate it would be valid to say that the Pioneer Stage, composed of herbaceous species, is short lived in the floodplain habitat. If the Pioneer Stage exists for a maximum of five years, there are then approximately 25 years remaining for the development of a Young Forest. The two stages following the Pioneer Stage are closely related, both to each other and to the Pioneer Stage. This was shown earlier in their similar soil properties (Figures 18 and 19). These early successional stages all develop near the stream and are subject to essentially annual flooding. The flooding is generally not severe enough to wash away the plants, but may retard growth of trees, since Populus trichocarpa is known to grow poorly when there is lack of substrate aeration (Smith, Haddock and Hancock, 1956; Smith 1957). It should be pointed out that it is not the rapidly flowing water which limits growth, but rather, the stagnant pools and fine sediment deposited during flooding. Thus, it is possible to explain the relatively long period between the Pioneer Stage and the Young Forest on the basis of frequently recurring floods and the effects of these floods. That is, floods may destroy early successional communities wholly or in part, or they may bring about the deposition of fine sediments or standing water which limit growth.

It has been pointed out previously that *Salix interior* is one of the earliest invaders of the Rock Creek floodplain. This fact has been noted in many other parts of North America also (Shelford, 1963). Results of soil analyses have shown that the Cottonwood-Willow Stage is similar in soil properties to the Young Cottonwood Stage. The difference between the two communities is primarily the water relationships. While *Populus trichocarpa* is able to exist on moist sites, *Salix* requires essentially wet conditions to germinate and grow and is adversely affected very quickly by lack of moisture (Fowells, 1965). Willows also have a very shallow root system and are dependent upon a constant supply of moisture throughout the growing season.

A sequential relationship between the initial three stages and the Young Forest stage is quite doubtful. The Young Forest stage appears to be secondary succession which occurs on areas which have been recent channels. It may also occur in areas which have been heavily grazed in recent times and then allowed to recover. For the initial three stages to develop into a forest would be possible, but would require that these areas be relatively free from severe flooding for 30 to 50 years. This could occur when there was a major channel change.

The Young Forest and the Mature Forest may also not be sequentially related. It should always be kept in mind, with regard to floodplain succession, that there are constantly changing conditions of stream flow and related deposition. An advanced successional stage may develop on an area because of the deposition of large amounts of fine textured soil and not because of a long developmental history of soil and vegetation. With these points in mind, it is instructive to consider the differences between the transects in different areas on the basis of their similarities to each other and their relative compositional indices. These differences indicate what changes might be expected to occur between the Young Forest and Mature Forest stages, especially when they are related to the histories of the areas. It has been pointed out previously that there are two groups of transects on the basis of similarity to each other. If only those transects which have not been recently disturbed are compared, it is found that they rank as follows on the basis of compositional index: BS-128.25; BL-166.16; N1-175.08; N2-208.25; HS-215.52. These rankings follow closely the known history of the areas and observations made in the field. Transect BS was the site of intensive efforts to alter the stream to prevent meandering. Because of this practice considerable areas of cobble were exposed. The area also appears to have been grazed prior to the time of purchase and fencing by the Montana Fish and Game Department. The author was not able to verify this, since the former land owners have moved away. The foregoing facts are thought to be respcnsible for the lower relationship between transect BS and other transects which are not presently disturbed. Transect BL was only slightly disturbed prior to the time of purchase and fencing by the Montana Fish and Game Department. According to the former landowner it was grazed only peridocially by 20 dairy cattle and there were no fires or wood cutting on the land. Transects N1 and N2 appear to have been the least disturbed of any areas studied. Two horses grazed the area on occasion, one small fire is known to have occurred, and there has been little known wood cutting on the area. In contrast to the other transects, transect HS has been subject to considerable disturbance, especially prior to about 1945. It is known that a fire burned the entire area in 1919 and in succeeding years considerable numbers of cattle and sheep grazed the area. However, the area has not been disturbed since about 1945 and presently supports a good stand of trees and shrubs.

