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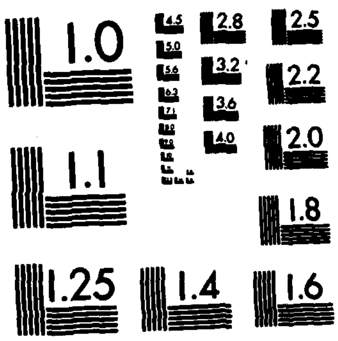

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SHORE VEGETATION OF LAKES OAHE AND SAKAKAWEA, MAINSTEM MISSOURI RIVER RESERVOIRS

46°

NORTH DAKOTA
SOUTH DAKOTA

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APOLOGIA

Like most final reports, the present one is a working document, presented with the knowledge that it is based on a considerable amount of data and observations yet knowing too that the conclusions and generalities are subject to change as more data are obtained. In most scientific studies one has data from controls with which to compare experimental data. In this sense controls were not possible for all phases of this study. Water level fluctuations are not duplicated on a year-to-year basis; some generalities are thus based on empirical data accumulated during the time of this study.

I have tried to avoid jargon in this report, but certain terminology is used that is usual in ecological reports. If questions arise related to use of terminology, I would be happy to respond to them.

I also apologize to those readers not completely familiar with scientific names of plants. There are no widely accepted common names for plants; in fact the same plant may have more than one common name within the bounds of our study region. Quite adequate floras of states and regions are becoming more abundant; I would hope persons dealing with plants (except for cultivated varieties) would more willingly accept the latinized plant names.

Finally, I would appreciate having my attention referred to significant ambiguities in the report.

George R. Hoffman

INTRODUCTION

Statement of the Problem

Though the exact number is unknown, man-made lakes are abundant, numbering in the thousands, and most are relatively new. Of the man-made lakes greater than 1,000 km^2 in surface area, only one was created before World War II. Fels and Keller (1973) tabulated the 41 largest man-made lakes, their locations and their surface areas; and they estimated the total surface area of all water surfaces created by man to be greater than 300,000 km^2. Lvovich (1969, cited by Ackerman 1973) estimated man-made lakes regulate 1/10 of the total runoff from land surfaces.

While there are many data accumulated on the ecologic characteristics of natural lakes, there are considerably fewer on man-made lakes. There is a general understanding of major changes that accompany the creation of a lake. Since most dams are built across rivers, the lakes formed inundate terrestrial plant and animal communities of the former floodplain and river terrace habitats. Aquatic habitats of the river are replaced by habitats more suited to different organisms, or to many of the same organisms in different abundances. As the lake fills and kills terrestrial vegetation, the nutrient input from the dead organic matter increases lake production to a bloom stage which subsides just before, or just after, the lake reaches full pool. Wave action, combined with man-controlled water level changes, create vast areas of barren, eroding shores which in turn provide habitat for numerous ephemeral weed-dominated plant and animal communities. The general end result is replacement of one group of biotic communities by another. Among the latter, the shore plant communities are essentially ephemeral, less stable than those they replaced, and subject to rapid change in composition as the water levels, directed by man, dictate.

The upper Missouri River, from eastern Montana to Southeastern South Dakota, has six mainstem dams and reservoirs. Within this impounded segment of the Missouri River, 510 km are still free-flowing and 1444 km are impounded (Benson 1968). Two of the largest of these reservoirs are Lakes Oahe and Sakakawea. At maximum pool Lake Oahe is 402 km long, has a shoreline of 3783 km and a surface area of 152,227 ha. For Lake Sakakawea comparable values are 322 km in length, 2415 km of shoreline and 173,279 ha of surface area (Benson 1968). Water levels in both these lakes are highest during the summer and lowest during the winter. The land area around the lakes between high and low water levels is the shore. The shore area around each lake depends upon the magnitude and elevation of annual water level fluctuation combined with the angle of slope along the shore. Estimates of shore areas for these two lakes over the period 1969-1976, based on 1968 lake basin morphometry, are given in Table 1. These areas represent a potential habitat for terrestrial plant and animal communities as well as a spawning habitat for certain fish species.

Table 1. Water level fluctuations and shore areas for Lakes Oahe and Sakakawea.

	Lake Oahe						Lake Sakakawea					
Year	Highest Water Level Month	Lowest Water Level Month	Water Level Fluctuation m	Water Level Fluctuation ft	Shore Area[a] ha[b]	Shore Area[a] mi^2	Highest Water Level Month	Lowest Water Level Month	Water Level Fluctuation m	Water Level Fluctuation ft	Shore Area ha[b]	Shore Area mi^2
1969	May	Jan	3.75	12.3	21,486	83	July	Mar	4.32	14.2	23,902	92
1970	June	Dec	2.87	9.5	17,776	69	July	Mar	3.57	11.7	21,031	81
1971	May	Dec	4.75	15.6	27,738	107	July	Feb	3.09	10.1	17,382	67
1972	July	Nov	4.57	15.0	25,810	100	Aug	Feb	2.77	9.1	15,308	59
1973	Apr	Jan	2.68	8.8	14,592	56	July	Feb	2.04	6.7	9.566	37
1974	Mar	Oct	2.19	7.2	11,822	46	July	Mar	3.41	11.2	20,733	80
1975	Aug	Jan	4.24	13.9	25,389	98	July	Mar	4.97	16.3	26,380	102
1976	July	Dec	1.86	6.1	10,364	40	July	Dec	2.71	8.9	15,314	59
Average			3.36	11.0	19,372	75			3.36	11.0	18,702	72

[a]Shore area is that area around the lake between high and low water levels.

[b]Shore area estimates from U.S. Army Corps of Engineers (1971, 1972).

Aims of the Present Study

Because so little is known of the ecological importance of these shore areas, and especially their potential in supporting vegetation, the present study was done. Primary aims of the study were as follows:

1. Describe quantitatively the shore vegetation of both lakes, and investigate its dynamics over a period of years.
2. Determine the possibility of experimentally establishing species along the shores.
3. Determine the responses of shore vegetation to the limiting factors of inundation, cattle grazing and soil nutrient status.

This report is a final report prepared for the U.S. Army Corps of Engineers, Omaha District. The author is solely responsible for its contents and interpretations. Parts of this final report have been published, other parts will be published in the open literature at which time the usual copyright laws will apply. Until then, the material in this report can be referenced; if other use is to be made of the material contained herein, please first contact the author or the U.S. Army Corps of Engineers, Omaha District, Operations Division.

ACKNOWLEDGMENTS

This study began in 1971 and ended in 1977. For the first two years the study was supported by the U.S. Army Corps of Engineers through the U.S. Fish and Wildlife Service, U.S. Dept. of Interior. Several persons have materially added to this study. Mr. Vern Cole of the Operations Division, U.S. Army Corps of Engineers, Omaha District, has been most supportive of my efforts throughout this study. He has believed in what I hoped to accomplish in this study and he worked very hard to keep the study supported for the six years. For these things I am grateful and wish to express my appreciation. Others of the Operations Division of the Corps of Engineers in Omaha have also been helpful and have provided me with information and other assistance when asked. Corps of Engineers field personnel at both Pierre, South Dakota and at Riverdale, North Dakota, have been very helpful in providing field equipment and materials when we needed them. Dr. Norman Benson, former Chief of the North Central Reservoir Investigations, Yankton, South Dakota, first stimulated my interest in this long-term project; and it was through his office that the support came during the first two years. He has shown a continued interest in the study over the years, and has given encouragement when most needed; for this I am grateful.

Mr. Lowell Stanley and Mr. Bruce Vanderveen were both half-time assistants on this project during the first two years. Lowell Stanley was a full-time research associate on the project from 1973 to 1977; he gave much to the project in terms of field work and data analysis.

Dr. Ted Van Bruggen, Curator of the University of South Dakota Herbarium, has helped immensely in plant species identification.

Finally, I wish to thank the University of South Dakota for providing research space in which to carry out the laboratory parts of this study.

With a great deal of patience, courage and good humor, Karen Rose typed the final draft of this report; her efforts are much appreciated.

GEOMORPHOLOGY OF LAKE SHORES

Following nomenclature of Thornbury (1954) for coastal areas, shore is defined as that area around the lake between low and high water levels. Shoreline marks the position on the shore of the water level at a particular time. While some use the terms shore and shoreline synonymously, they will be distinguished here as the shoreline provides a suitable mobile line of reference moving up and down along the shore through the course of a year.

Wave action within a newly-formed lake immediately begins eroding headlands and depositing materials in embayments. The result is a change from less regular to more regular shoreline. Water level fluctuations serve to enhance the processes of erosion and deposition initiated by wave action. While remodeling of the lake shores continues over a long period of time, it is most obvious during the early years in the existence of a lake. As cliffs erode, benches or terraces form at their bases. Continued wave action over long periods reduces the benches or terraces to gradual slopes eventually producing an equilibrium profile of the shore. In general fine textured materials (silt + clay) wash away from the shore to deeper parts of the lake leaving behind coarser materials to form the shore substrates. Exceptions to this are found in embayments of a young lake where deposits of fine materials can make up most of the shore substrate. Though shore substrates are considered in more detail later, the geologic parent materials of the shores determine to some extent the rates of erosion and deposition, and thus in turn the rates of shoreline remodeling. With its abundance of variously-sized boulders, glacial till produces armoured shores comprised of conspicuously large boulders remaining after most of the silt and clay has washed away. Armoured shores are most common along headlands of young lakes; and while they are suitable for very little plant growth armoured shores are ordinarily subject to no further erosion. Quite the opposite is the situation of shore substrates having high clay and silt content particles of which are readily suspended and carried far from shore.

Shore remodeling is further enhanced where large masses of earth slump into the lake. This happens relatively frequently around Lake Oahe where Pierre Shale is predominant and is seamed with bentonite. The mass of earth moved downslope into or near the water may then take the brunt of wave action as the erosion process continues. Patches of terrestrial vegetation on the moved mass may remain intact and become shore vegetation for a temporary period until inundation kills most of the species.

Another factor in the shoreline remodeling process is the abundance of logs of trees inundated and killed while the lake was filling. Logs frequently float into embayments, remain entangled there and eventually are covered by deposits of clay and silt particles. New shore areas thus formed in embayments are vegetated and subject to the continued physical forces of wave action accompanying water level fluctuations.

THE STUDY REGION

Climate

A continental climate prevails over the entire study region which extends across the upper and part of the middle Missouri River valley. For five climatic stations near Lakes Sakakawea and Oahe (Fig. 1) a summary of precipitation and temperatures is given in Table 2. Total precipitation ranges from 37.2 cm at Williston, N.D. at the western end of Lake Sakakawea to 40.5 cm at Garrison, N.D. near the eastern end of the Lake. Bismarck, N.D., just north of the upper end of Lake Oahe has an annual average precipitation of 39.0 cm, Mobridge, S.D. near the middle of the Lake has an annual average of 40.3 cm and Pierre, S.D., at the southern end of the Lake has an annual average of 40.7 cm. At all these locations 75-77% of the total precipitation falls during the six month period April - September.

Temperatures over the region are generally characterized as extreme, cold during the winters and hot during the summers. Mean maximum and minimum temperatures for January and July for the same five locations follow:

	January		July	
	Maximum	Minimum	Maximum	Minimum
Williston, N.D.	-7°C	-19°C	29°C	13°C
Garrison, N.D.	-7°C	-19°C	29°C	13°C
Bismarck, N.D.	-7°C	-18°C	30°C	14°C
Mobridge, S.D.	-4°C	-17°C	32°C	16°C
Pierre, S.D.	-2°C	-14°C	33°C	17°C

Fig. 1. Location of five weather bureau stations close to Lakes Oahe and Sakakawea. Also shown are the 38 study sites on each of the two lakes. Major tributaries enter the Missouri River from the west.

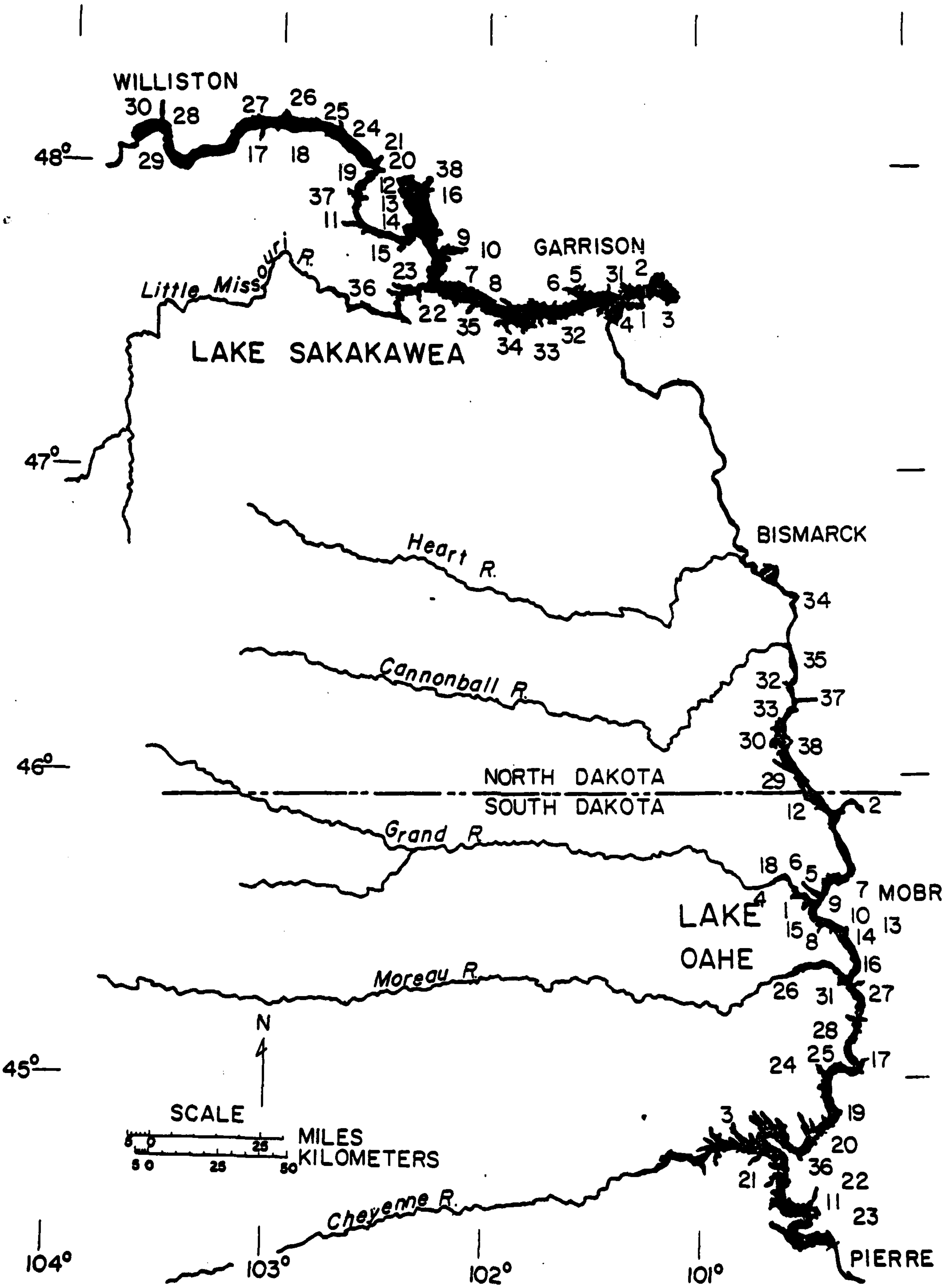

WILLISTON
GARRISON
LAKE SAKAKAWEA
Little Missouri R.
Heart R.
BISMARCK
Cannonball R.
NORTH DAKOTA
SOUTH DAKOTA
Grand R.
MOBRID(
LAKE OAHE
Moreau R.
Cheyenne R.
PIERRE
48°
47°
46°
45°
104°
103°
102°
101°
N
SCALE
MILES
KILOMETERS