The evidence would indicate that the kind of vegetation found on a certain area is not only a function of the lack of disturbance, but also of the physiography of the floodplain and the kind and amount of deposition which occurs. If the transects are again compared in order of their compositional indices it is found that, in general, the transects having lower compositional indices also have more trees in the 0-1 dm.

size class. This is especially true for those trees less than one meter tall. The status of _Populus trichocarpa_ as a continuing dominant on the Rock Creek floodplain must be questioned. It is the most shade-intolerant species of any of its known associates and is classified as being very intolerant (Baker, 1949). _Populus trichocarpa_ appears to be able to maintain itself in the Rock Creek floodplain for several reasons. An important reason for the continued dominance of _Populus trichocarpa_ is that the recurrence of floods provides bare, moist, seedbeds for the germination of seeds. Once germination occurs its rapid juvenile growth rate exceeds that of more of its associates and helps it maintain a favorable position in stands (Fowells, 1965). Although black cottonwood evidently occurs with _Pseudotsuga taxifolia_ (Fowells, 1965) in certain localities, there is no evidence that Douglas Fir is invading the floodplain. There is also no evidence that _Pinus flexilis_, which also occurs on the hillside near Rock Creek, is invading the floodplain. Since _Populus trichocarpa_ grows well up to an age of 200 years (Fowells, 1965), it would seem that older trees provide a constant seed source. The recurrence of floods provides new seedbeds and the young trees are able to grow faster than their competitors. Thus, there seems to be a cycle of events associated with the life cycle of _Populus trichocarpa_ which are enabling it to maintain dominance in the floodplain habitat.

With regard to shrub associates of *Populus trichocarpa* it is also instructive to note the importance values of various shrubs in the transects. Fowells (1965) indicates that *Rubus spectabilis* is an indicator of good site quality for black cottonwood. Although this species did not occur in the study areas, *Rubus idaeus* attained its highest importance values in the two transects having the highest compositional indices. However, *Rubus parviflorus* is an indicator of medium site quality and so the use of *Rubus* as an indicator of site quality is still questionable for this study. *Cornus stolonifera* is an indicator of medium site quality (Fowells, 1965) and it has its lowest importance value in transect BS and its highest importance values in transects N1, N2, and HS.

Due to the changing nature of the floodplain ecosystem, one would expect to find few predictably changing environmental gradients. Rather, plants would be distributed in response to a complex of environmental factors in a mosaic pattern. As with Swindale and Curtis (1957) it appeared advisable to utilize the plants themselves in an investigation of their sociology because they respond to the product of environmental factors. Thus, the herbaceous taxa were arranged according to a compositional index which was based upon the association tendencies of constituent species within each strand or transect.

The plant species grouped together respond similarly to the environment as shown by their peaks at different compositional indices (Figure 13) and by their change in relative frequency with change in compositional index. It is also interesting to note that while the taxa represented show wide divergence at low indices they are clustered in a rather narrow range at high indices. One explanation of this could be that stability and diversity of ecological communities tends to increase as advanced successional stages more successfully utilize free energy. However, this may only indicate the broad variation which exists in any transect across the floodplain and also the fact that there is more variation in early successional stages.

Plant Distribution

The most critical factors affecting the distribution of floodplain taxa are light, water, and soil. However, it is evident from this study that such factors as temperature, fire and grazing animals have also affected the distribution of plants within the area studied. Fire and grazing animals are largely environmental factors which have been introduced by man. The effects of grazing have been dealt with throughout this paper, and fires do not appear to have greatly affected the areas studied.

As the mature forest is approached, one would expect a decreasing amount of light and the increasing importance of shade tolerant species. It has already been pointed out that Populus trichocarpa is very intolerant of shade, but continues to dominate the vegetation because of other compensating factors. Shrubs apparently are affected by such environmental factors as available moisture, soil type and amount of grazing, in addition to light. It is difficult to assess the influence of light on herbaceous taxa without specific environmental measurements in relation to given species. The effect of light on plants is greatly altered by other environmental factors such as temperature (Daubenmire, 1959). However, one would expect to find shade tolerant plants in the most advanced stages, such as the mature forest. Essentially all of the herbaceous species in the heavily grazed areas and in the early successional stages would be either facultative sciophytes or obligate heliophytes.

The distribution of water in the floodplain habitat also is an important factor in the distribution of plants. Figures 8, 9, 10 and 11 give an indication of which important species are restricted exclusively to the floodplain. The sites these species occupy would not be more than two feet above the stream level and therefore probably subject to periodic flooding. The roots of many of these species would also be in contact with ground water during much of the growing season. Many of the species most characteristic of the Mature Forest would occupy sites which possessed moist soils. On the other hand, species such as Equisetum arvense are indicators of poor site quality (Fowells, 1965), primarily because this indicates that such sites are flooded from four to six weeks during an ordinary year. It should be noted that some species which occur in the grazed areas have wide ecological amplitude and grow in areas considerably above the stream level, while many of the species characteristic of advanced successional stages are confined exclusively to the floodplain.

Soil and Vegetation

Soil samples from floodplain areas are best compared by levels rather than horizons, since the presence of fine textured materials tends to result from deposition by water rather than the normal soil forming processes. Soils in the Rock Creek floodplain were compared at the 0-20 cm. level and at the greater-than-20 cm. level, with regard to both physical and chemical properties.

Soil texture - the relative percentages of sand, silt, and clay in a given soil - affects plants in regard to: relative resistance to root penetration, infiltration of water, rate of water movement, water holding capacity, soil structure, soil aeration and soil temperature (Daubenmire, 1959). All of the soils examined along Rock Creek are composed primarily of sand.

The best soils, occurring in the Mature Forest, would be classified texturally as sandy loams (Soil Survey Staff, 1951). Most of the soils, especially those in early successional stages, would be classified as sands being more than 85 percent sand. Soils having a high sand content offer little resistance to root penetration, allow immediate infiltration of water, allow rapid movement of water in the soil, and have good soil aeration. However, these coarse textured soils would have few nutrient ions and have little or no structure since these two attributes depend largely upon the absorptive capabilities of soil colloids. Although the soils sampled in early successional stages are almost entirely sand, some of the foregoing statements would have to be modified for soils of the advanced successional stages.

One additional measurement was made on the soil samples: 15 atmosphere moisture retention percentage. The water holding capacity of the soil is closely related to the amount of fine textured material and to the corresponding surface area available for adsorption of colloidal materials. On this basis the moisture retention test is an index of the physical properties of the soil in relation to plant growth. Figure 18 indicates that the moisture retention percentage of soils in the advanced successional stages is greatly improved, and shows the improvement better than the comparison of sand, silt, and clay percentages at the stages. The improvement in physical properties of the soil with regard to plant growth is also important to soil fertility considerations, since many of the nutrient ions utilized by plants are held adsorbed by soil colloids (Daubenmire, 1959).

The 15-atmosphere percentage is also used as an index of the permanent wilting percentage, and therefore, as the acceptable index of the lower limit of the available range of soil moisture. This lower limit appears to be an intrinsic property of the soil that is largely determined by soil texture (U.S. Salinity Laboratory Staff, 1954). It is difficult to set the upper limit for the range of water content available to plants in the field. It has been found by the United States Bureau of Reclamation (1948) that for the Sandy soils occurring on the Yuma Mesa, Arizona, the water retained in a sample of soil at the 1/10-atmosphere percentage satisfactorily approximates the upper limit of available water under field conditions. Assuming that the 15-atmosphere percentage does accurately estimate the permanent wilting percentage, it is notable that Rock Creek floodplain species occurring in early successional stages require a constant supply of water in view of the almost non-existent capacity to hold water. In contrast, the plant taxa occurring at more advanced stages are more independent of the constant water supply.