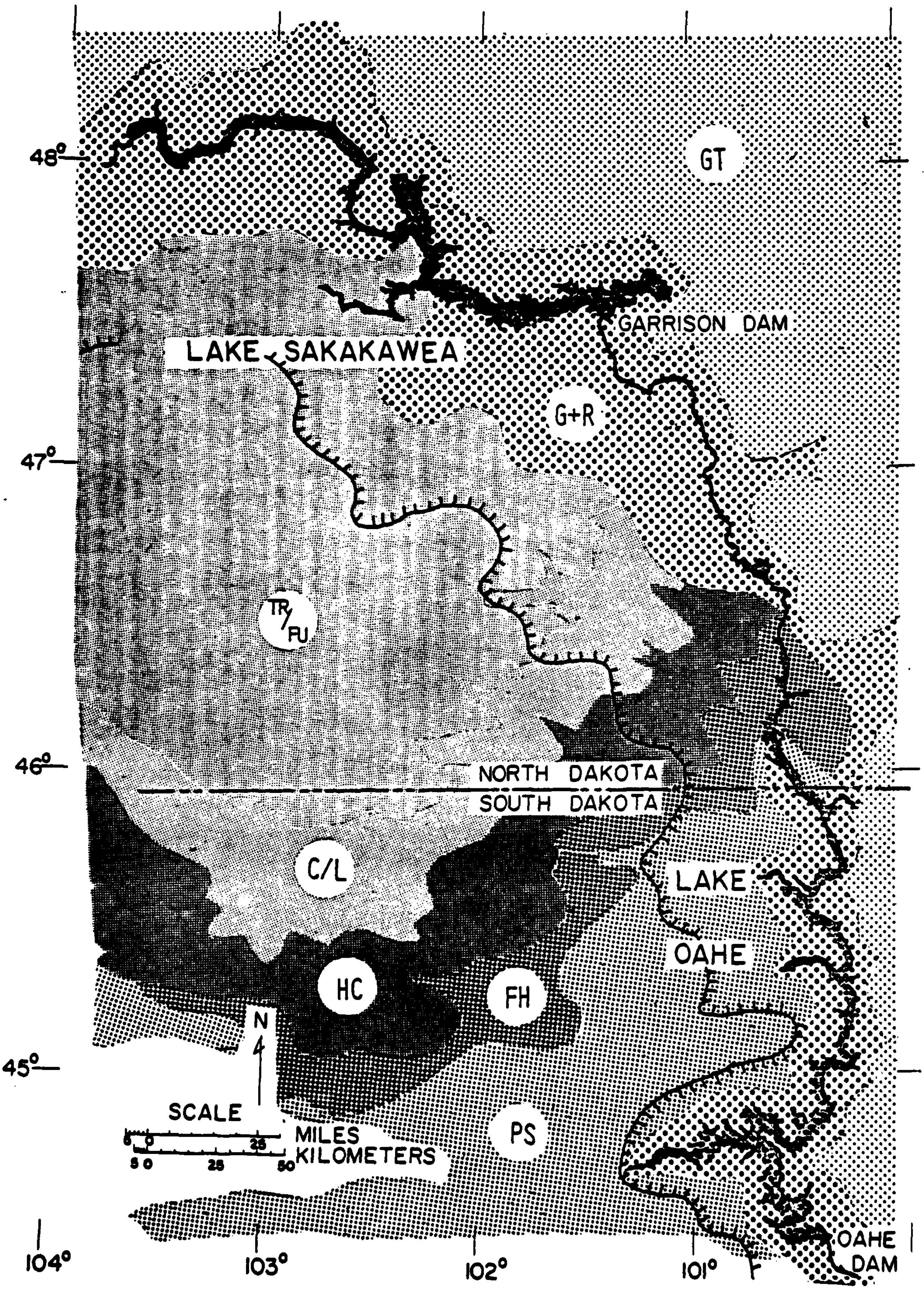
Table 2. Climatic data from Williston, N.D. at the western end and from Garrison, N.D. at the eastern end of Lake Sakakawea. Also, climatic data from Bismarck, N.D. at the northern end, from Mobridge, S.D. from near the middle, and from Pierre, S.D. at the southern end of Lake Oahe. Precipitation (P) is average, in cm, and temperatures (T) are averages in °C.

	Williston[a]		Garrison[a]		Bismarck[a]		Mobridge[b]		Pierre[b]	
Month	P, cm	T, °C	P, cm	T, °C	P, cm	T, °C	P, cm	T, °C	P, cm	T, °C
January	1.2	-12.1	1.5	-13.0	0.9	-12.7	1.1	-10.3	1.1	-8.1
February	1.2	-10.2	1.4	-10.8	1.1	-10.7	1.2	- 8.1	1.6	-6.1
March	1.9	- 3.0	1.9	- 4.6	1.9	- 2.9	2.4	- 1.7	2.9	-0.4
April	2.7	6.0	3.2	5.3	3.5	6.2	3.3	7.8	3.8	8.7
May	4.2	12.4	5.2	12.2	4.9	12.7	5.6	14.4	6.2	15.1
June	9.1	17.0	8.8	16.9	8.5	17.9	8.9	19.4	8.0	20.3
July	5.4	21.4	6.0	21.1	5.9	22.3	5.5	23.9	4.3	25.3
August	3.6	19.8	4.6	19.6	3.8	20.7	4.8	22.8	5.2	24.0
September	3.1	13.9	3.2	14.0	3.6	14.7	2.8	16.7	2.9	17.9
October	2.0	7.4	2.0	7.3	2.5	7.6	2.9	9.5	2.3	10.9
November	1.5	- 2.0	1.6	- 2.8	1.4	- 2.0	1.0	- 0.2	1.2	1.3
December	1.4	- 9.0	1.1	- 9.4	1.0	- 9.2	0.8	- 6.9	1.2	-5.2
Annual	37.3	5.1	40.5	4.7	39.0	5.4	40.3	7.3	40.7	8.6

[a] U.S. Dept. of Commerce (1959).

[b] U.S. Dept. of Commerce ([illegible]

Fig. 2. Geologic formations of the study region. GT = glacial till, G + R = glacial drift plus residuum, TR/FU = Tongue River/Fort Union formation, C/L = Cannonball/ Ludlow formation, HC = Hell Creek formation, PS = Pierre Shale. Ornamented line indicates apparent extent of glaciation. FH = Fox Hills formation



48°
47°
46°
45°
104°
103°
102°
101°
GT
GARRISON DAM
LAKE SAKAKAWEA
G+R
TR/FU
NORTH DAKOTA
SOUTH DAKOTA
C/L
LAKE
OAHE
HC
FH
PS
N
SCALE
MILES
KILOMETERS
OAHE DAM

Precipitation effectiveness decreases southward along Lake Oahe owing to greater evaporative rates during the warmer summers combined with high clay contents of most of the substrates that hold soil moisture close to the surface.

Geology

Though the Missouri River generally marks the southern and western limits of glaciation in the Dakotas, at least minimal glaciation occurred beyond the River (Fig. 2). Under the glacial deposits in our study region are very thick sedimentary deposits of tertiary and Cretaceous age. In western North Dakota the most widespread is the Tertiary Tongue River formation, sediments well-known for their lignite beds and their scoria-capped buttes and hills (Leonard 1930). Upper Tertiary deposits are most evident adjacent the Little Missouri River where glaciation did not occur and where erosion has produced prominent badland topography. Because the glacial mantle was relatively thin near the River, erosion has exposed the older Tertiary sediments leaving the glacial debris primarily on the upper slopes and crests of hills. In Fig. 2 such areas in the study region are shown as mixtures of glacial drift and residuum. Fox Hills Sandstone, an upper Cretaceous deposit is exposed along the lower Connonball River valley and southward along the northern part of Lake Oahe. Southward along Lake Oahe both glacial drift and Cretaceous Pierre Shale are present, the latter being the most widespread sedimentary formation in western South Dakota. The major tributaries of both Lakes Oahe and Sakakawea enter the Lakes (former Missouri River) from the west and south sides and have cut valleys through the thin glacial mantle and deep into the soft shales and sandstones of sedimentary origin. No tributaries of comparable magnitude enter the River from the northern or eastern sides, and apparently never did even before the Pleistocene, a point of considerable interest in historical geology (Flint 1955).

As with Lake Sakakawea, Lake Oahe is long and narrow and much of the shore area is the former bluffs adjacent the former River valley. Erosion on both sides of Lake Oahe has cut through the thin glacial mantle into the Pierre Shale forming a labyrinth of steep-walled gullies and ravines back from the lake shore. This peculiar topography is known locally as the Missouri River "breaks". In localized areas along both Lakes loess and gravel deposits of Pleistocene origin are part of the shores. Fox Hills Sandstone and the Pleistocene gravels have weathered into sandy textured substrates while the loess weathered into a silt loam substrate. The Tertiary and Cretaceous sedimentary substrates weather into soils ranging from sands to clays. Edaphic characteristics of the shore substrates are considered in detail later in this report.

Detailed descriptions of the upland soil profiles of our study region are not included here. Shore vegetation along both Lakes is for the most part rooted directly in transported or residual parent material that is but slightly altered.

Soil profiles are not distinguishable along the lake shores. For descriptions of the mature soil profiles of the uplands the reader is referred to Westin et al. (1967), Omodt et al. (1968), and Patterson et al. (1968).

Regional Vegetation

Natural potential vegetation within the region of North and South Dakota delimited by 44° to 49° north latitude and the 100th to the 104th meridians consists of both steppe and forest. The uplands of normal soils support a steppe vegetation dominated by *Agropyron smithii*, *Bouteloua gracilis*, *Stipa viridula* and *S. comata*. Associated with these dominants is a rich mixture of forbs and other graminoids (Kuchler 1964). With few exceptions, shrubs that are present on the upland do not alter the physiognomy of the steppe but rather form a mosaic with the herbaceous species present. A detailed description of steppe vegetation of western North Dakota is provided by Whitman and Hanson (1938), and some of the woody communities are described by Nelson (1961). Most of the natural vegetation of the region has been altered as a result of cattle and sheep grazing and agriculture. Ravines of the "breaks" area support woody vegetation consisting of an admixture of *Juniperus virginiana*, *Acer negundo*, *Fraxinus pennsylvanica*, *Celtis occidentalis*, *Prunus virginiana*, *Ulmus americana*, *Shepherdia argentea* and *Symphoricarpos occidentalis*.

Except for limited stretches along the River, reservoirs have replaced the gallery forest that followed the river across the Dakotas into Montana. Where fragments of it still remain, the dominants are Populus deltoides, Ulmus americana, U. rubra, Fraxinus pennsylvanica, Acer negundo, Quercus macrocarpa, Fraxinus pennsylvanica and a few other species of limited importance. In a study of the floodplain-river terrace forests along the Missouri River from just south of Garrison Dam to just north of the upper end of Lake Oahe, Burgess et al. (1973) encountered 229 plant species in the variously-aged gallery forests. For many of these species the 115 km stretch of gallery forest is their last refuge. Even here, lack of flooding which was an integral part of the former environment, and land clearing for agriculture are taking their toll on what is left of this forest (Burgess et al. 1973).

NATURAL DEVELOPMENT OF SHORE VEGETATION

Methods of Study

Vegetational Analyses.---During most of the growing season, 1971, we traveled extensively around both Lakes Oahe and Sakakawea collecting plants and selecting sites for study. As steep eroding cliffs are characteristic of much of the shoreline, these were eliminated immediately as possible study sites. Vegetation becomes established on most shore areas where slope is not excessively steep and these were areas selected for study. Initially we selected 50 sites around each lake. The sites were distributed widely enough to include the various geologic substrates present as well as the range of climatic conditions. After two years of sampling we reduced by 12 around each lake the number of sampling sites allowing us to more efficiently cover the very large study area and still continue to obtain adequate vegetational data. Locations of study sites are shown on Fig. 1.

At each site selected we drove steel stakes into the ground, one well above the highest water level and one lower on the shore where vegetation is inundated yearly. The stakes permanently marked the upper and lower ends of transects along which we placed a steel tape and at meter intervals estimated canopy coverages of plant species within 2 x 5 dm plots. Using a canopy coverage technique described by Daubenmire (1959), we estimated coverages of each species in classes as follows:

Coverage Class	Coverage Interval	Average Coverage
1	0 - 5%	2.5%
2	6 - 25%	15.5%
3	26 - 50%	38.0%
4	51 - 75%	63.0%
5	76 - 95%	83.5%
6	96 -100%	98.0%

For each species in a plot we recorded the number that corresponded to our estimate of its canopy coverage. Because species were often stratified in our plots, it was possible for the total coverage in a plot to exceed 100%. In the laboratory the numbers were converted to coverage values using the average coverages for the particular coverage intervals. The numbers were then averaged for each species within each vegetational zone. The coverage classes as defined provide little chance for consistent human error in assigning species to coverage classes, and when applied to many small (0.1 m^2) plots the coverage estimates yield relatively precise averages (Daubenmire 1959, 1968). It is important to note that the coverage estimates are for actual rather than relative coverage. The value of the coverage data is in providing quantitative estimates of the importance of plant species which adds to the overall descriptions of the vegetation and its responses to yearly water level fluctuations.

Soil Analyses.---At each site we collected along the sampling transect 6 to 10 soil samples of the upper dm of mineral soil. These were air-dried in the field, then taken to the laboratory where they were composited and passed through a 2 mm sieve to remove gravel. On each sample we did the following tests: mechanical analysis to determine particle size distribution, pH of the soil paste using a glass electrode, readily exchangeable Ca, Mg, K and P using "quick" soil tests, total N using the Kjeldahl method, and percent organic matter using a modified Walkley-Black method (Moodie et al. 1963). At a number of our sites we used the gypsum block-conductivity method of measuring soil moisture through the growing season. Gypsum blocks were buried 1 dm, 2 dm and 3 dm deep at positions along the study transect.

Vegetation Classification.---Shore vegetation around Lakes Oahe and Sakakawea is a mosaic of shifting plant populations that respond noticeably to yearly water level fluctuations. Because vegetational responses among various sites may be similar owing to possible similar intrinsic habitat factors, we examined data for vegetational similarities. Grouping similar sites was done initially by simple inspection of the data. Additionally, the vegetation zones that have developed around both lakes were sufficiently clear that much of the quantitative data obtained in the field supported some of the impressions gained early in the study.

Further analysis of data was done by calculating coefficients of similarity (C.S.) between each pair of sites within each vegetation zone. I used the following familiar expression to calculate the coefficients:

$$C.S. = \frac{2W}{A + B} \times 100$$

where

A = sum of coverage values for one site

B = sum of coverage values for second site

W = sum of lower coverage values for all species the two sites have in common

The similarity is then expressed as a percentage. Only total similarity in species composition and coverage values can yield 100% similarity between two sites. The actual calculations were done on an IBM 360/175 computer. There were 38 sites on each lake. Coefficients of similarity were determined for each pair of sites within each vegetation zone. Two vegetation zones around Lake Oahe and three zones around Lake Sakakawea yielded five matrices of 704 similarity coefficients each. There were enough high coefficients within the five matrices that corresponded to my subjective analyses of similar sites to encourage further analysis.

I used two techniques to objectively classify, or group, the coefficients of similarity. One technique was the weighted pair-group method (Sokal and Sneath 1963) and the other was an agglomerative method described by Orloci (1967) and used by Sheard and Jonescu (1974). Detailed descriptions of the techniques and their assumptions can be found in the literature cited above. Briefly the methods of grouping sites are these. In the weighted pair-group method the pair of sites having the highest similarity value is clustered; then a new matrix of similarity coefficients is calculated with one less column (site). Eventually individual sites will be clustered with clusters of two or more sites, and clusters will be grouped with other clusters in which case the new value of the cluster is the average of the cluster present and the site (or cluster) added. This particular method tends to distort the cluster value in favor of the newly added member. Clustering using the agglomerative technique is also based on grouping together those values showing greatest similarity. In this case, however, the values will be the smallest as they represent Euclidean distances derived from a normalized data matrix. After each clustering cycle a new normalized data matrix is calculated from which pairs of sites, or clusters plus sites, or clusters plus clusters, are grouped together. In both methods only those having the greatest similarity are clustered during each clustering cycle (Sheard and Jonescu 1974).

In both of these techniques recalculating either the data matrix or the distance matrix following each clustering cycle results in a "new" value for each pair of sites, or each pair of clusters and clusters. The more new values that are calculated the greater the probability of eventually grouping sites that one would not group based on examination of the original coefficients of similarity. Whether the clustering techniques fail to group sites that should be grouped only the investigator can determine. The techniques have no "truth" _per se_ inherent in them, and only a thorough knowledge of the biology and ecology of the shore vegetation can provide the background of the worth or the "truth" of the objective classifications. Further, no two clustering techniques provide identical results; thus it becomes the responsibility of the investigator to determine the usefulness of the techniques to the problem at hand. In my judgement the techniques were of some use in sorting out similar shore sites and grouping them. Dendrograms showing how the sites became clustered are presented below.

Lake Oahe Vegetation

Description and Successional Trends.---Around Lake Oahe two zones of vegetation are readily distinguished. The upper zone, zone one, is upland steppe in various expressions from pristine to over-grazed to recently cultivated. Zone one has not been inundated and is therefore by definition not part of the shore of the Lake. Zone two vegetation is that of the shore; it is in various stages of development depending to a great extent on the time of last inundation, the pressures of grazing, erosion and deposition, and other factors affecting its development. The lowest fringe of zone two vegetation is inundated almost yearly.

Most of zone one vegetation has been disturbed by grazing, in some locations grazing so severe that very little native vegetation remains. Quantitative data of the vegetation of zone one is presented in Table A of the Appendix. A summary of the 12 most important species of zones one and two is given in Table 3. Zone one vegetation is floristically rich; nearly 200 species were encountered in our plot samples. The wide diversity of topographic positions, geologic substrates, and uses of the upland steppe combined with the manner of our sampling prevented constancy values from being very high for most species of zone one (Table A). Vegetation of zone one varies considerably from one site to the next. Six sites were apparently seeded to Agropyron cristatum and Bromus inermus, both of which dominated these sites. As indicated in Table 3 the average coverages of these two species are comparatively high, but their constancies are rather low. Four of the upland sites had been so depleted by grazing that only alien species made up the bulk of the vegetation remaining. Nineteen of the sites were grazed to various degrees but still had some native steppe species remaining. Nine sites were relatively undisturbed or grazed lightly so that many native species were still present. Agropyron smithii is dominant over most of zone one and is very widely distributed throughout the study region. Bromus japonicus, common on grazed sites, is second in importance in this zone. The remaining species of zone one have much smaller coverage and constancy values. Of the 12 species listed in Table 3, eight have coverages no higher than 3.2%, only two species have coverages of 6.2% or higher and the remaining two species have coverages of 12% and 30%. The constancies of all but two species are 26% or less.

The primary focus of the study on Lake Oahe was zone two (shore) vegetation. During a "normal" year at least part of

Table 3. Twelve constant-dominant species from
one and two on Lake Oahe. Values given are ave
(COV) and constancy (CON) for the years 1972-19

Species	Zone One COV	Zone One CON
Bromus japonicus	12 %	52%
Agropyron cristatum	6.4	16
Bromus inermis	6.2	19
Symphoricarpos occidentalis	3.2	18
Aster ericoides	2.7	26
Poa pratensis	2.5	22
Melilotus officinalis	2.0	17
Lactuca oblongifolia	1.0	21
Stipa viridula	1.4	20
Agropyron smithii	30	78
Hordeum jubatum	1.4	24
Kochia scoparia	3.2	12
Rumex crispus		
Lactuca serriola		
Chenopodium album		
Polygonum ramosissimum		
Helianthus annuus		
Populus deltoides		
Salix spp.[a]		
Polygonum lapathifolium		
Potentilla norvegica		

[a]These include S. exigua, S. amygdaloides,

this zone is inundated. Occasionally water levels are high enough to inundate most of the zone; during other years lower water levels inundate only the lowest fringe of the shore. Overall, zone two vegetation is a mosaic of shifting plant communities most members of which become established during the fall or spring when the water level is low. Survival and continued development of the shore vegetation depends considerably on the timing and magnitude of water level fluctuations. Water level fluctuation patterns in Lake Oahe complicate the explanation of shore vegetation development. Not only is the magnitude of the fluctuation important, but also the timing and duration of the fluctuation. An early spring rise in water level may eliminate much potential vegetation that a slower rise in water level to the same elevation might not eliminate. Additionally, a long duration of high water level might eliminate species that would survive a briefer period. Plant species inundation tolerance will be discussed in greater detail below; here the emphasis is on the rather broader effects of water level fluctuations on shore vegetation.

The total shore area is given in Table 1. However, individual sites vary in length depending on slope of the shore and the time of the year. A shore slope of 10° provides considerably less area of shore than a shore slope of 5°. In late June, when water level is near maximum, the shore at a particular site may be little more than a fringe of vegetation at the edge of the water. In the fall, at the same site, the shore may be a hundred or more meters across.

Inundation drowns many shore species every year. The presence of these species the following year requires reestablishment by germination, or by vegetative propagation from nearby populations. Annual species can reestablish only by germination. Shore species are unequally tolerant to inundation and the composition of the shore community is influenced to some extent by this factor. Generalizations are hard to come by owing to the fact that patterns of water level fluctuations have never been the same during two consecutive years, so what may be a suitable explanation for the success or failure of shore species one year may not hold for another year. Cattle grazing also influences shore vegetation, and this factor is discussed in detail below.

Shore vegetation development is apparent only during years between "unusually" high water. It is during this time that the development may be considered directional and therefore successional. High water sets back vegetation to an early developmental stage or to the barren shore. The unknown stage in the succession is the climax, because time lapses between years of "unusually" high water level are insufficient for a climax community to develop. On the other hand the mosaic of communities that are present and existing in response to the fluctuating water levels might themselves be considered climax of a sort. Without becoming bogged down with ecologic terminology, the vegetation changes that occurred are described; and generalities are given where warranted. Alternative interpretations can be made from the data provided in Tables A and B in the Appendix.

The first year after "unusually" high water some species become very conspicuous. Some of these in turn decrease noticeably in abundance after that first year. As shown in Table 4, several species declined in coverage during the period 1972-1974. In 1975 the water level was again very high (Fig. 3). In 1976 these same species again were abundant and decreased somewhat in 1977. The timing of water level fluctuation is apparently important. The increased water levels during the early spring of 1971 possibly retarded or prevented much vegetation development. In 1972 the maximum water level in Lake Oahe was less than 1 m lower than that of 1971, yet there was considerably more shore vegetation. The delayed rise in water level during 1972 may have benefitted the shore vegetation development.

In Table 4 I have tabulated coverage values for 1972-1977 for the same 12 species listed in Table 3. The patterns of increasing or decreasing coverages are not the same for all 12 species. In Lake Oahe water level was high during both 1971 and 1972 (Fig. 3). In 1972, possibly related to the delayed rise in water, as discussed above, *Rumex crispus* was very abundant on the shore. In the late summer of 1971 seedlings of this species were abundant over much of the shore after the water had receded. The plants were well-established before high water of the following summer. As shown in Table 4 the large coverage of 1972 was followed by decreasing coverages in 1973 and 1974 when water levels peaked almost 2 m below the 1972 level. In 1975 the water level reached an all-time high (Fig. 3) and many shore species

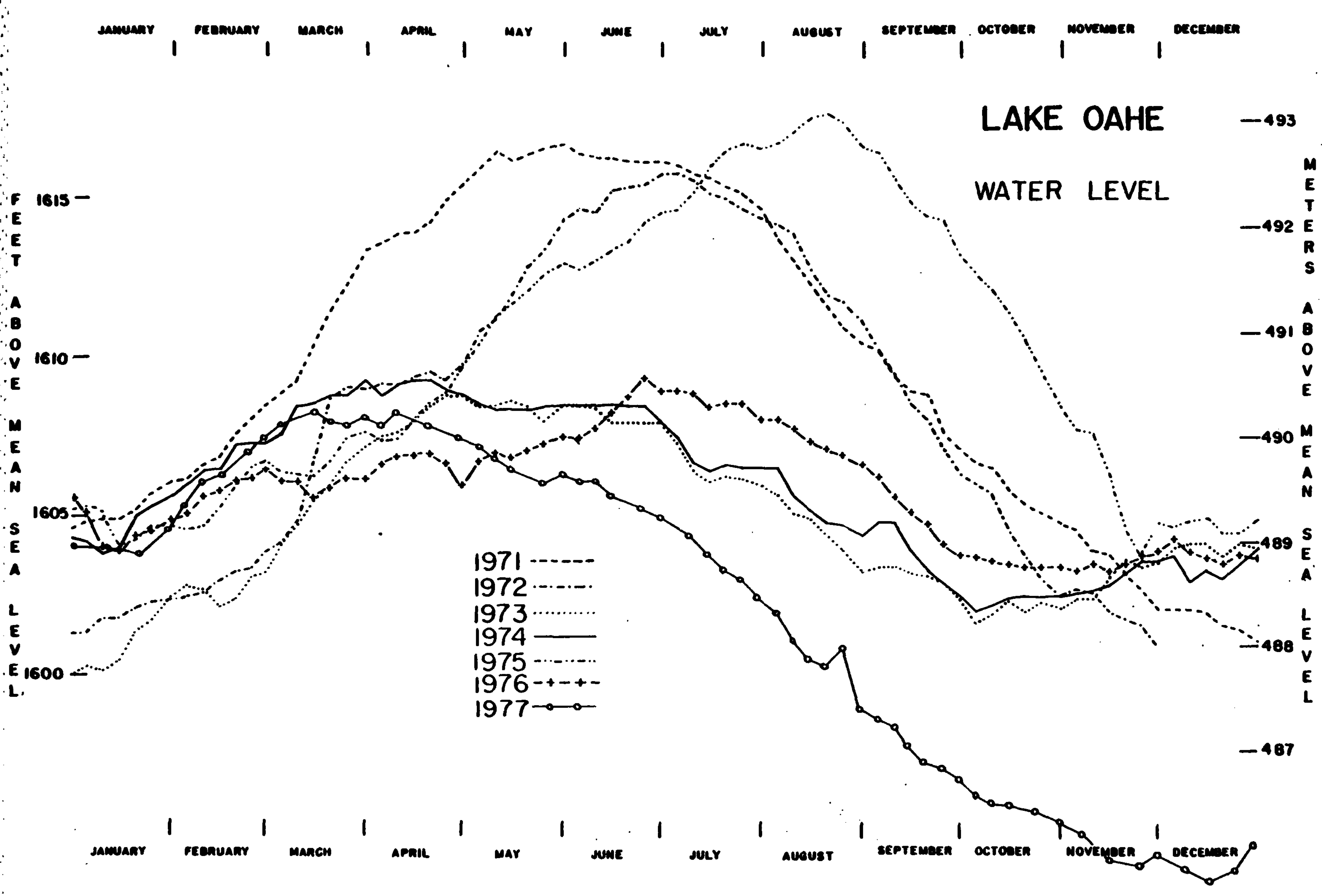
Table 4. Coverage values of 12 species important in zone two, Lake Oahe.

Species	Coverages, in Percent					
	1972	1973	1974	1975	1976	1977
Agropyron smithii	25	8.8	13	16	4.2	2.8
Hordeum jubatum	6.9	9.2	10	1.9	7.5	10
Kochia scoparia	1.5	4.4	7.7	0.1	7.6	10
Rumex crispus	30	17	4.6	0.8	22	12
Lactuca serriola	1.7	2.9	6.4	2.5	0.3	0.8
Chenopodium album	1.1	1.0	0.5	1.9	3.5	11
Polygonum ramosissimum	1.7	3.3	0.3	0.7	1.2	0.1
Helianthus annuus	2.3	1.2	0.9	0.4	2.3	1.3
Populus deltoides	2.2	1.2	1.5	2.9	0.8	1.0
Salix spp.[a]	0.7	0.5	0.4	3.8	0.6	0.6
Polygonum lapathifolium	0.6	0.5	0.1	0.1	3.0	0.7
Potentilla norvegica	2.0	0.9	0.3	+[b]	0.4	1.5

[a]These include *S. exigua*, *S. amygdaloides*, and *S. rigida*.

[b]+ = trace, or less than 0.1%.

Fig. 3. Water fluctuation curves for Lake Oahe, 1971-1977.


LAKE OAHE
WATER LEVEL
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
FEET ABOVE MEAN SEA LEVEL
1615
1610
1605
1600
METERS ABOVE MEAN SEA LEVEL
493
492
491
490
489
488
487
1971
1972
1973
1974
1975
1976
1977

were drowned. Rumex crispus was drastically reduced; but in 1976, when peak water level was lower again, R. crispus was very abundant. In 1977 it shows a drop in coverage. The pattern is reasonably clear for R. crispus. Other species, though less abundant than R. crispus, responded in much the same way. Polygonum lapathifolium, Helianthus annuus and Potentilla norvegica are three examples listed in Table 4. In an ecological context these species are pioneers, the first to dominate the bare shore after inundation has drowned much of the vegetation.

At the same time that the above species, plus numerous others listed in Table B, Appendix, decline in abundance other species become more abundant. This latter group dominate the shore vegetation 2 to 3 years after the year of high water. Conspicuous members of this group listed in Table 4 include Hordeum jubatum, Kochia scoparia and Lactuca serriola. They were most abundant in 1974, three years following the high water in 1971. The high water in 1975 drastically reduced their abundance, and they show another period of recovery during 1976-1977 (Table 4).

Another group of species exhibits dynamics less distinctly related to water levels. Among this group are Agropyron smithii, Polygonum ramosissimum, Populus deltoides, Salix spp. and Chenopodium album. Most species of this group are opportunistic in ways that relate to water levels less directly. Along with R. crispus, Agropyron smithii is the most common species along the shore of Lake Oahe. It establishes both by germination and by vegetative propagation. Its abundance in the steppe above the shore provides a source of plants for the shore habitats. In places it spreads by rhizomes to form sizeable clones on the shore. The plant also tolerates considerable inundation; in fact it elongates its culms to accomodate rising water level and produces leaves at the surface of the water. While useful to the plant in surviving periods of high water, this characteristic has limitations to both depth and duration of high water. As shown in Table 4, the coverage values of *A. smithii* are not related to patterns of water level fluctuations. This is due in part to its abundance above the shore and the capacity to spread vegetatively onto the shore when few other species are abundant there. Its coverage in 1975, the highest water-level year, was 16% (Table 3) when the average cover of the second important species was less than 4%. Like *R. crispus*, *Agropyron smithii* is abundant on all the soil types (textural classes) that occur around Lake Oahe.

Populus deltoides and *Salix spp.* are relatively important species along the shore, but they are often killed by high water. These trees germinate during a brief period shortly after their seeds reach moist mineral soil. This peculiarity gives rise to rows of tree seedlings parallel to the shoreline, the position of the rows indicating the location of moist soil when fresh disseminules landed and germinated. These tree species are most successful on loam or sandy loam substrates (Vanderveen and Hoffman 1973).

Chenopodium album is an annual weed. In some years, like 1977, it is very abundant. It is most successful on loam substrates (Vanderveen and Hoffman 1973). In many annuals seed production varies from year to year and this accounts, in part, for the variable coverages listed for the species (Table 4).

Vegetation Classification.---Descriptions of vegetation classification are available for the interested reader (Whittaker 1962, Daubenmire 1968). I will present only a brief description of major points that seem to me relevant to the vegetation of the present study. The usefulness of classifying vegetation is apparent to those working in either, or both, theoretical and basic ecology and practical and applied ecology. The need to classify vegetation is much the same as the need to classify plants, or animals, or to organize soils and geologic substrates into a usable, and hopefully natural, scheme. The classification is of primary value in allowing further analysis of the vegetation within the framework of the scheme.

Vegetation of the 38 study sites on Lake Oahe show both similarities and differences. Grouping them on the basis of similarities is complicated primarily by deciding to what level of similarity is required; and in the end this can only be decided by the investigator. No two sites are identical, any more than are two individuals within a species. Obviously, there must be some similarities among the sites to allow recognition of the vegetation dynamics, discussed above. This level of similarity may in the end be sufficient for our needs.

Initially, we hypothecated greater similarity among sites having greatest soil texture similarities, particularly in view of the presence of heavy clay soils derived from Pierre Shale, and the very light sandy soils derived from the Fox Hills Sandstone, and even the intermediate loamy soils derived from glacial till and loess. Some species did show differences in coverages when segregated according to soil textural classes. Using the same 12 species of Tables 3 and 4, I have listed in Table 5 their 1972 coverage values according to soil textures. It is clear from the data in Table 5 that *Agropyron smithii* is about equally abundant on clays, silt loams, and loams, though it is somewhat less abundant on sandy loams. *Hordeum jubatum* is most abundant on silt loams, but is also abundant on loams. *Rumex crispus*, the third dominant species of the shore is abundant on all soil textural types, but is somewhat more abundant on loams. No species was clearly most abundant on clay substrates, though *Lactuca serriola* was slightly more abundant on clay than on sandy loam. This peculiar distribution would itself be worthy of further investigation. Only *Potentilla norvegica* was most abundant on sandy loam. The remaining species listed in Table 5 are clearly, or somewhat, more abundant on loam and silt loam soils. What the data, and others not shown in Table 5, indicate is that species vary considerably with regard to their soil preferences. Emphasis on soil texture as a sole factor influencing species distributions is an oversimplification of the real situation,

Table 5. Relation of plant species coverage and soil texture. Values are based on field data of 1972, Lake Oahe, zone two.

	Soil Textural Classes			
Species	Clay	Silt Loam	Loam	Sandy Loam
Agropyron smithii	18 %	15 %	17 %	8.2%
Hordeum jubatum	4.7	12	8.4	2.8
Rumex crispus	30	28	45	33
Lactuca serriola	1.2	0.1	0.3	1.0
Chenopodium album	0.4	3.3	1.8	0.8
Polygonum ramosissimum	2.6	3.3	--	0.2
Kochia scoparia	0.3	1.3	2.0	1.6
Helianthus annuus	2.1	1.5	4.4	1.2
Populus deltoides	0.1	1.1	2.1	2.2
Salix spp.[a]	0.1	--	0.9	0.4
Polygonum lapathifolium	0.3	1.9	1.0	--
Potentilla norvegica	1.0	1.5	--	3.2

[a]These include *S. exigua*, *S. amygdaloides*, and *S. rigida*.

particularly in view of the fluctuating water levels each year and the differences in nutrient status of the substrates (discussed more below).

Objective groupings of sites based on vegetation similarities are portrayed in Figs. 4 and 5. Fig. 4 is a dendrogram showing site groupings using the weighted pair group technique, described above. While there is a general tendency to group sites having similar soil textures, there are some significant exceptions. The greatest similarity shown in Fig. 4 is between sites 6 and 14, a sandy clay loam and a silt loam respectively. To these is added site 4, a clay loam. All three are loams of some kind. Sites 15 and 27 are similar, and grouped together; and site 15 is a loam and 27 is a clay. Site 7, a silt loam, is then added to 15 and 27; and all three are then grouped with 2 and 23, a sandy clay loam and a sandy loam respectively that were grouped earlier. Continued inspection of the results of the objective classification will show that vegetational similarities are not necessarily correlated positively with substrate textures. The agglomerative method of grouping the sites, using Euclidean distances of a normalized data matrix, and shown in Fig. 5, produced a somewhat better fit in terms of soil textures. None-the-less this technique is a bit less than perfect as well and the final judgment regarding the classification of the sites must rest with the investigator.

A final point is to be made regarding classification of shore vegetation. All sites are in an early successional stage. Even though chance plays an important role in the

Fig. 4. Clustering of Lake Oahe study sites based on 1973 vegetation data and using a weighted pair clustering technique.