In addition to the physical soil properties, several chemical soil properties were measured in the five successional stages. The soil pH varied between 6.4 and 7.0 (Table XII, Appendix) for nearly all soil samples tested. The pH range is probably optimum for many native plants and is thought to be the optimum pH for Populus trichocarpa (Fowells, 1965). Changes in the chemical soil properties measured only occurred significantly in the upper 20 cm. of soil.

Figure 19 shows that there is a significant increase in the amount of organic matter in the soils of the advanced successional stages. In most places in the Mature Forest, litter of leaves and twigs covered the forest floor to a depth of three inches. A large amount of litter would be contributed annually since all of the important trees and shrubs are diciduous. However, for this litter to be mineralized and incorporated into the soil would require that the site be free from flooding. The organic matter is apparently being incorporated well into the soils of the two most advanced stages of succession since they have percentages of organic matter in the range of 10-12 percent. This high percentage of organic matter makes a productive substrate in relation to mineral nutrients, food of micro-organisms, water holding capacity and soil structure (Daubenmire, 1959). It should also be pointed out that organic matter is related to the nitrogen content of the soil, with the nitrogen generally being about 1/20 that of the organic matter (Buckman and Brady, 1960). According to both lysimeter studies (Bizzel and Lyon, 1927; Lyon and Bizzel, 1936) and studies of the chemical characteristics of natural waters (Hem, 1959) nitrogen in the form of nitrate is readily removed from the soil. This factor is important in the floodplain habitat. If litter and humus were continually removed by floods the associated organic matter and nitrogen could not be replenished nearly as quickly as they were removed.

Potassium, an important plant nutrient, was also measured in the Rock Creek floodplain soils and shows a decided increase with increasing vegetational development. That potassium is abundant in most soils except sandy soils (Bizzel and Lyon, 1927; Lyon and Bizzel, 1936) is supported by evidence in Figure 19, which shows a marked increase in the better soils. Potassium is also very readily removed from the soil because it combines easily with the products of weathering and its salts are highly soluble (Hem, 1959). This factor could be important in limiting the growth of some plant taxa at early successional stages.

In contrast to nitrogen and potassium, phosphorus is very tightly bound in the soil and lysimeter studies show only a trace found in leachate (Bizzel and Lyon, 1927; Lyon and Bizzel, 1936). Hem (1959) indicates that the analysis of phosphate is not usually included in the chemical analysis of natural water, primarily because the amount is small enough to be ignored without serious error. The amount of phosphorus in the soil is also very small. Phosphorus is considered by biologists and agronomists to be the most critical nutrient element in the ecosphere (Cole, 1958; Odum, 1959). In the floodplain of Rock Creek phosphorus does not appear to change as markedly as the other elements with vegetational development. The slightly higher concentration of phosphorus in the better soils is probably because of the greater percentage of fine textured material and the consequently greater colloidal properties. Buckman and Brady (1960) indicate that the amount of phosphorus ranges from 0.10 to 0.15 percent on the average. In the Rock Creek floodplain it reaches a maximum of about six parts per million, which is much lower. Of the major nutrients considered in this study it appears that phosphorus is probably the most limiting at the late stages of successional development.

There is a close correlation between conductance measurements and the concentration of cations in solution (Thorne and Peterson, 1954). In regard to the Rock Creek floodplain, it is shown (Figure 19) that, in general, there are more cations in the upper 20 cm. of soil than in the soil below this level. These conductivity measurements were taken on a saturation extract and it has been pointed out by the U.S. Salinity

Laboratory Staff (1954) that sands tend to be underrated with regard to salinity by the saturation extract technique. This is primarily because sands have a higher saturation percentage than do other soils relative to the field moisture range. The floodplain soils of Rock Creek are not saline, but these considerations may cause conductivity readings to be low especially in the early successional stages.