LAKE OAHE, ZONE 2

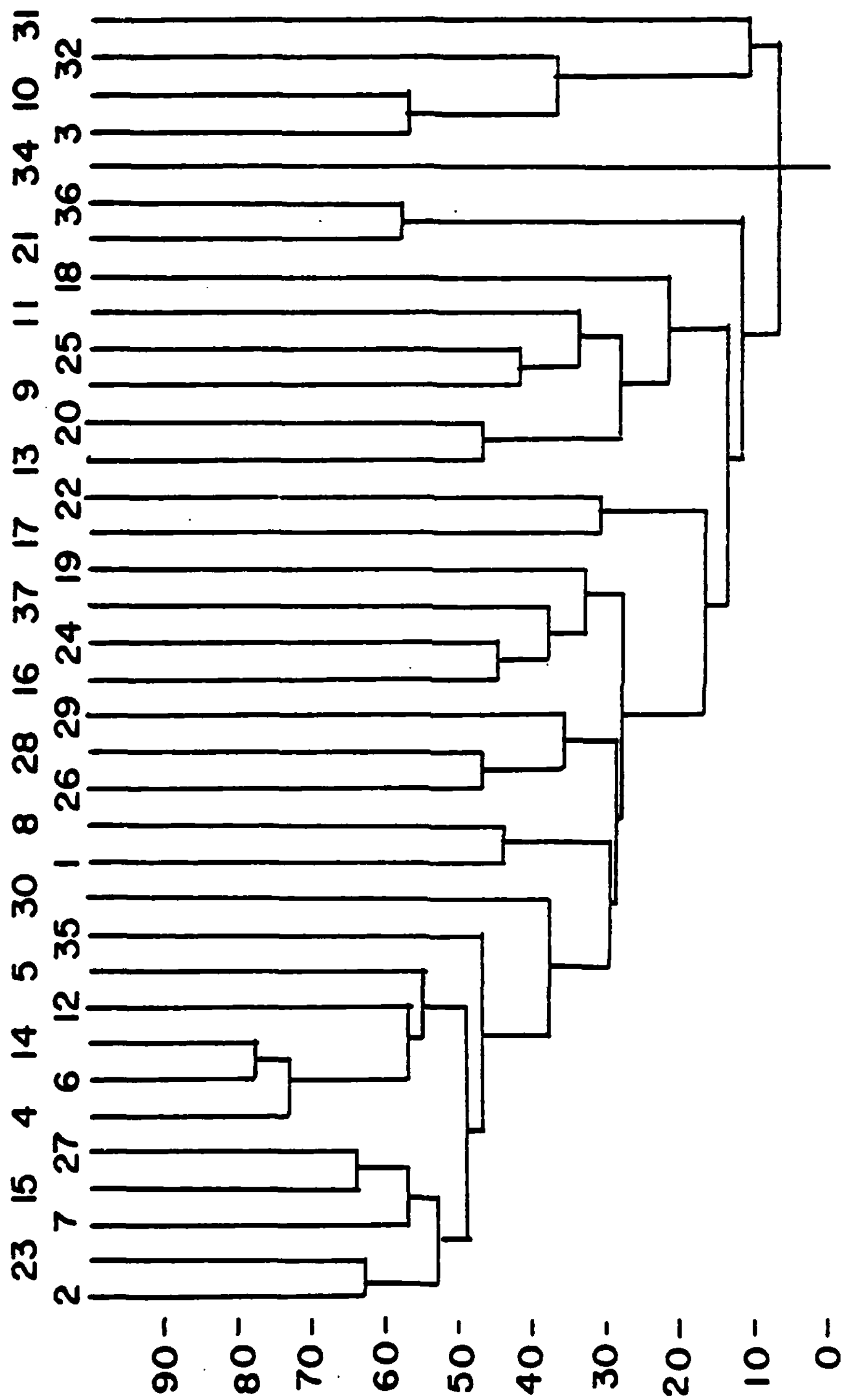
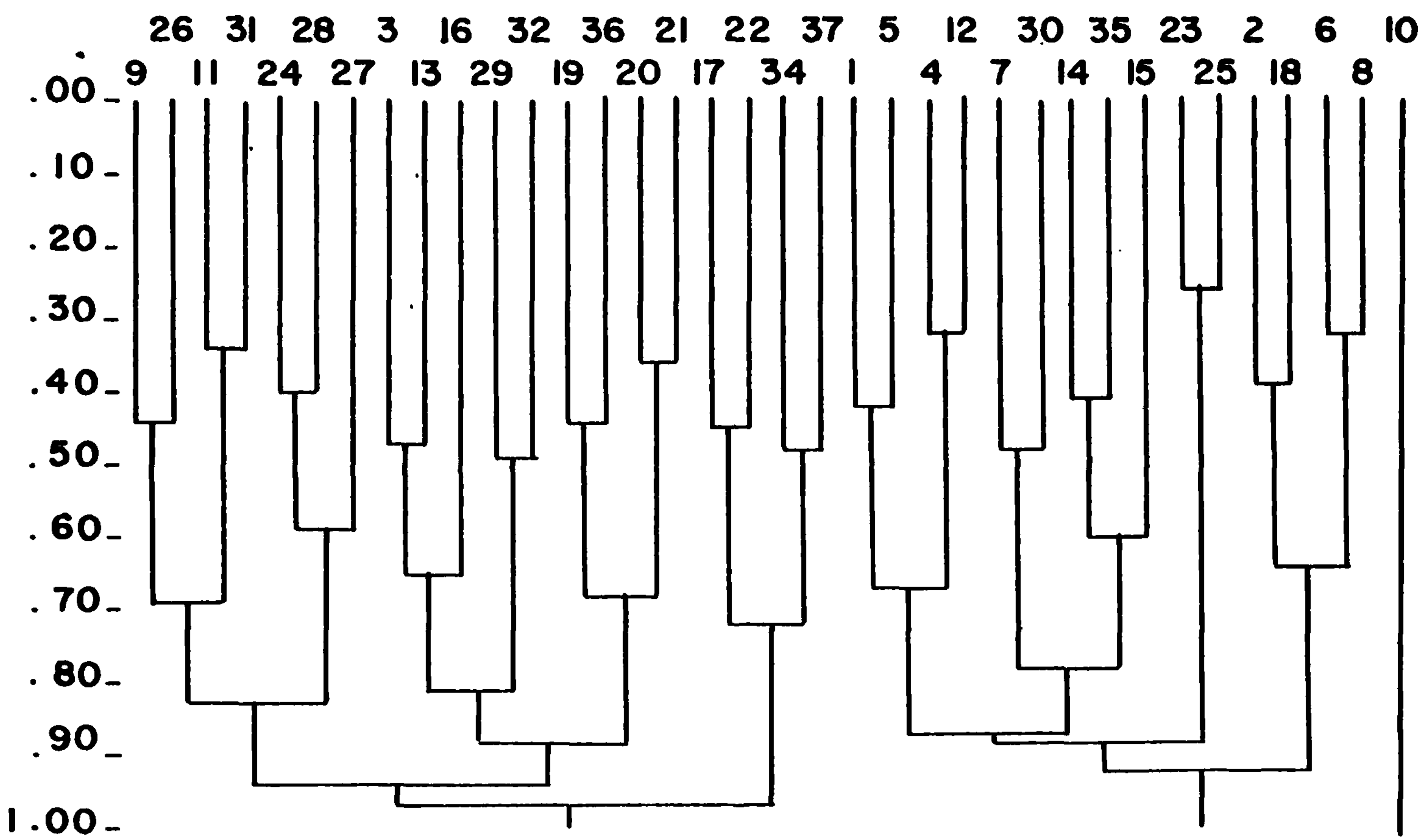


Fig. 5. Clustering of Lake Oahe study sites based on 1973 vegetation data and using an agglomerative clustering technique.

LAKE OAHE, ZONE 2



composition of communities the first year following high water, and many of the first year species survive to the second and third years, the vegetation composition is still sufficiently distinct, especially among the dominants, that a simple subjective grouping satisfies the initial needs of the present study. The objective computer generated groupings (Fig. 4 and 5) can be useful in refining the subjective classification.

In summary, the following types of vegetation occur along the shore of Lake Oahe:

DOMINANTS:	SECONDARY SPECIES:
Agropyron smithii *Hordeum jubatum* *Rumex crispus* OR *Agropyron smithii* *Bromus japonicus* *Hordeum jubatum* OR	*Panicum capillare* *Bromus japonicus* *Lactuca serriola* *Rumex salicifolius* *R. maritimus* *Helianthus annuus* *Conyza canadensis* *Salix* spp. *Populus deltoides* *Chenopodium album* *Polygonum lapathifolium*
Kochia scoparia *Hordeum jubatum* *Agropyron smithii*	*Poa pratensis* *Lactuca serriola* *Melilotus* spp. *Convolvulus arvense* *Sonchus arvensis*

These three community types are distinguishable for three years following high water on the shore. For reasons stated above, there is considerable variation from site to site, and in places one or more of the dominants or the secondary species may be lacking from the community. In other places species listed above as secondary are dominants.

Edaphic Characteristics of the Substrates.---Results of the soils tests are presented in Table 6. As indicated above, several textural classes were present, ranging from clays to sandy loams. Most substrates are slightly alkaline, have considerable Ca, Mg and K contents, and highly variable amounts of organic matter and total N. Many of the substrates are raw parent material and have been but slightly altered by the soil-forming processes. We did not run tests on levels of micronutrients. Electrical conductivities of soil extracts indicated no salinity (sodium) problems. None of the pH values were high enough to indicate an alkali problem.

In the field we tested soil moisture status of several substrates throughout the growing seasons of 1973 and 1974. Soil moisture was not limiting at any of the locations during the times of our measurements.

Lake Sakakawea Vegetation

Description and Successional Trends.---Around Lake Sakakawea three zones of vegetation are evident. Zone one is the upland steppe vegetation that has never been inundated, but areas of which have been grazed or cultivated. Zone two is the upper part of the shore that is inundated occasionally. The high water in 1969 set the upper limit of zone two which remained until 1975 when the record high water level occurred (Fig. 6). Zone three vegetation is a distinct fringe of vegetation close to the edge of the water that is inundated

Table 6. Edaphic characteristics of substrates of Lake Oahe shore sites.

	Mechanical Analysis				Readily Available Nutrients, ppm					Organic	
Site	Sand	Silt	Clay	Textural Name	Ca	Mg	K	P	N	Matter	pH
1	27 %	43 %	30 %	Clay loam	8000	1500	320	200	.08 %	.08 %	6.6
2	53	23	24	Sandy clay loam	16000	750	320	50	.21	T[a]	6.8
3	18	26	56	Clay	12000	750	320	200	.08	.05	7.4
4	27	35	38	Clay loam	12000	500	240	200	.16	T	7.4
5	33	27	40	Clay-Clay loam	8000	375	80	100	.04	.07	7.4
6	50	28	22	Sandy clay loam	12000	500	320	100	.50	.04	7.3
7	27	63	10	Silt loam	8000	500	320	200	.29	1.0	7.1
8	40	50	10	Loam	12000	250	320	200	.16	.07	7.2
9	40	47	13	Loam	8000	500	320	200	.09	T	7.5
10	22	21	57	Clay	16000	1000	160	200	.05	.10	7.7
11	25	54	21	Silt loam	24000	---	160	25	--	--	7.7
12	30	61	9	Silt loam	8000	750	160	200	.23	.19	7.1
13	32	25	43	Clay	8000	750	320	200	.10	T	7.3
14	31	53	16	Silt loam	8000	250	320	200	.24	T	
15	34	50	16	Loam	4000	375	320	200	.16	T	6.8

Table 6, cont'd.

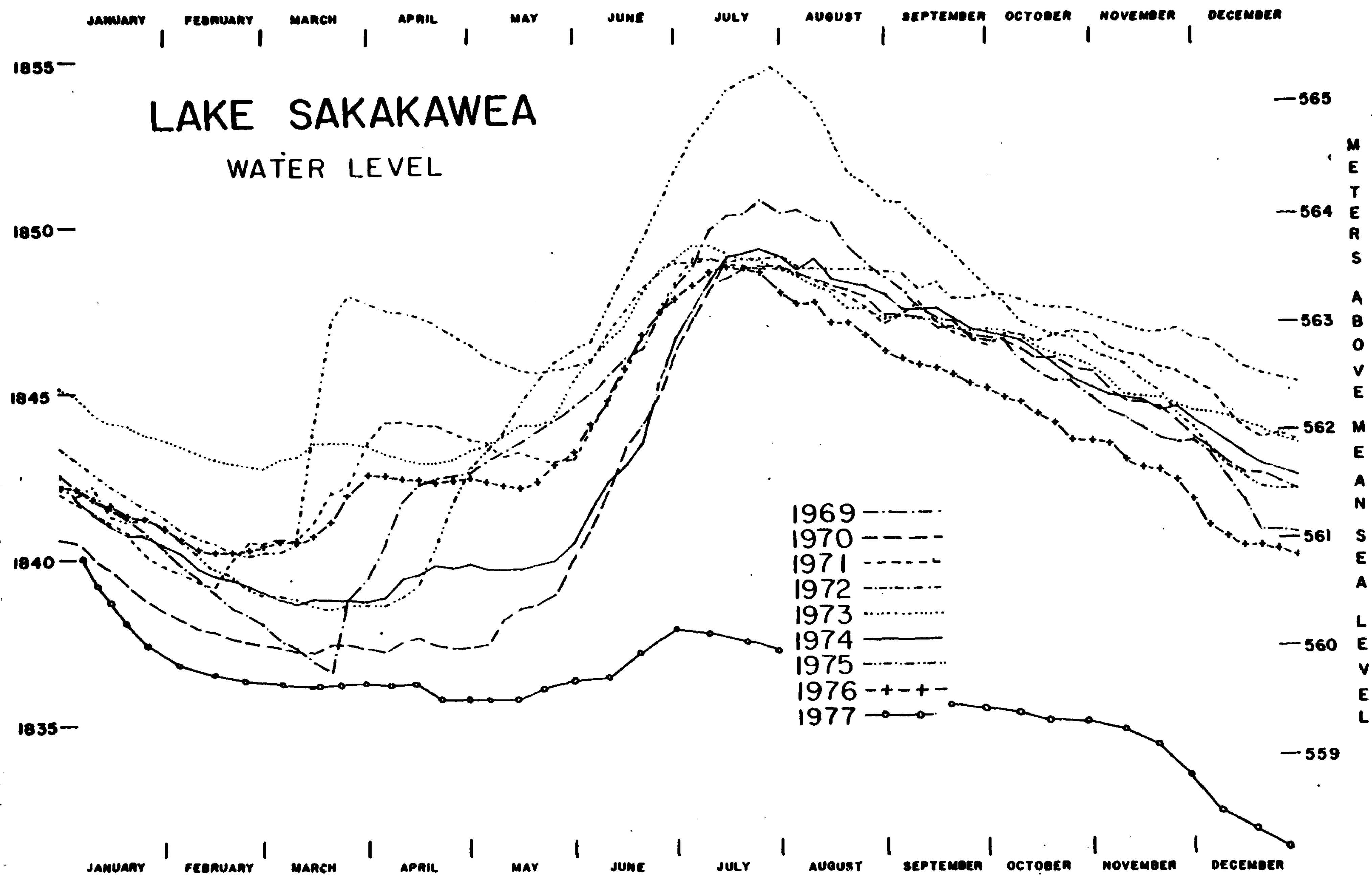
	Mechanical Analysis				Readily Available Nutrients, ppm					Organic	
Site	Sand	Silt	Clay	Textural Name	Ca	Mg	K	P	N	Matter	pH
16	22 %	34 %	44 %	Clay	3000	750	320	125	.07 %	.14 %	6.4
17	54	35	11	Silt loam	6000	750	240	200	.11	.27	7.2
18	26	26	48	Clay	3000	750	160	100	.11	T	7.3
19	44	29	27	Clay loam	8000	500	340	200	.18	T	7.2
20	33	46	21	Loam	6000	750	320	200	.10	T	7.8
21	25	36	39	Clay loam	8000	750	320	200	.20	.14	7.4
22	52	39	9	Sandy loam	4000	250	240	200	.00	T	7.3
23	59	31	10	Sandy loam	8000	500	320	200	.21	.74	7.4
24	23	40	37	Clay loam	12000	500	320	200	---	.21	7.2
25	30	61	9	Silt loam	8000	1000	320	200	.32	.28	7.3
26	58	22	20	Sandy clay loam	12000	500	320	200	.10	T	7.6
27	26	29	45	Clay	5000	500	240	125	.01	.03	5.6
28	8	40	52	Silty clay	2500	250	140	100	.23	.38	6.5
29	65	23	12	Sandy loam	6000	750	320	200	.25	.42	6.4
30	66	22	12	Sandy loam	3000	500	160	75	.16	.59	6.8
31	36	32	32	Clay loam	6000	375	320	75	---	T	6.4

Table 6, cont'd.

	Mechanical Analysis				Readily Available Nutrients, ppm					Organic	
Site	Sand	Silt	Clay	Textural Name	Ca	Mg	K	P	N	Matter	pH
32	75 %	18 %	7 %	Sandy loam	4000	750	480	300	.04 %	T	7.2
33	26	66	8	Silt loam	3000	750	160	100	---	.22 %	---
34	44	34	22	Clay	8000	250	240	300	.22	.37	7.6
35	54	37	9	Sandy loam	6000	750	480	600	.20	T	7.4
36	28	64	8	Silt loam	3000	1000	400	400	---	.51	7.2
37	72	19	9	Sandy loam	2000	500	160	100	.18	T	7.5
38	58	32	10	Sandy loam	4000	500	400	400	.23	T	7.5

[a]T = trace.

Fig. 6. Water level fluctuation curves for Lake Sakakawea, 1969-1977.


LAKE SAKAKAWEA
WATER LEVEL
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
1855
1850
1845
1840
1835
565
564
563
562
561
560
559
METERS ABOVE MEAN SEA LEVEL
1969
1970
1971
1972
1973
1974
1975
1976
1977

nearly every year. Zone two exhibited succession from 1971, the first year of this study, through 1974, the year before the all-time high water. Following the 1975 water level, zone two was much expanded and many species were eliminated. What succession had occurred was set back to an early stage of development.

Zone one vegetation, the upland steppe, was once dominated by Agropyron smithii and Stipa viridula with a rich mixture of forbs, shrubs and graminoids. In the lower parts of the landscape, or where moisture is otherwise more favorable, woody vegetation predominates. Around Lake Sakakawea much of the uplands have been distinctly altered by grazing and cultivation. During this study we encountered 142 species of plants in sample plots in zone one (Table C, Appendix). Throughout the vegetation matrix low-growing shrubs like Symphoricarpos occidentalis, Rosa woodsii and R. arkansana, are locally abundant and in places can form quite extensive pure stands. Agropyron smithii is ubiquitous and also locally abundant over much of the western Dakotas. Close to the shore where water balance is more favorable, it often forms pure stands, apparently out-competing numerous associates (Weaver 1942). Where grazing has been evident for an extended period, Poa pratensis, Agropyron cristatum, Agropyron repens and Lactuca oblongifolia are more abundant (Table 7).

As in the case of Lake Oahe the study at Lake Sakakawea centered mainly on the shore vegetation, referred to above as zones two and three vegetation. From 1971 to 1974 zone two

Table 7. Eleven constant-dominant species from each of the three vegetation zones around Lake Sakakawea. Values given are average coverage (COV) and constancy (CON) for the years 1971-1976.

	Zone One		Zone Two		Zone Three	
Species	COV	CON	COV	CON	COV	CON
Bromus inermis	5.0 %	17 %				
Symphoricarpos occidentalis	5.6	28				
Stipa viridula	3.0	30				
Stipa comata	3.0	27				
Lactuca oblongifolia	1.9	36				
Aster ericoides	1.7	26				
Agropyron cristatum	9.7	21	1.9 %	16 %		
Poa pratensis	3.6	31	6.9	42		
Agropyron smithii	23	68	11	58	0.4 %	13 %
Agropyron repens	5.7	28	5.0	40	1.8	20
Hordeum jubatum	2.0	16	13	77	2.5	48
Poa palustris			3.4	32		
Cirsium arvense			2.9	28		
Puccinellia nuttalliana			4.5	37	2.0	37
Phalaris arundinacea			5.2	17	5.7	29
Rumex crispus			5.2	53	4.7	53
Polygonum lapathifolium			3.4	39	19	90
Alopecurus aequalis					1.8	18
Beckmannia syzigachne					1.0	27
Polygonum ramosissimum					0.6	21
Typha latifolia					0.9	12

vegetation extended from the high water mark set in 1969 at 564.2 m down about 1.5 - 2.0 m, depending somewhat on inundation tolerances of species along the lower part of the zone. The actual width of the zone depends on the slope of the shore which differs at different locations around the lake. Dominant species of zone two are Agropyron smithii and Hordeum jubatum with Rumex crispus. Poa pratensis and Agropyron repens next on the list (Table 7). Polygonum lapathifolium is relatively widespread among the study sites (39% constancy) but it has only 3.4% coverage in the zone. Hordeum jabatum was by far the most widespread species in the zone with a constancy of 77%. Other ccnstant-dominants of zone two are listed in Table 7. A complete list of the 134 species encountered in zone two is given in Table D, Appendix. Zone two is a rich mixture of species, most of which are opportunistic in establishing over a wide area of the shore at the time the water level is low. The lower edge of zone two vegetation is marked by a sharp ecotone with zone three which is dominated by Polygonum lapathifolium. The lower portion of zone two is inundated almost yearly. Vegetation succession in zone two apparently responds to water level fluctuations. Following the high water of 1969, results of sampling should indicate whatever successional trends were obvious in zone two until 1975 when high water again eliminated most of the vegetation. Coverages of the 11 most important species of zone two for the years 1971-1976 are given in Table 8. Hordeum jubatum, Agropyron smithii, Poa pratensis and Puccinellia

Table 8. Coverage values of 11 species important in zone two, Lake Sakakawea

Species	Coverages, in Percent					
	1971	1972	1973	1974	1975	1976
Hordeum jubatum	11	24	12	7.8	0.0	8.2
Agropyron smithii	6.7	19	13	12	10	4.9
Poa pratensis	2.4	16	7.6	14	0.9	0.4
Puccinellia nuttalliana	5.2	11	0.4	5.5	0.0	0.3
Agropyron repens	4.1	6.7	7.1	4.7	0.0	2.4
Phalaris arundinacea	1.7	6.7	6.6	7.2	0.0	4.0
Poa palustris	+[a]	6.2	7.5	1.4	0.2	5.3
Cirsium arvense	0.3	3.9	4.4	6.7	0.7	1.3
Rumex crispus	3.2	3.9	2.6	4.3	0.0	12
Polygonum lapathifolium	1.5	3.8	3.7	2.5	0.0	5.4
Agropyron cristatum	2.5	1.7	2.1	1.0	3.8	0.1

[a] + = less than 0.1% coverage.

nuttalliana all increased significantly from 1971 to 1972, then decreased from 1972 to 1973. From 1973 to 1974 *H. jubatum* and *A. smithii* decreased and remained nearly the same, respectively, while *P. pratensis* and *P. nuttalliana* both increased significantly.

Agropyron repens and *Poa palustris* both increased from 1971 to 1972, then increased and remained about the same, respectively, from 1972 to 1973; and both decreased from 1973 to 1974. *Polygonum lapathifolium* showed a similar pattern from 1971 to 1974. *Phalaris arundinacea* and *Rumex crispus* both increased from 1971 to 1972 and both decreased from 1972 to 1973 (*Phalaris* only slightly); then both increased again from 1973 to 1974.

The only species in Table 8 that increased in coverage each year from 1971 to 1974 was *Cirsium arvense*. The only species that decreased from 1971 to 1972 was *Agropyron cristatum*, which then increased from 1972 to 1973 and decreased from 1973 to 1974.

In 1975 the all-time high water level in Lake Sakakawea drowned many plants of zone two (Table 8); but in 1976 both *Rumex crispus* and *Hordeum jabatum* showed a considerable increase in coverage.

These various trends in coverage from 1971 to 1974 are not simple to explain. One difficulty lies in the unknown autecologic requirements of most species of this vegetation. Another is the lack of consistent patterns of water level fluctuations during the years of the study. Following 1969, the peak water levels in Lake Sakakawea were very close from one year to the next, until 1975. The major differences in the fluctuations were in the patterns of spring rise and late summer to early fall recession (Fig. 6). We have observed literally thousands of _Rumex crispus_ seedlings established on the bare moist shore during the late summer when water is receding. Cooler and cooler temperatures during the fall retard, then finally stop, the germination and establishment of _Rumex_, though the water level continues to recede usually reaching its low point during February or March of the following year. The _Rumex_ overwinter as rosettes until the next summer when the plants flower. Just as around Lake Oahe, _Rumex_ is most abundant around Lake Sakakawea during the summer following high water (see Table 8 and Fig. 6). There is a positive correlation between the timing of water level recession and the coverage of _Rumex crispus_ the following summer. More dense and extensive stands dominated by _Rumex crispus_ are established during those years when water level recedes somewhat earlier following its peak in middle to late July. Certain it is that only a few years of data were obtained, but the hypothecated relationship holds. Coverage of _Rumex crispus_ was 3.8%, 7.5% and 2.8% in 1971, 1972 and 1973 respectively. Water level receded earlier in 1971 allowing more _Rumex_ to extablish which was reflected by the 7.5% coverage in 1972. In 1972 water level receded more slowly (Fig. 6), which retarded somewhat the establishment of _Rumex_ and its 1973 coverage was only 2.8%. Water level receded earlier again in 1973 and the abundance of _Rumex_ was up to 4.3% in 1974.

Following the all time high water level in 1975, Rumex coverage was 12% in 1976. This was unusually high coverage, and even though water level dropped rapidly in 1976 the coverage of Rumex in 1977 was down to 4.3% in zone two. Both Poa pratensis and Pucinellia nuttalliana follow similar coverage trends as Rumex crispus. The major difference is that the two grasses exhibited much greater differences between years of low and high coverage. Both grasses are perennials, and during years following more rapid water level recession they too reinitiate growth in the fall before cold temperatures slow and finally stop their growth.

It is tempting, but too speculative, to implicate patterns of the spring rise in water levels to the changing coverages of certain plant species. At present we can record the changes in species coverages, but we are unable to account for all the changes. It is entirely possible that the four year period, 1971-1974, followed too closely the high water year of 1969 to show very many clear trends in vegetation development. As indicated above we also know so little about the autecologic requirements of most of the species that predictability of vegetation development is severely limited on that regard alone. One event did have predictable results. The high level in 1975 set back most of the vegetation development along the shore. The years 1976 and 1977 were ones of early recovery from the high water.

Zone three vegetation is that nearest the water and is inundated almost yearly. The zone ordinarily occupies the elevational range 560.0 - 563.4 m, though the actual range varies depending upon water level fluctuation through the growing season. Many of the constant-dominants of zone three are shared with zone two (Table 7), and three species---Agropyron smithii, Agropyron repens and Hordeum jubatum---are shared with both zones one and two. Four species---Alopecurus aequalis, Beckmannia syzigachne, Polygonum ramosissimum and Typha latifolia---occur as dominants only in zone three. The major dominant of zone three is Polygonum lapathifolium. While it also occurs in zone two, its coverage and constancy in zone three are the key to recognizing the zone. Polygonum establishes on the shore during the spring below the edge of the Rumex-dominated zone two, before the water level is sufficiently high to inundate the zone. Like most of the regularly occurring species of zone three, Polygonum lapathifolium is relatively tolerant of inundation. Of the 107 species encountered in this zone only 25 occurred during four of the six years shown in Table E, Appendix. Most species of the zone are eliminated by inundation, become reestablished the following year only to be drowned again; and the cycle is repeated. Also, because the vegetation is just at the edge of the water, and the timing and magnitude of water fluctuation varies from year to year, the species could possibly be inundated about the time of sampling. This is a rather remote possibility owing to the fact that 38 sites are sampled yearly and a species need be sampled at just one site to be included for that year in Table E.

In addition to Polygonum lapathifolium, Phalaris arundinacea and Rumex crispus both have average coverages of nearly 5% (Table 7). Though it has only 2.5% coverage, Hordeum jabatum had a constancy of 48%. Puccinellia nuttalliana had an average coverage of 2.0% and a constancy of 37%. The remaining seven species listed in Table 7 for zone three have coverages and constancies that seem low until compared with the remainder of zone three species. Seven of the eleven dominants of zone three are also present in zones two and/or one. The boundary, however, between zones two and three is quite distinct, can be observed from considerable distance, and any manipulation of the vegetation data to obscure the ecotone would do an injustice to a basic sensory perception. Additionally, the ecotone between zones two and three represents a point along the gradual environmental gradient that is of singular ecological significance. It represents that point where cool temperatures during the fall when water is receding retard, then halt, germination and establishment of zone two species. Below this point, zone three species become established in the spring before the water has reached that level. Certain it is that some zone three species do become established during the late summer and early fall particularly during those years when water recedes early; the dominants Rumex crispus and Polygonum lapathifolium follow the pattern described above more faithfully than most of the other species.

Phalaris arundinacea is a large, vigorous grass that appears reasonably well-suited to the shore environment. It is important at a number of sites on Lake Sakakawea. Once established, it persists and also spreads. Though its average constancy was 29% and its coverage 5.7% during the years 1971-1976, it is instructional to examine the dynamics of the species at a site where it is dominant. At Sanish Bay the plant spread from a relatively few tussocks to an almost continuous fringe along the lower shore. Its coverage went from a meager 12% in 1971 to 42% in 1972, 62% in 1973, 75% in 1974, down to 11% in 1975, the year of high water, and back up to 38% in 1976, then down somewhat, to 23% in 1977. Where this species was seeded at other sites, it has succeeded remarkably well even to the stage of spreading over a larger territory.

Trends in zone three vegetation are discernible, and cause and effect of the trends is determined mainly by deduction. The total coverage of the eleven important species in Table 9 shows the following trends:

TOTAL COVERAGE	YEAR
21.2 %	1971
51.1 %	1972
29.7 %	1973
41.4 %	1974
11.0 %	1975
54.9 %	1976

Except for 1976, the total coverage values relate closely to the timing of water level recession in the late summer and early fall of the previous years. For example, if water level recedes relatively early in one year, the total coverage of zone three increases the following year. If water levels recede somewhat later during the late summer/early fall of one year, then the total coverage of zone three decreases the following year. The correlation between total coverage and time of water level recession the previous year breaks down completely for 1975-76. The water level reached an all-time high in 1975, and receded rather slowly at the end of the season; yet the total coverage in zone three had its highest value in 1976. The explanation I suggest for this is based mainly on the success of Polygonum lapathifolium in 1976 with its coverage of 41% (Table 9). The high water in 1975 drowned most of both zone two and zone three vegetation to such a degree that recovery of even Rumex crispus was limited (Table 9), especially during the fall of 1975. The more water-tolerant Polygonum lapathifolium was less decimated by the high water of 1975, and the lack of strong competition with Rumex crispus during the spring of 1976 permitted considerable expansion of zone three vegetation, especially that of Polygonum lapathifolium. This explanation is offered less as a hypothesis, since there is no practical way of testing it, than it is as suggestion based on some knowledge of the autecologies of the species involved.

Individual species of zone three exhibit somewhat independent changes in coverage from year to year (Table 9), responding in their own ways more to the physical factors of

Table 9. Coverage values of 11 species important in zone three, Lake Sakakawea.

Species	Coverages, in Percent					
	1971	1972	1973	1974	1975	1976
Polygonum lapathifolium	11	15	12	16		41
Rumex crispus	3.8	7.5	2.8	7.6	2.3	4.4
Phalaris arundinacea	1.7	6.5	7.8	6.1	7.5	4.7
Hordeum jubatum	1.8	3.8	1.6	3.2		2.1
Puccinellia nuttalliana	0.4	4.6	1.1	1.8		
Alopecurus aequalis		6.7	0.2	0.1		0.2
Agropyron repens	1.1	2.0	1.9	2.7		1.3
Beckmannia syzigachne	0.1	2.1	1.2	1.2		0.4
Typha latifolia	0.1	0.5	0.6	2.1	1.2	
Polygonum ramosissimum	0.9	1.1	0.2	0.2		0.8
Agropyron smithii	0.3	1.3	0.3	0.3		+[a]

[a] + = less than 0.1% coverage.

the environment than to any competitive adjustments among species populations. (Cattle grazing as a factor is discussed below.) Polygonum lapathifolium, Rumex crispus, Hordeum jubatum and Agropyron repens all followed trends in coverages much the same as that of the total vegetation of the zone. Beckmannia syzigachne, Agropyron smithii, Puccinellia nuttalliana, Alopecurus aequalis and Polygonum ramosissimum all increased from 1971 to 1972 and decreased from 1972 to 1973. While Puccinellia increased from 1973 to 1974, Polygonum ramosissimum, Beckmannia syzigachne and Agropyron smithii remained the same; and Alopecurus aequalis decreased. All five species were absent from sample plots in 1975, then either remained absent in 1976 or recovered in small amounts. The remaining two species of the zone---Phalaris arundinacea and Typha latifolia---both increased from 1971 through 1973, then Phalaris decreased and Typha increased in 1974. Neither species was absent in 1975, in fact Phalaris was relatively abundant, then decreased in 1976 (Table 9). Typha was absent from any sample plots in zone three in 1976, but it did survive the 1975 inundation in locations where it occurred before 1975.

Because the water level in Lake Sakakawea was very low in 1977, zones two and three were extensive. In some places species diversity was high in both zones. Additionally, Melilotus alba and M. officinalis were abundant 1977, something unrelated to the water level as these clovers are sporadically abundant throughout the study region. The broad zones around the lake allowed better expression of both zones and also considerable intermingling of species of both zones. The dominant of zone two the first year after high water is ordinarily Rumex crispus which is replaced by the second year by Hordeum jubatum as the dominant species. Zone three is ordinarily dominated by Polygonum lapathifolium each year. In 1977, two years after the high water year of 1975, Polygonum lapathifolium did indeed dominate zone three and Hordeum jubatum was dominant over most of zone two. Interestingly, Rumex crispus was more abundant in zone three than in zone two. The very low water level in 1977 provided a broad intermediate zone somewhat similar to zone three as well as to zone two; this is where Rumex crispus was most abundant.