Use and Management of Floodplain Ecosystems

Man must be educated to the fact that they are integral components of a vast and complex ecological system. Odum (1959) has pointed out that man's power to change and control seems to be increasing faster than man's realization and understanding of the results of the profound changes of which he is now capable. The floodplain is an area of considerable activity by man and other organisms and the diversified interests of agriculture, recreation, water supply and flood control must cooperate in the wise management of the floodplain. It would seem to be in the general interests of all concerned that the floodplain plant communities, especially those nearest the stream, be left undisturbed. If a practicable program could be evolved for fencing a strip of land parallel to each stream bank, it is thought that the interests of all users of Rock Creek would be valuably served.

APPENDIX

Table XII. Measured properties of soil pedons sampled at various locations within the Rock Creek floodplain. (Methods of analysis are noted in Methods section)

Depth	Mechanical Analysis									
cm.	Sand %	Silt %	Clay %	15-atmos. %	pH	Cond. m/mho	O.M. %	K lb./acre	p ppm	Color
1.										
0-20	68.8	18.4	12.8	17.4	6.5	0.40	7.80	320	3.94	D10YR2/1 M2.5Y2/0
20-40	86.6	7.0	6.4	3.0	6.5	0.45	0.50	60	2.17	D10YR 6/4 M2.5Y5/4
40+	75.2	16.2	8.6	4.1	6.9	0.16	1.10	30	2.17	D10YR 5/3
2.										
0-20	56.0	28.0	16.0	43.6	7.2	0.55	10.80	740	5.67	D10YR 4/1 M10YR 3/1
20-40	77.0	14.0	9.0	5.1	7.3	0.38	1.60	270	3.40	
40+	89.0	7.0	4.0	3.0	7.3	0.29	0.52	69	2.36	
3.										
0-20	59.6	30.0	10.4	23.2	6.0	0.72	15.20	420	3.50	D10YR 2/1 M2.5YR2/0
20+	93.8	3.0	3.2	2.1	5.7	0.18	0.38	47	1.58	
4.										
0-5	81.8	12.0	6.2	12.0	6.7	0.36	7.00	410	7.25	D19YR 3/2 M2.5Y 2/0
5-20	83.6	9.0	7.4	5.0	6.5	0.14	0.48	74	2.11	
20+	89.6	6.0	4.4	3.2	6.7	0.17	0.79	65	2.01	

Table XII. Continued.

Depth cm.	Mechanical Analysis Sand %	Silt %	Clay %	15-atmos. %	pH	Cond. m/mho	O.M. %	K lb./acre	p ppm	Color
5. 0-20	80.0	12.0	8.0	7.3	6.8	0.55	3.30	150	3.83	D10YR 4/1 M2.5Y2/0
20+	90.8	4.2	5.0	3.0	6.3	0.35	0.78	55	3.53	
6. 0-20	86.6	8.1	5.3	3.6	6.8	0.34	1.10	58	2.11	
20+	92.6	4.1	3.3	2.1	6.7	0.28	0.35	22	1.90	
7. 0-20	83.6	9.0	7.4	5.0	6.8	0.28	1.70	92	2.43	
20+	92.8	4.0	3.2	1.7	6.7	0.20	0.43	30	1.78	
8. 0-20	92.0	6.0	2.0	3.8	6.3	0.23	1.50	60	2.81	
20+	94.9	3.0	2.1	1.8	6.1	0.50	0.25	22	1.54	
9. 0-20	95.6	2.1	2.3	1.6	6.4	0.20	0.26	28	2.54	
20+	92.9	5.0	2.1	1.4	6.4	0.24	0.28	30	2.32	

Table XII. Continued.