In zone three Rumex crispus is dominant or codominant on 11 sites, and Polygonum lapathifolium is dominant or codominant on 23 sites. Allowing for normal variation, only two kinds of communities are distinguishable in zone two in 1977. One community is dominated by Hordeum jubatum. The second community is dominated by Phalaris arundinacea. In 1977 Agropyron repens along with Melilotus spp. were important in most of zone two sites.

Based only on 1977 field data, the following plant communities were delimited:

Zone Two

Community	Dominants	Secondary Species
1.	Hordeum jubatum Melilotus alba Melilotus officinalis Agropyron repens	Poa palustris Potentilla norvegica Cirsium canadensis Phalaris arundinacea Rumex crispus

2.	_Phalaris arundinacea_	_Melilotus alba_ _Melilotus officinalis_ _Agropyron smithii_

Zone Three

1.	_Polygonum lapathifolium_ _Rumex crispus_ _Hordeum jubatum_	_Kochia scoparia_ _Salsola kali_ _Rumex maritimus_ _Phalaris arundinacea_ _Potentilla norvegica_

Vegetation Classification.---Lake Sakakawea sites were classified objectively with the same techniques used for Lake Oahe sites. Because all sites around Lake Sakakawea occur on substrates of a loam texture and there is considerable uniformity in other edaphic factors, there is little vegetational distinction among the sites solely on the basis of substrates. In zone one sites were grouped more on the apparent similarities in past history than any other factor. Highly overgrazed sites were closely grouped, as were sites that represented near-virgin steppe.

In classifying zone two and zone three vegetation the groupings of sites changed somewhat each year, reflecting the changes in vegetation among the sites and certainly the role that chance plays in the composition of individual sites. Dendrograms for sites of zones two and three are shown in Figs. 7 and 8 based on data collected in 1973. The dendrogram for zone two, Fig. 7, shows three clusters of sites. The cluster composed of sites 5, 25 and 26 were dominated in 1973 by _Agropyron repens_ and _Agropyron cristatum_ in addition to _Rumex crispus_ and _Hordeum jubatum_. The cluster of sites 6, 31, 14, 16, 10 and 19 were dominated in 1973 by _Agropyron_

Fig. 7. Clustering of Lake Sakakawea zone two study sites based on 1973 vegetation data and using a weighted pair clustering technique.

LAKE SAKAKAWEA, ZONE 2

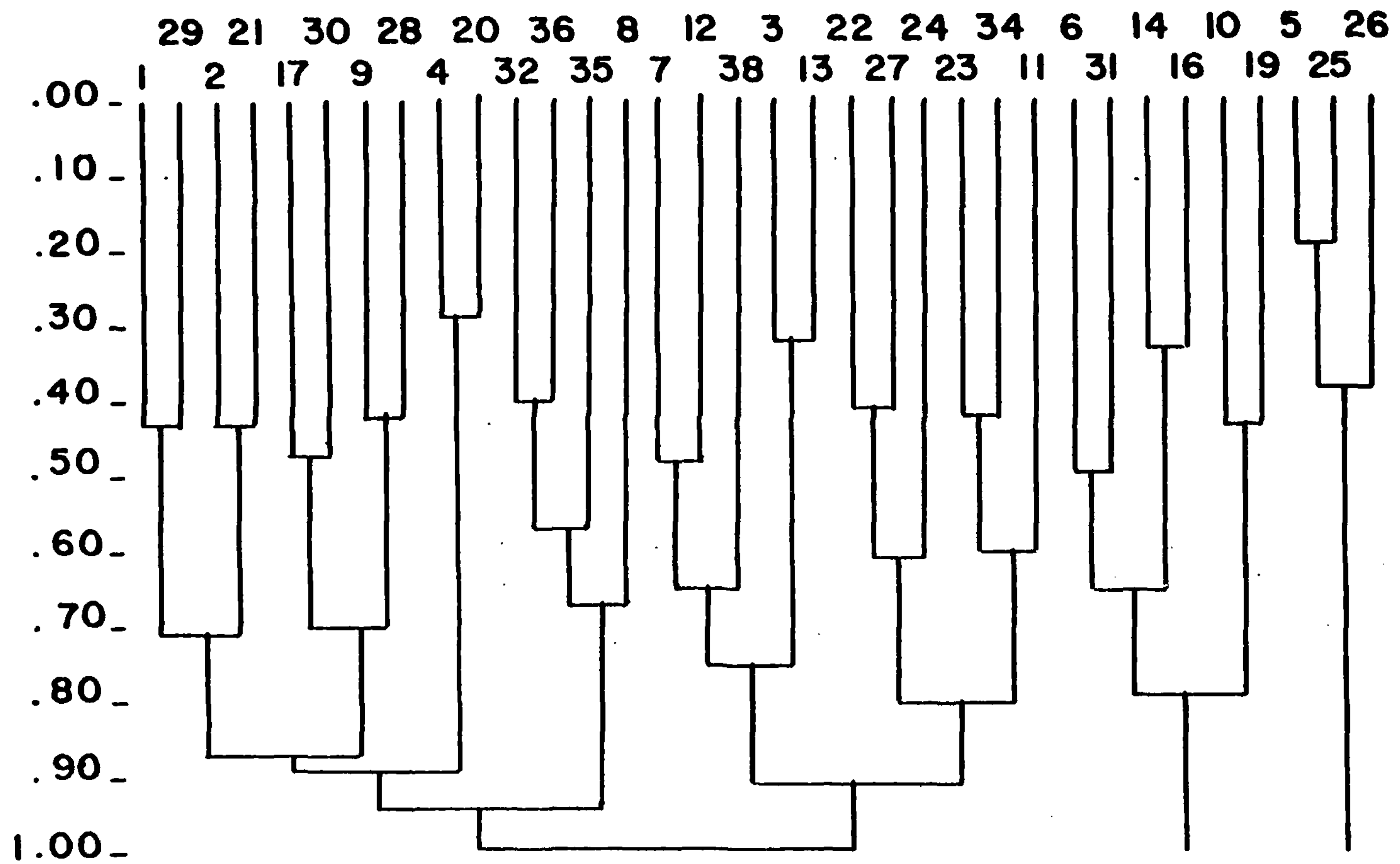
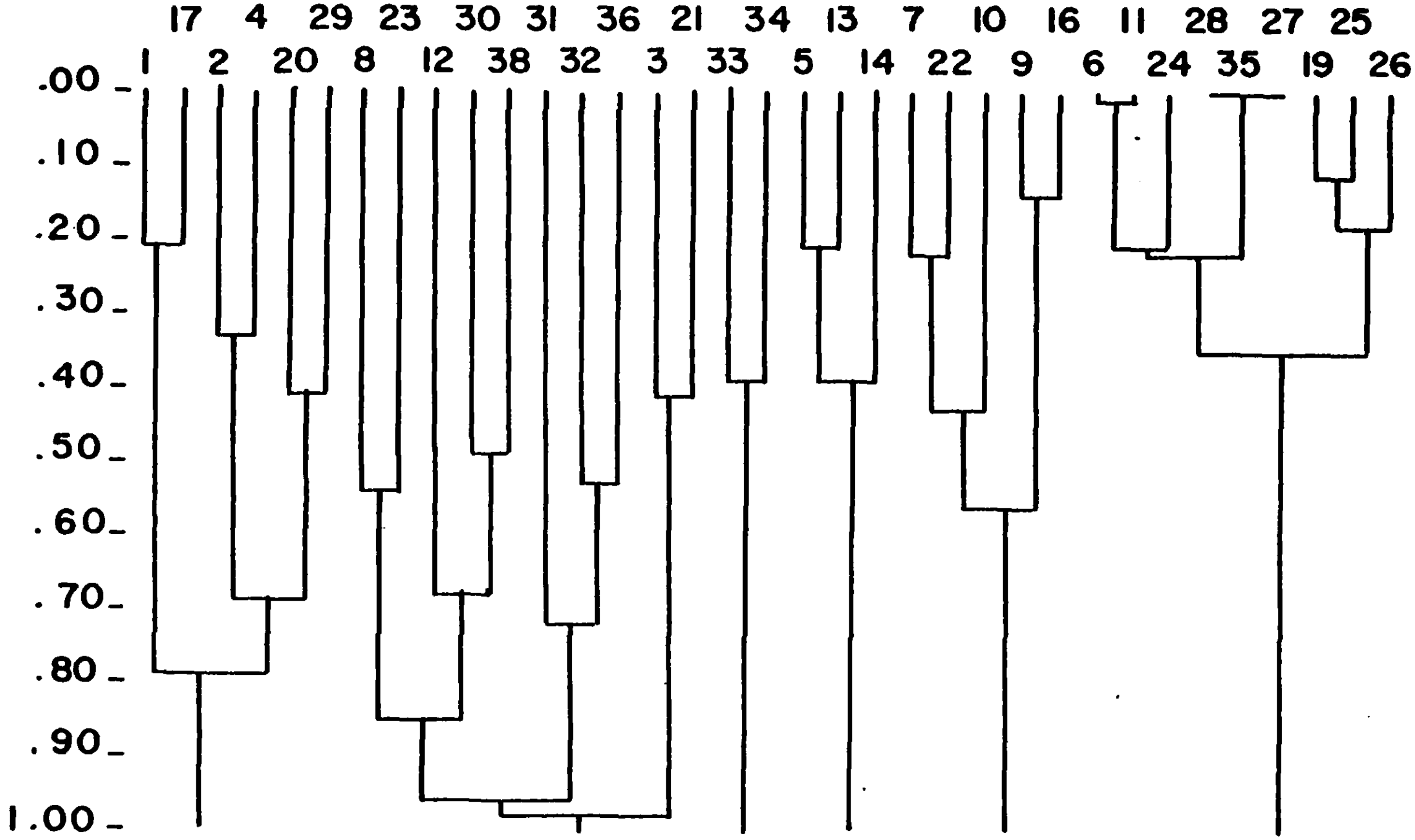


Fig. 8. Clustering of Lake Sakakawea zone three study sites based on 1973 vegetation data and using a weighted pair clustering technique.

LAKE SAKAKAWEA, ZONE 3



repens, Poa palustris, Melilotus spp. and Poa pratensis in addition to Rumex and Hordeum. The final large cluster of sites is dominated by Hordeum jubatum and Rumex crispus with minor secondary species occurring among the various sites.

Zone three vegetation groupings are shown in Fig. 8; six groups of sites are shown in the figure. The variability is more apparent than real among the sites, because all species are given equal weight in the computer program that generated the groupings shown. In assessing the shore vegetation the ecologist would hardly give equal weight to all species. The explanation for the groupings as shown is this. Sites 1, 17, 2, 4, 20 and 29 all have considerable Phalaris arundinacea along with Polygonum lapathifolium as dominant species. In this case these six sites should be recognized as separate, because of the importance of Phalaris as a dominant shore species that has much potential over a broader range of the shore, in terms of both geography and time. Sites 6, 11, 24, 28, 35, 27, 19, 25 and 26 all have considerable amounts of Agropyron cristatum, Poa palustris and Beckmannia syzigachne along with Polygonum lapathifolium. Sites 33 and 34 have these same species as dominants, but for some reason peculiar to the computer program they were not lumped with the previous group. Sites 7, 22, 10, 9 and 16 are dominated by Poa pratensis and Hordeum jabatum in addition to Polygonum lapathifolium. Sites 5, 13 and 14 are dominated by Kochia scoparia along with Polygonum lapathifolium. Finally, the remaining sites of zone three are dominated by Polygonum lapathifolium with a few secondary species that have much coverage.

The same shortcomings that applied to objective classification of Lake Oahe zone two vegetation also apply to Lake Sakakawea vegetation. The groupings only reflect the site similarities for 1973. Manipulating the data for another year results in somewhat different groupings since some of the dominant species in 1973 are much less important at a later (or earlier) time. Additionally, the methods of objective classification differ in their end results as seen in Figs. 4 and 5 for Lake Oahe vegetation. In the final analysis the investigator must determine the usefulness of such classifications and whether they reflect similarities and/or differences that are important ecologically.

Edaphic Characteristics of the Substrates.---Substrates on the shore of Lake Sakakawea are relatively uniform in texture and certain chemical properties (Table 10). In general nitrogen contents are higher and phosphorus contents are lower than in substrates of Lake Oahe. All the substrates are loams ranging from sandy loams to silty clay loam at one site. The pH values are less than 7.0 at 16 of the sites and at only two sites is the pH 8.0 or higher. Nitrogen and phosphorus contents are quite variable, depending upon the kind of substrate and past vegetational history.

Table 10. Edaphic characteristics of substrates of Lake Sakakawea shore sites.

	Mechanical Analysis				Readily Available Nutrients, ppm					Organic	
Site	Sand	Silt	Clay	Textural Name	Ca	Mg	K	P	N	Matter	pH
1	48 %	34 %	18 %	Loam	3000	125	120	25	.30 %	.65 %	6.6
2	55	22	23	Sandy clay loam	3000	250	80	25	.20	.48	6.9
3	47	28	25	Loam	2000	125	160	25	.24	.14	6.8
4	40	42	18	Loam	3000	125	160	100	.23	.01	7.4
5	42	43	15	Loam	2000	250	80	62	.21	.27	6.4
6	35	43	22	Loam	3000	250	160	62	.69	1.3	7.0
7	25	52	23	Silt loam	2000	250	160	62	.31	.48	6.3
8	14	43	43	Silty clay loam	3000	500	160	62	.27	.12	7.8
9	59	26	15	Sandy loam	2000	250	160	62	.13	1.9	6.3
10	65	22	13	Sandy loam	3000	250	160	38	.18	.14	7.3
11	61	27	12	Sandy loam	3000	250	160	62	.15	.69	6.3
12	39	40	21	Loam	3000	125	160	100	.28	.14	6.7
13	47	32	21	Loam	3000	250	160	38	.18	.18	7.3
14	40	34	26	Loam	3000	500	120	12	.17	.18	7.5
15	27	47	26	Loam	3000	600	160	12	.17	.10	6.7
16	62	28	10	Sandy loam	3000	500	160	62	.17	.01	7.2

Table 10, cont'd.

Site	Sand	Silt	Clay	Textural Name	Ca	Mg	K	P	N	Organic Matter	pH
	Mechanical Analysis				Readily Available Nutrients, ppm						
17	62 %	28 %	10 %	Sandy loam	3000	600	160	38	.14 %	.10 %	7.7
18	25	43	32	Clay loam	3000	600	160	12	.23	.10	7.7
19	48	27	25	Sandy clay loam	3000	600	160	12	.11	.14	7.1
20	32	51	17	Loam	3000	500	160	100	.25	.10	7.4
21	31	56	13	Silt loam	2000	600	120	12	.16	.10	8.5
22	73	16	11	Sandy loam	3000	250	160	62	.22	.05	6.5
23	51	28	21	Sandy clay loam	3000	400	160	100	.25	5.1	7.4
24	40	40	20	Loam	3000	1000	160	100	.27	.10	6.1
25	75	18	7	Sandy loam	3000	1000	160	12	.11	.05	7.5
26	46	37	17	Loam	3000	500	120	100	.28	.10	8.0
27	42	42	16	Loam	3000	1000	160	25	.14	.05	7.8
28	52	23	25	Sandy clay loam	3000	1000	160	25	.13	.05	7.5
29	41	38	21	Loam	3000	1000	120	12	.08	.10	6.7
30	49	27	24	Sandy clay loam	3000	1000	160	25	.07	.14	6.0
31	49	33	18	Loam	1000	1000	120	62	.16	.10	7.2

Table 1Q cont'd.

	Mechanical Analysis				Readily Available Nutrients, ppm					Organic	
Site	Sand	Silt	Clay	Textural Name	Ca	Mg	K	P	N	Matter	pH
32	35 %	40 %	25 %	Loam	3000	1000	120	38	.25	.10	7.3
33	30	52	18	Silt loam	2000	1000	160	62	.19	.10	6.7
34	52	35	13	Loam	3000	1000	80	62	.07	.05	6.4
35	40	36	24	Loam	3000	1000	160	62	.20	---	7.0
36	30	46	24	Loam	2000	1000	120	100	.36	.14	6.2
37	45	36	20	Loam	3000	1000	160	100	.25	.05	7.5
38	65	21	14	Sandy loam	3000	1000	120	25	.16	.10	7.8

EXPERIMENTAL ESTABLISHMENT OF PLANTS ON LAKE SHORES

In 1973 the scope of the study was broadened to include experiments on establishing plant species on the shore of both lakes. From the limited data of 1971 and 1972, it seemed apparent that some naturally-occurring species were more tolerant than others of inundation. Additionally, as discussed above, some species appeared more abundant following high water only to be replaced the following year by other species which may or may not be more tolerant of inundation. No data were available to permit ranking of species regarding relative inundation tolerance. It seemed logical to select species that were indeed hydrophytes, such as *Typha* and *Scirpus*, as well as other species that show preference for very mesic habitats, such as *Phalaris*. Ecologically, the absence of a species from a habitat means little; but the presence of a plant species is important if we understand the significance of its presence. Along the Lake shores the presence and/or absence of any species could indicate the presence and/or absence of disseminules at the right time for germination and establishment. The patterns of vegetation zonation, discussed above, do suggest species response to environmental conditions resulting in more than a haphazard scattering of species. In selecting plants for experimental establishment the choices included some not found at any of our sites in 1971 or 1972, some that were present, and some that we would never expect to find at our sites but wished to try them. The availability of disseminules and/or transplants also determined to some extent the choices of species.