Depth cm.	Mechanical Analysis Sand %	Silt %	Clay %	15-atmos. %	pH	Cond. m/mho	O.M. %	K lb./acre	p ppm	Color
10.										
0-20	53.0	38.0	9.0	21.1	7.3	2.00	10.20	1000	8.85	D10YR2/1 M2.5Y2/0
20-40	79.8	15.0	5.2	5.4	7.3	0.70	1.70	740	4.06	D10YR5/2 M10YR3/3
40+	86.6	10.0	3.4	3.0	7.5	0.68	0.97	410	2.99	
11.										
0-20	65.2	24.0	10.8	15.2	6.2	0.42	4.60	300	2.74	D10YR3/1
20+	88.7	6.1	5.2	4.6	6.1	0.21	1.40	110	2.40	
12.										
0-30	53.0	32.0	15.0	26.8	5.8	0.55	5.10	140	2.82	D10YR3/1 M10YR2/1
30+	77.6	14.2	8.2	7.2	4.4	2.80	1.10	50	1.45	D10YR5/1 M2.5Y4/0

Table XIII. Location of areas from which soil samples in Table XII were collected during the summer of 1966.

No.	Location
1.	Mature Forest - Natural Area
2.	Mature Forest - Natural Area
3.	Immature Forest (Stand I) - Grazed Area
4.	Immature Forest - Natural Area
5.	Cottonwood-Willow Stage - Grazed Area
6.	Cottonwood-Willow Stage - Natural Area
7.	Young Cottonwood Stage - Natural Area
8.	Young Cottonwood Stage - Beaver Lodge Fishing Access
9.	Pioneer Stage - Beaver Lodge Fishing Access
10.	Stand II (Central Stand) - Grazed Area
11.	Stand III (South Stand) - Grazed Area
12.	Wet site in the natural area with the important vegetative cover being *Alnus incana* and *Calamogrostis canadensis*

Table XIV. A systematic list of the plant taxa occurring on the floodplain and first terraces of Rock Creek. (Those species occurring on the floodplain proper are marked by an asterisk).

ACERACEAE

Acer glabrum (Rocky Mountain Maple)*

APOCYNACEAE

Apocynum androsaemifolium (Spreading Dogbane)

BERBERIDACEAE

Berberis repens (Oregon Grape)*

BETULACEAE

Alnus incana (Thinleaf Alder)*
Betula occidentalis (Water Birch)*

BORAGINACEAE

Cynoglossum officinale (Houndstongue
Hackelia floribunda (Many Flowered Stickseed)
Mertensia paniculata (Tall Bluebell)*
Myosotis micrantha (Slender Forget-Me-Not)*
Myosotis sylvatica (Alpine Forget-Me-Not)*

CAMPANULACEAE

Campanula parryi (Parry Harebell)*

CAPRIFOLIACEAE

Symphoricarpos albus (Common Snowberry)*

CARYOPHYLLACEAE

Cerastium nutans (Longstem Chickweed)*
Cerastium vicsocum (Sticky Chickweed)*
Lychnis alba (White Cockle)*
Silene cucubalus (Bladder Silene)*
Stellaria longifolia (Long leaf Chickweed)*
Stellaria media (Common Chickweed)*
Spergularia rubra (Red Sperry)*

Table XIV. Continued.

CHENOPODIACEAE

Salsola kali (Russian Thistle)
Chenopodium album (Lamb's Quarter)*

COMPOSITAE

Achillea millefolium (Yarrow)*
Anaphalis margaritaceae (Pearly Everlasting)*
Antennaria dimorpha (Low Pussytoes)*
Antennaria rosea (Rose Pussytoes)*
Arctium lappa (Great Burdock)*
Arnica chamissonis (Arnica)*
Arnica longifolia*
Artemisia campestris (Field Sagewort)*
Artemisia frigida (Fringed Sagewort)
Artemisia ludoviciana (Cudweed Sagewort)
Artemisia michauxiana (Michaux Sagebrush)*
Artemisia tridentata (Big Sagebrush)*
Aster canescens (Hoary Aster)*
Aster ciliolatus*
Bidens cernua (Nodding Beggartick)*
Centaurea maculosa (Spotted Knapweed)*
Chaenactis douglasii (Douglas Dusty Maiden)
Chrysanthemum leucanthemum (Oxeye Daisy)*
Chrysopsis villosa (Golden-aster)
Cirsiumvulgare (Bull Thistle)*
Cirsium arvense (Canada Thistle)*
Grindelia squarrosa (Curlcup Gumweed)*
Helianthus annus (Common Sunflower)
Liatrus punctata (Dotted Blazingstar)
Ratibida columnifera (Prairie coneflower)
Rudbeckia laciniata (Cutleaf Coneflower)*
Senecio indecorus*
Senecio serra*
Solidago nana*
Solidago spatulata
Sonchus asper (Prickly Sowthistle)*
Sonchus uliginosus*
Taraxicum officinale (Common Dandelion)*
Tragopogon dubius (Common Salsify)

CONVOLVULACEAE

Convolvulus arvensis (Field Bindweed)

Table XIV. Continued.

CORNACEAE

Cornus stolonifera (Red Dogwood)*

CRASSULACEAE

Sedum stenopetalum (Yellow Stonecrop)*

CRUCIFERAE

Barbarea orthoceras (American Wintercress)*
Capsella bursa-pastoris (Shepherd's Purse)*
Rorippa nasturtium-aquaticum (Watercress)*
Thlaspi arvense (Fanweed)

CUPRESSACEAE

Juniperus communis (Common Juniper)*
Juniperus horizontalis (Creeping Juniper)*
Juniperus scopulorum (Rocky Mountain Juniper)

CYPERACEAE

Carex nebraskaensis (Nebraska Sedge)*
Carex sp. (Sedge)*
Eleocharis sp. (Spike-sedge)*

ELEAGNACEAE

Shepherdia canadensis (Canadian Buffalo Berry)*

ERICACEAE

Arctostaphylos uva-ursi (Kinnikinnick)*
Pyrola chlorantha (Greenish-flowered Wintergreen)

GERIANACEAE

Geranium richardsonii (Richardson Geranium)*
Geranium viscosissimum (Sticky Geranium)*

Table XIV. Continued.

GRAMINEAE

Agrostis alba (Redtop)*
Agrostis scabra (Ticklegrass)*
Agrostis variabilis (Alpine Bentgrass)*
Agropyron repens (Quackgrass)*
Agropyron smithii (Bluestem)
Agropyron spicatum (Bluebunch Wheatgrass)
Agropyron subsecundum (Bearded Wheatgrass)*
Bromus inermis (Smooth Brome)
Bromus japonicus (Japanese Chess)
Bromus tectorum (Downy Chess Brome)*
Bouteloua gracilis (Blue Grama)
Calamogrostis canadensis (Bluejoint)*
Glyceria striata (Fowl Mannagrass)*
Oryzopsis hymenoides (Indian Ricegrass)
Phalaris arundinaceae (Reed Canary Grass)*
Phleum pratense (Timothy)*
Poa pratensis (Kentucky Bluegrass)*
Sitanion hystrix (Squirreltail)
Stipa columbiana (Columbia Needlegrass)*
Stipa comata (Needle-and-thread)

HYDROPHYLLACEAE

Phacelia hastata (Silverleaf Phacelia)
Phacelia linearis (Linear-leaf Phacelia)

IRIDACEAE

Sisyrinchium montanum (Mountain Blue-eyed Grass)*

JUNCACEAE

Juncus effusus (Common Rush)*
Juncus sp. (Rush)

LABIATAE

Mentha arvensis (Field Mint)*
Monarda fistulosa (Horse Mint)*
Salvia reflexa (Lance-leaved Sage)*

Table XIV. Continued.

Salvia sylvestris (Woodland Salvia)*
Scutellaria galericulata (Marsh Skullcap)*

LEGUMINOSAE

Astragalus sp. (Milkvetch)
Lupinus lepidus (Pacific lupine)*
Medicago sativa (Alfalfa)
Melilotus alba (White Sweetclover)*
Melilotus officinalis (Yellow Sweetclover)*
Trifolium dubium (Small Hop Clover)*
Rifolium repens (White Clover)*
Vicia americana (American Vetch)

LILIACEAE

Allium textile
Colochortus nuttallii
Smilicina racemosa (Feather Solomon's Seal)*
Smilicina stellata (Starry False Solomon's Seal)*
Streptopus amplexifolius (Large Twisted-stalk)*
Zygadenus intermedius (Rocky Mountain Death Camas)