Methods

We selected 17 sites for plantings, 8 on Lake Sakakawea and 9 on Lake Oahe (Fig. 9). The sites were selected on the bases of slope, substrates, geographic distribution and accessibility. Most sites have a slope of less than 10°, they are well-distributed around the Lakes, include most of the substrates surrounding the lakes, and are accessible by automobile. Because cattle grazing is important throughout the study region, and cattle have ready access to the Lake shores, we built exclosures at 12 sites where there was no protection from grazing. The remaining five sites are in areas presumably free of grazing.

Exclosures were built using steel posts spaced about 10 m apart and strung with four strands of barbed wire. The corners of the exclosures were reinforced with additional posts and wire. "No trespassing" signs were posted to reduce the possibility of vandalism at the study sites. All exclosures were approximately 50 x 100 m with the long dimension perpendicular to the shoreline and the lower ends of the exclosure were low enough on the shore that at least the lower part of each exclosure was inundated yearly. An exception was 1977 when water levels were very low and 1975 when water levels were high enough to inundate all the area of most of the exclosures. We visited the exclosures several times yearly to assess plant growth and repair fences. During the tenure of the study, only one exclosure, at Site 13, was removed by a rancher.

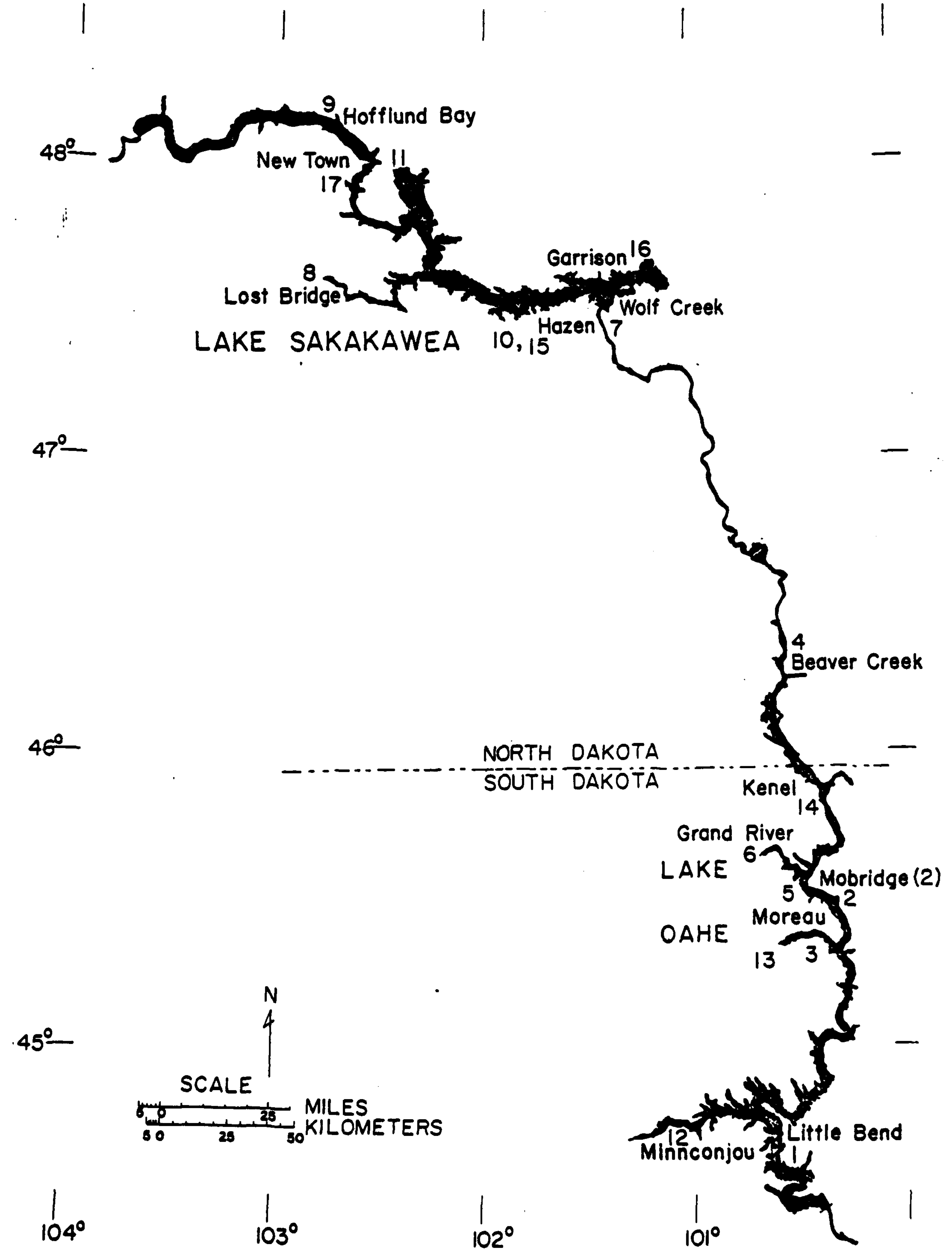
Whether started from disseminules or transplants, all species were planted in rows perpendicular to the shoreline. Species were started in the spring or fall when the water levels were low. The lowermost plants of each row extended far enough onto the lower shore to be inundated the following growing season. We tried in every case to use disseminules or transplants of species ecotypes that were adapted to the region. Most species were obtained from the Soil Conservation Service Plant Materials Center in Mandan, North Dakota, the Lincoln-Oakes Nursery of Bismarck, North Dakota, or from the field where we collected them ourselves. U.S. Army Corps of Engineers personnel, using heavy equipment, plowed and disked some of our planting sites. We used a hand-operated roto-tiller to prepare the remaining sites for planting.

Disseminules were seeded rather heavily, by hand, in furrows about 5 cm deep and were then covered with mineral soil. Transplants were spaced 5 - 10 m apart depending somewhat on the slope and therefore the width of the shore during a "normal" year. Transplants of *Typha* and *Scirpus* taken from nearby ponds were 1 - 2 dm in diameter at the base. Plants were started during both the spring and fall of 1973, 1974 and 1975, and during the spring of 1976. We visited the sites periodically each year to determine survival of each species. The site locations are shown in Fig. 9.

Longevity of Established Species

Table 11 summarizes times of plantings and periods of survival of the species. Throughout the table the symbol # indicates the species were killed by high water in 1975.

Fig. 9. Study sites for planting experiment are numbered 1 through 17. Site 13 was abandoned after less than a year. Sites for grazing and fertilizer studies are named.



9 Hofflund Bay
48°
New Town
11
17
8
Lost Bridge
Garrison 16
Wolf Creek
Hazen 7
LAKE SAKAKAWEA 10, 15
47°
4
Beaver Creek
46°
NORTH DAKOTA
SOUTH DAKOTA
Kenel
14
Grand River
6
LAKE
Mobridge (2)
5
2
Moreau
OAHE
13
3
N
45°
SCALE
MILES
KILOMETERS
12
Minnconjou
Little Bend
1
104°
103°
102°
101°

Table 11. Times of seeding and/or transplanting species onto experimental sites, indicated by letters. Times when plants were checked for survival are indicated by numbers and symbols.[a]

Species	Site Number 1	2	3	4	7	8	9	12	14	15	16	17
Seeded Species												
Phalaris arundinacea	A,B 0	A,B,C + #	A,B,C, F + #	A,B,C 1 #	A,B,C + *	A,B,C 1 #	A,B,C 0	D,G 0 *	D,E,G + #	D,E,G + *	D,E,G + *	D,E,G + *
Agropyron smithii	A,B 0	A,B,C 0	A,B,C + #	A,B,C 1 #	A,B,C 1 #	A,B,C 1 #	A,B,C 0	D 0	D,E 0	D,E + #	D,E + #	D,E 0
Agropyron cristatum	A,B 0	A,B 1 #	A,B + #	A,B 1 #	A,B + #	A,B 1 #	A,B 0					
Panicum virgatum	A,B 0	A,B 0	A,B 0	A,B 0	A,B 0	A,B 0	A,B 0		E 0	E + #	E + #	E + #
"Pasture Mix"[b]	A,B 0	A,B 0	A,B + #	A,B 1 #	A,B 1 #	A,B 1 #	A,B + #					
Alopecurus arundinaceus		C 0	C,F + *	C,F 0 *	C + *	C,F 0 *	C 0	D,G 0 *	D,E + #	D,E,G + *	D,E,G + *	D,E + #
Puccinellia nuttalliana		C 0	C 0	C 0	C 0	C 0	C 1 #	D 0	D,E 0	D,E 0	D,E + #	D,E 0
Agropyron elongatum		C 0	C + #	C 1 #	C 1 #	C 0	C 0					
Bromus biebersteinii		C 1 #	C + #	C 1 #	C + #	C 0	C 0					
Elymus cinereus		C 1 #		C 1 #	C 1 #	C 0	C 0					

Table 11, cont'd.

Species	1	2	3	4	7	8	9	12	14	15	16	17
						Site Number						
Sorghastrum nutans									E 0	E 0	E 0	E 0
Sporobolus airoides									E 0	E 0	E 0	E 0
Poa pratensis								D 0	D,E 0	D,E 0	D,E + #	D,E 0
Species Transplanted												
Phragmites australis	A 0	A 1 #	A 1 #	A 1 #	A + *	A 1 #	A + #					
Alopecurus aequalis	A 0	A 0	A 0	A 0								
Phalaris arundinacea	A + #	A + #	A + #	A + #	A + *	A 1 #	A 0		E + #	E + *	E,G + *	E,G + *
Typha latifolia	A 1 #	A 1 #	A 1 #	A + #	A + *	A 0	A 1 #					
Scirpus validus	A 0	A 1 #	A 0	A + #	A + *	A 0	A 1 #					
Salix amygdaloides	A 0	A + #	A + #	A 1 #								
Populus deltoides	A 0	A,C + #	A,C 1 #	A,C 1 #	C + #	C 1 #	C 0		E + #	E + #	E + #	E + #

Table 11, cont'd.

Species	Site Number 1	2	3	4	7	8	9	12	14	15	16	17
Agropyron smithii		A + #		A + #								
Distichlis spicata		A 1 #										
Alopecurus arundinaceus									E + #	E + #	E,G + *	E,G + *
Celtis occidentalis		C + #	C + #	C 1 #	C + #	C 0	C 0					
Fraxinus pennsylvanica		C + #	C + #	C 1 #	C + #	C 1 #	C 1 #		E + #	E + #	E + #	E + #
Salix alba		C 1 #	C + #	C + #	C + *	C 1 #	C 0		E + #	E + *	E + #	E + #
Vitis riparia								E + #	E + #	E + #	E + #	E + #
Pinus ponderosa									E + #	E + #	E + #	

[a]Letters indicate times of planting: A = summer, 1973; B = fall, 1973; C = spring, 1974; D = fall, 1974; E = spring, 1975; F = Fall, 1975; G = spring, 1976.
Symbols indicate periods of survival: 0 = seedlings never emerged; 1 = at least some of the plants alive in summer, 1974; + = at least some of the plants alive in June, 1975; * = at least some plants survived the high water of 1975 ; # = plants failed to survive high water of 1975.

[b]"Pasture mix" is a mixture of *Bromus inermis*, *Agropyron cristatum*, *A. trachycaulum*, *A. intermedium*, and *Elymus junceus*.

Most species that survived one or two years were killed by the very high water in 1975. Of the species planted in 1973 or 1974 the only survivors of the 1975 high water were some plantings of *Phalaris arundinacea*, *Alopecurus arundinaceus*, *Phragmites australis*, *Typha latifolia*, *Scirpus validus* and *Salix alba*. Almost as significant were the additional species that survived two years of relatively normal water level fluctuations,. during 1973 and 1974, including *Agropyron smithii*, *A. cristatum*, *A. elongatum*, *Bromus biebersteinii*, "pasture mix", *Salix amygdaloides*, *Populus deltoides*, *Celtis occidentalis* and *Fraxinus pennsylvanica*. A "normal" water level year in 1975 might have allowed some of these to survive longer; lack of control of the water level has introduced one of the most important variables in the entire study.

In the fall, 1974, and spring, 1975, we planted *Phalaris arundinacea*, *Alopecurus arundinaceus*, *Puccinellia nuttalliana*, *Poa pratensis* and *Agropyron smithii* at sites 12, 14, 15, 16 and 17. Only *Phalaris* and *Alopecurus* survived the high water of 1975 at any of these sites. Additional species planted in the spring, 1975, shown by E in Table 11, failed to survive the high water in 1975 possibly due to the very short time between establishment and inundation. Finally, some species were planted in the fall, 1975, and spring, 1976, shown by F and G, respectively, in Table 11. When we examined the sites for the last time in 1977, both *Phalaris arundinacea* and *Alopecurus arundinaceus* were successfully established and spreading. What appears to be an excellent way in which to establish both these species was discovered at Site 3, the Moreau River site on Lake Oahe. As the water receded in 1975 small pools created by littoral currents eroding small areas from the shore remained for some time in the fall. Before they dried up we heavily seeded them by broadcasting disseminules of both Phalaris and Alopecurus. In 1977 both species had not only established but had spread vegetatively over a considerably larger area. The method may be worth noting if larger areas of the shores are to be seeded in the future.

These planting experiments have been of value primarily in determining the feasibility of establishing shore vegetation and whether species can indeed survive more than a single year on the shores. Unfortunately the high water of 1975 eliminated the possibility in this study of observing whether most species could survive longer than two years; certainly only a small number of species withstood the 1975 inundation. Lack of control of the water level made it impossible to draw more from these experimental plantings. In one, or two, locations along the lake shores where water levels could indeed be controlled experiments could yield the kinds of quantitative data necessary for stronger conclusions regarding species tolerances to inundation. Such an experiment would be much more efficient in yielding results than the experiments required in the present study.

The unusually high water in 1975 did itself provide a unique opportunity to determine maximum inundation tolerance of a number of species already established along the shore, and above it. Results of this effort are described below.

LIMITING FACTORS FOR SHORE VEGETATION

Inundation

Experiments to establish plant species on the lake shores provided initial evidence that some plants could be established at least for a period of 1 - 2 years and that others could survive for longer periods. It appeared that species differed considerably in their tolerances to inundation. The literature contains numerous examples of the effects of inundation on plants. Ahlgren and Hansen (1957) reported hardwoods to be more resistant than conifers to temporary inundation. Green (1947) reported that *Ulmus americana*, *Acer saccharinum*, *Betula nigra*, *Populus deltoides*, *Fraxinus pennsylvanica*, *Salix nigra* and *Quercus palustris* all reacted differently to periods of inundation. For some species growth was increased and for others growth was decreased. Flooding above the root crown killed all species within four years.

Among grass species *Buchloe dactyloides* apparently survived 6 to 19 months inundation if it began when the plants were dormant (Porterfield 1945), and up to 36 days inundation if flooded during the growing season. After flooding turfs of *Festuca elatior*, Davis and Martin (1949) found the plant survived all depths of flooding, from 2.5 cm to 15 cm. Species of *Melilotus* survived best only in shallow water when the leaves were above water. There seems to be some general agreement that terrestrial herbaceous species do survive inundation longer if their leaves are above water, and that flowing water is tolerated longer than stagnant water. There are exceptions. Maintaining water levels at the soil surface, and at 25 and 40 cm below the surface, Finn et al. (1961) found grasses more tolerant than legumes and that grasses actually increased production up to 21 days maximum inundation with Phleum pratense and Bromus inermis to be less tolerant. Waddington and Baker (1965) reported Poa pratensis tolerated low oxygen diffusion rates, a condition accompanying flooding of the soil; but Beard and Martin (1970) reported the survival of inundated Poa pratensis as well as Festuca rubra, Poa annua and Agrostis palustris was limited by increased temperatures of the water.

To gain further insight into species tolerances to inundation two approaches were used. In one we determined periods of survival of a number of species during the time of record high water in 1975. In the second we inundated a number of grass species in the laboratory to determine relative tolerances to inundation under the conditions of the experiment.

Methods

(1) Field Methods.---At 36 sites in 1976 we determined the survival of plants to the record high water level of 1975. The plants observed were all present in 1974; some were planted and the remainder occurred naturally along a d above the shore. All the grasses and forbs observed were at least a year old in 1976 and were considered to be mature. All the shrubs were well-established and mature; and among the trees we considered those less than five years old and less than 0.5 dm diameter at the base to be seedlings. All other trees were grouped into a single category of mature (Table 12).

By determining the elevation of surviving individuals with reference to the high water elevation at each site, and knowing the elevation of the water through the year, we could closely approximate both maximum depth and length of time each surviving plant was inundated. The highest water level at each site is clearly marked by a narrow zone of dead wood, bark chips and other debris floated there and remaining when the water receded. We used the upper edge of this zone as the level of highest water in 1975. With the aid of a surveying level and leveling rod, we measured at the ground surface the vertical distance of the surviving plants below the high water elevation marked by the zone of debris. After determining the elevation of each plant base, we added the height of each plant which provided a calculated elevation to which elevations of water levels could be related. Thus, in reporting inundation periods, I am giving both the calculated days of complete inundation and the days the bases of plants were surrounded by surface water.