ONAGRACEAE

Epilobium angustifolium (Fireweed)
Epilobium latifolium (Broad-leaved Willow Herb)*
Epilobium sp. (Willow Herb)
Oenothera rydbergii (Rydberg's Evening Primrose)

ORCHIDACEAE

Corallorrhiza maculata (Large Spotted Coral-root)*
Habenaria hyperborea (Northern Green Bog-orchid)*
Spiranthes romanzoffiana (Hooded Ladies Tresses)*

PINACEAE

Pinus contorta (Lodgepole Pine)
Pinus flexilis (Limber Pine)

Table XIV. Continued.

Pinus ponderosa (Ponderosa Pine)
Pseudotsuga taxifolia (Douglas-fir)

PLANTAGINACEAE

Plantago major (Broadleaf Plantain)*
Plantago purshii (Wooly Plantain)

POLEMONIACEAE

Collomia linearis (Narrow-leaved Collomia)*

POLYGONACEAE

Eriogonum umbellatum (Sulfur eriogonum)
Rumex crispus (Curl Dock)*
Rumex venosus (Veiny Dock)*

PORTULACACEAE

Lewisia rediviva (Bitterroot)

PRIMULACEAE

Steironema ciliatum (Fringed Loosestrife)*

RANUNCULACEAE

Actea rubra (Western Baneberry)*
Anemone cylindrica (Candle Anemone)*
Aquilegia flavescens (Yellow Columbine)*
Clematis lingusticifolia (Western White Clematis)*
Delphinium bicolor (Low Larkspur)
Ranunculus acris (Tall Buttercup)*
Ranunculus aquatilis (Aquatic Buttercup)*
Ranunculus glaberrimus (Sagebrush Buttercup)*
Ranunculus hyperboreus (High Northern Buttercup)*
Thalictrum sparsiflorum (Few-flowered Meadow Rue)*

Table XIV. Continued.

ROSACEAE

Agrimonia striata (Roadside Agrimony)*
Amelanchier alnifolia (Western Serviceberry)
Fragaria vesca (Woodland Strawberry)*
Geum strictum (Yellow Avens)*
Potentilla gracilis (Northern Cinquefoil)
Potentilla pennsylvanica (Pennsylvania Cinquefoil)
Prunus virginiana (Chokecherry)*
Rosa acicularis (Prickly Rose)*
Rubus idaeus (Red Raspberry)*
Sorbus scopulina (Mountain Ash)*

RUBIACEAE

Galium boreale (Northern Bedstraw)*
Galium trifidum*

SALICACEAE

Populus angustifolia (Narrowleaf Cottonwood)*
Populus tremuloides (Quaking Aspen)*
Populus trichocarpa (Black Cottonwood)*
Salix amygdaloides (Peachleaf Willow)*
Salix exigua (Slender Willow)*
Salix sp. (Willow)*

SAXIFRAGACEAE

Parnassia palustris (Northern Parnassia)

SCROPHULARIACEAE

Castilleja lineariaefolia (Wyoming Indian Paintbrush)*
Linaria vulgaris (Butter and Eggs)*
Mumulus guttatus (Common Monkey Flower)*
Mimulus lewisii (Lewis Monkey Flower)*
Penstemon Rydbergii (Rydberg Penstemon)*
Verbascum thapsus (Flannel Mullein)*
Veronica americana (American speedwell)*

Table XIV. Continued.

TYPHACEAE

Typha latifolia (Common Cattail)*

UMBELLIFERAE

Cicuta douglasii (Waterhemlock)*
Heracleum lanatum (Cow-parsnip)*
Lomatium cous (Mountain Lomatium)

URTICACEAE

Urtica dioica (Stinging Nettle)*

VIOLACEAE

Viola arvensis (Pansy)*
Viola canadensis (Canada Violet)*
Viola sp. (Violet)*

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