(2) Laboratory Methods.---Species for laboratory experiments were selected on the basis of their potential importance along the shores, and to some extent on the basis of their availability. The following species were used in these experiments: *Agropyron repens*, *Agropyron smithii*, *Alopecuris aequalis*, *Alopecurus arundinaceus*, *Beckmannia syzigachne*, *Bromus inermis*, *Hordeum jubatum*, *Phalaris arundinacea*, *Poa pratensis*, *Puccinellia nuttalliana* and *Stipa viridula*. Disseminules were collected when ripe and returned to the laboratory in paper bags, then stored in the laboratory in

sealed glass jars at room temperature until used. The disseminules were germinated on filter paper in petri dishes in an environmental control chamber programmed for 16 hrs light (approximately 30,000 lux) at 21°C and 8 hrs dark at 10°C. After germination seedlings were transplanted to loam soil in tin cans 10 cm in diameter and 20 cm tall. The cans were previously painted on the outside with aluminum paint, and on the inside lined with plastic to prevent direct contact of plant roots with the metal of the can. The pots were all placed in an environmental control chamber programmed for 16 hrs daylight (30,000 lux) at 21°C and 8 hrs darkness at 10°C. When the seedlings were 1-3 cm tall they were weeded to leave the five most vigorous seedlings in each pot.

The field capacity (capillary capacity) of the soil used was 24.7% and the pots were brought up to field capacity (by weight) by watering with deionized water every three days. When the plants were six weeks old, three pots of each species were exposed to the following treatments:

1) Soil moistened to two times field capacity and maintained at this moisture level for 30 days.
2) Plants inundated for 5 days in a tank 40 cm deep 40 cm wide and 115 cm long with tap water at 21°C flowing through the tank at the rate of 1 liter every 3 minutes. A four bulb flourescent fixture mounted above the tank provided 340 lux just below the surface of the water, 16 hr of every 24 hr during the treatment.
3) Same as 2) except inundation period was 15 days.

4) Same as 2) except inundation period was 30 days.

5) Same as 2) except inundation period was 45 days.

6) Same as 5) except leaves were clipped off below the water surface. This treatment was only given to three species which had elongated their leaves above the water surface in other treatments.

7) Same as 2) except inundation period was 60 days.

8) Three control pots of each species for each treatment were maintained in the growth chamber for comparison with each treatment.

After each treatment soil moisture was allowed to evaporate back to field capacity as plants recovered for 20 days in the environmental chamber. At the end of the treatment plants were photographed with the controls. After the 20 day recovery period, treatment and control plants were rephotographed. Their height was measured, and finally the roots and shoots were removed, air dried and weighed. Before and after each experiment the means of shoot height and number of shoots per pot were determined. After the experiments we dried and weighed 5 shoots and 5 roots from each pot. Using a t-test mean shoot and root biomass data of treated and control plants were compared.

<u>Results</u>

<u>(1) Field Observations</u>.---Among the trees observed, <u>Salix</u> <u>spp</u>. tolerated longest inundation periods, up to 60 days complete inundation and 83 to 149 days with surface water around their bases (Table 12). <u>Salix</u> seedlings also survived surprisingly well during the 1975 high water. <u>Populus</u>

Table 12. Inundation periods of plant species that survived the high water of 1975.

Species	Mature (M) or seedlings (S)	Lake Sakakawea: Days exposed to surface water	Lake Sakakawea: Days completely inundated	Lake Sakakawea: Maximum water level above plants, m	Lake Oahe: Days exposed to surface water	Lake Oahe: Days completely inundated	Lake Oahe: Maximum water level above plants, m
TREES							
Salix amygdaloides[a]	S	94	46	.72	149	60	.79
Salix amygdaloides	M				136	0	
Salix exigua	S	92	44	.65	97	13	.20
Salix rigida	S				103	22	.34
Salix alba	S	83	32	.48			
Populus deltoides	S	69	18	.23	76	0	
Fraxinus pennsylvanica	S	44	32	.48			
Fraxinus pennsylvanica	M	30	0				
Acer negundo	M	19	0				
Celtis occidentalis	M	0	0				
Ulmus pumila	M	29	0				
Ulmus rubra	M	24	0				
Ulmus americana	M	0	0				
SHRUBS							
Rosa spp.[b]	M	46	25				
Symphoricarpos occidentalis	M	40	0				

Table 12, cont'd.

Species	Mature (M) or seedlings (S)	Lake Sakakawea: Days exposed to surface water	Lake Sakakawea: Days completely inundated	Lake Sakakawea: Maximum water level above plants, m	Lake Oahe: Days exposed to surface water	Lake Oahe: Days completely inundated	Lake Oahe: Maximum water level above plants, m
Crategus chrysocarpa	M	32	0				
Shepherdia argentea	M	28	0				
Prunus virginiana	M	0	0				
Juniperus horizontalis	M	0	0				
Eleagnus argentea	M	0	0				
GRAMINOIDS							
Agropyron repens	M	82	55	.99	97	62	.74
Agropyron smithii	M	94	67	.63	56	13	.49
Alopecurus arundinaceus	M	85	46	1.07			
Phalaris arundinacea	M	106	43	.76	76	0	
Phragmites australis	M	89	0		143	0	
Poa pratensis	M	38	15	.25			
Bromus inermis	M	19	0				
Carex sp.[c]	M				73	36	.41
Scirpus validus	M	93	18	.17	150	34	.32
Typha latifolia	M	85	3	.32	138	10	.16

Table 12, cont'd.

Species	Mature (M) or seedlings (S)	Days exposed to surface water	Days completely inundated	Maximum water level above plants, m	Days exposed to surface water	Days completely inundated	Maximum water level above plants, m
FORBS							
Polygonum coccineum	M	76	43	.71			

[a]Nomenclature follows Van Bruggen (1976).

[b]These include Rosa woodsii and R. arkansana.

[c]An unidentified Carex.

deltoides seedlings tolerated up to 18 days complete inundation and as much as 76 days of surface water. Hosner (1960) reported twice as many Salix nigra seedlings survived 30 days complete inundation as did Populus seedlings. Casual observations we made indicated that most of the naturally occurring Populus and Salix did survive the high water of 1975. Most of the Populus deltoides planted in 1975 by the Army Corps of Engineers did not survive the high water. Prior to 1975 both Salix and Populus were relatively common around both reservoirs. The trees occurred mostly in rows parallel to the shorelines. Because the timing and magnitude of water fluctuation are not identical from year to year, innumerable Salix and Populus seedlings are killed by high water each year; but over a long period of time there appear to be about as many new seedlings established as are killed. We have observed a number of Populus along the shorelines grow from seedlings to saplings, 2 - 3 m tall, during the period 1971 to 1975, indicating some degree of tolerance to high water each year.

Two additional trees, Fraxinus pennsylvanica and Acer negundo, tolerate less water and only at one site did Fraxinus tolerate complete inundation. Under greenhouse conditions Hosner (1960) found 3 of 15 Fraxinus seedlings tested tolerated 30 days complete inundation. Silker (1948) recommended Fraxinus for shore areas only where inundation is occasional and of short duration. Green (1947) found mature Fraxinus to be very tolerant with few dead specimens even

AD-A124 469 SHORE VEGETATION OF LAKES OAHE AND SAKAKAWEA MAINSTEM MISSOURI RIVER RESERVOIRS(U) SOUTH DAKOTA UNIV VERMILLION DEPT OF BIOLOGY G R HOFFMAN APR 78 2/3

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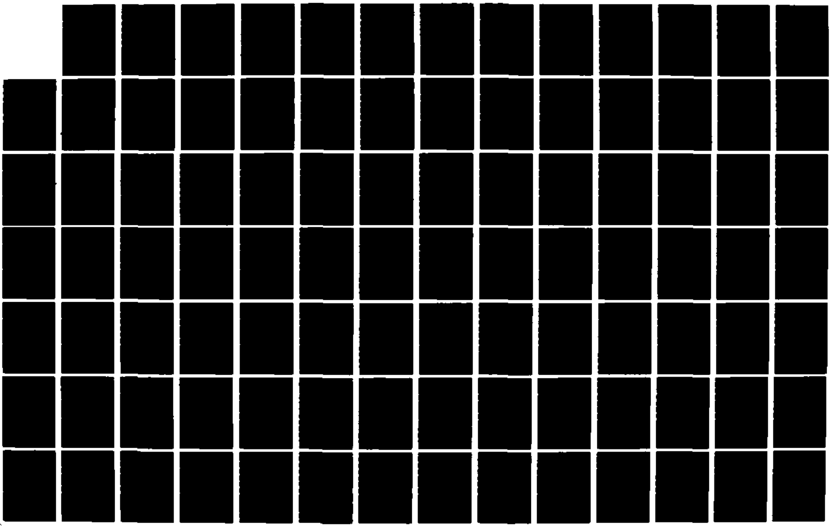

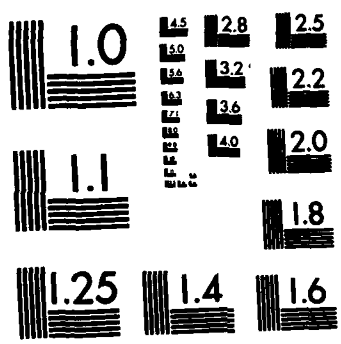

MICROCOPY RESOLUTION TEST CHART
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after two years with their bases surrounded by .46 to 1.2 m of water.

In two locations near Lake Sakakawea the lower ends of established windbreaks oriented perpendicularly to the shoreline were inundated. Mature trees in these windbreaks included *Ulmus americana*, *Ulmus pumila*, *Ulmus rubra* and *Celtis occidentalis*. *U. americana* and *Celtis* were most sensitive to the high water; both species survived only *above* the level of highest water in 1975. In contrast *U. pumila* and *U. rubra* survived surface water for 29 and 24 days respectively. Our observations on *U. americana* conflict with those of Green (1947) who found that though *U. americana* were dying after two years exposure in .46 to 1.2 m of water "many were still strong". In a greenhouse study Hosner (1960) observed *U. americana* seedlings failed to survive 30 days complete inundation and only 4 of 15 seedlings survived 20 days complete inundation.

The high water of 1975 affected shrubs that we do not ordinarily encounter along the shores per se. Most of the shrubs are common above the highest water levels. Of the shrubs observed only *Rosa woodsii* and *R. arkansana* were totally inundated and some individuals tolerated 25 days complete inundation (Table 12). Owing to the general absence of shrubs along the shores we judged their tolerance to water to be minimal. This was illustrated by a sizeable clone of *Symphoricarpos occidentalis* the lower half of which was inundated in 1975. After the water had receded the lower half of the clone which had been under water was dead. *Crategus* chrysocarpus, Shepherdia argentea and Symphoricarpos all tolerated some surface water. Eleagnus angustifolia, Prunus virginiana and Juniperus horizontalis were drowned in saturated soil above the maximum water level in 1975.

Around Lakes Oahe and Sakakawea herbaceous vegetation dominates the shores. Typha latifolia and the Scirpus validus are emergent hydrophytes that are common in potholes and other mesic habitats in our region; and both tolerate much water. In the quiet embayments of the reservoirs these two species persist for several years; even where wave action is obvious Typha can survive for several years (Table 12). While high water in 1975 eliminated many of both species, Scirpus survived 161 days exposed to surface water including 50 days of complete inundation. Typha survived 138 days exposure to surface water including 10 days of complete inundation (Table 12). Considering the usual habitats of these two species in our region, the 1975 inundation periods are not unusually long. The reservoir shores do, however, offer more hazards for emergent hydrophytes, particularly in the form of wave action and siltation both of which can be important limiting factors. At one site in 1975 both species were temporarily eliminated by 123 days of exposure to surface water that reached a maximum depth of 2.3 m. At this same site in 1976 both species were regenerating from underground rhizomes.

Agropyron repens is common along the shores of both reservoirs and tolerates considerable water. In 1975 it survived up to 97 days exposure to surface water including 62 days complete inundation (Table 12). Though this species is considered a "noxious weed" in South Dakota, it may be of value to reconsider the label with regard to its importance along shores of fluctuating water level reservoirs. Agropyron smithii showed somewhat similar tolerance to inundation, surviving up to 94 days exposure to surface water including 67 days of complete inundation (Table 12). Alopecurus arundinaceus is a large perennial grass that occurs in mesic habitats in North Dakota; so far it has not been encountered around Lake Oahe except where we planted it. Plants of this species withstood up to 85 days exposure to surface water including 46 days complete inundation (Table 12). Where planted along the shores, it has persisted several years.

Bromus inermis is widely planted along roadsides in our region, but it tolerates little water. It was killed by complete inundation in 1975 and survived up to 19 days exposure to surface water. In Oklahoma Rhoades (1967) observed that B. inermis tolerated no more than 5 days inundation; and in Canada Bolton and McKenzie (1946) reported the species tolerated flooding for 24 days before being affected.

Phalaris arundinacea is one of the most tolerant plants to the shore environment of Lakes Oahe and Sakakawea. As indicated above we have observed it spread from small clumps to large areas at several sites. In 1975 it survived up to 106 days exposure to surface water including 43 days complete inundation. Bolton and McKenzie (1946) reported Phalaris survived 35 to 49 days of water 3.0 to 4.6 dm deep; Finn et al. (1961) reported it was as productive in soils saturated with water as in soils maintained at field capacity. *Phragmites australis* also tolerates much water. Because it grows 2 to 3 m tall, it was never completely inundated in 1975, but it did tolerate up to 143 days exposure to surface water. Near the upper end of Lake Sakakawea a sizeable stand of *Phragmites* occurs in the middle of the reservoir where water to a depth of about 1 m is present throughout most of the growing season.

Poa pratensis occurs along both reservoirs where inundation is not prolonged. In 1975 this grass survived 38 days of surface water including 15 days of complete inundation. *Carex spp*. commonly occur in mesic habitats; and around the reservoirs they occur where wave action is not severe. In 1975 an unidentified *Carex* tolerated 73 days exposure to surface water including 36 days of complete inundation.

Polygonum coccineum is the only broad-leaved herbaceous plant we observed in this survey. It was seen only around Lake Sakakawea in 1975 and survived 76 days of surface water including 43 days complete inundation.

Table 12 reflects apparent differences in species tolerances to high water in 1975. The differences observed are due in part to differences in the shore environments of the two reservoirs, as described above. Differences in climates, growing seasons, soils, patterns of water level fluctuations all have some influence on the shore vegetation. As a result direct comparisons of inundation tolerances shown in Table 12 are somewhat hazardous. Around most of Lake Oahe the growing season is longer than that of the Lake Sakakawea vicinity. Water levels also peak later in Lake Oahe than in Lake Sakakawea; thus shore vegetation should, theoretically, have a longer period of growth before being inundated. The lowest water levels in the reservoirs are important because they determine the lowest limits, in relation to the highest water levels, that plants can become established. For 1975 the lowest water level in Lake Oahe was 488.9 m above mean sea level, recorded on January 16. The highest water level for Lake Oahe in 1975 was 493.1 m recorded on August 24. The measured water rise was 4.2 m. For Lake Sakakawea the lowest and highest water levels in 1975 were 560.4 m on April 2 and 565.3 m on July 31 respectively, a difference of 4.9 m. The difference between low and high water levels reveals only part of the hazard of inundation for shore plants. For some species the rate of water level rise can be more important than the ultimate peak reached. For example, *Agropyron smithii*, *Phalaris arundinacea*, *Alopecurus arundinaceus*, *Alopecurus aequalis* and *Agropyron repens*, when exposed to gradually rising water levels, elongate their culms and maintain a few leaves just at or above the water surface and survive prolonged periods of inundation. We have not documented for these plants the maximum rate of water level increase, the ultimate water level tolerated, or the length of time these grasses will tolerate inundation. Obviously, as they are terrestrial grasses, they will hardly tolerate indefinite periods of total inundation. The field observations reported in the present study is a first approximation at answering some of the questions about plant survival to inundation on the reservoir shores. Patterns of water level fluctuation have never coincided from one year to the next in either reservoir. Additionally, the rise and fall of water levels in Lake Oahe occurs over a longer period than in Lake Sakakawea so that plants on Lake Oahe shore are in general exposed to longer inundation periods. For example, in 1975 a point 1.8 m below the highest water level must have been passed twice during the season, once when the water was rising and once when the water was falling. The length of time between the rise and fall of water levels at that point was 151 days on Lake Oahe and 110 days on Lake Sakakawea. The more gradual rise in water level in Lake Oahe could allow plants more time to adjust, if at all possible, but the longer period of inundation at that point on Lake Oahe could also be detrimental to plants there.

Another significant difference between the shore environments of the two reservoirs is their surrounding soils discussed above. Much of Lake Oahe is surrounded by Pierre shale which weathers into a substrate with much clay. Plants rooted in this medium may be subject to extremes of waterlogging when the medium is wet and desiccation when the medium is dry. Most of the substrate surrounding Lake Sakakawea is derived from glacial till most of which weathers into a loamy substrate. Plants rooted in this medium are less subject to extremes of soil moisture conditions.

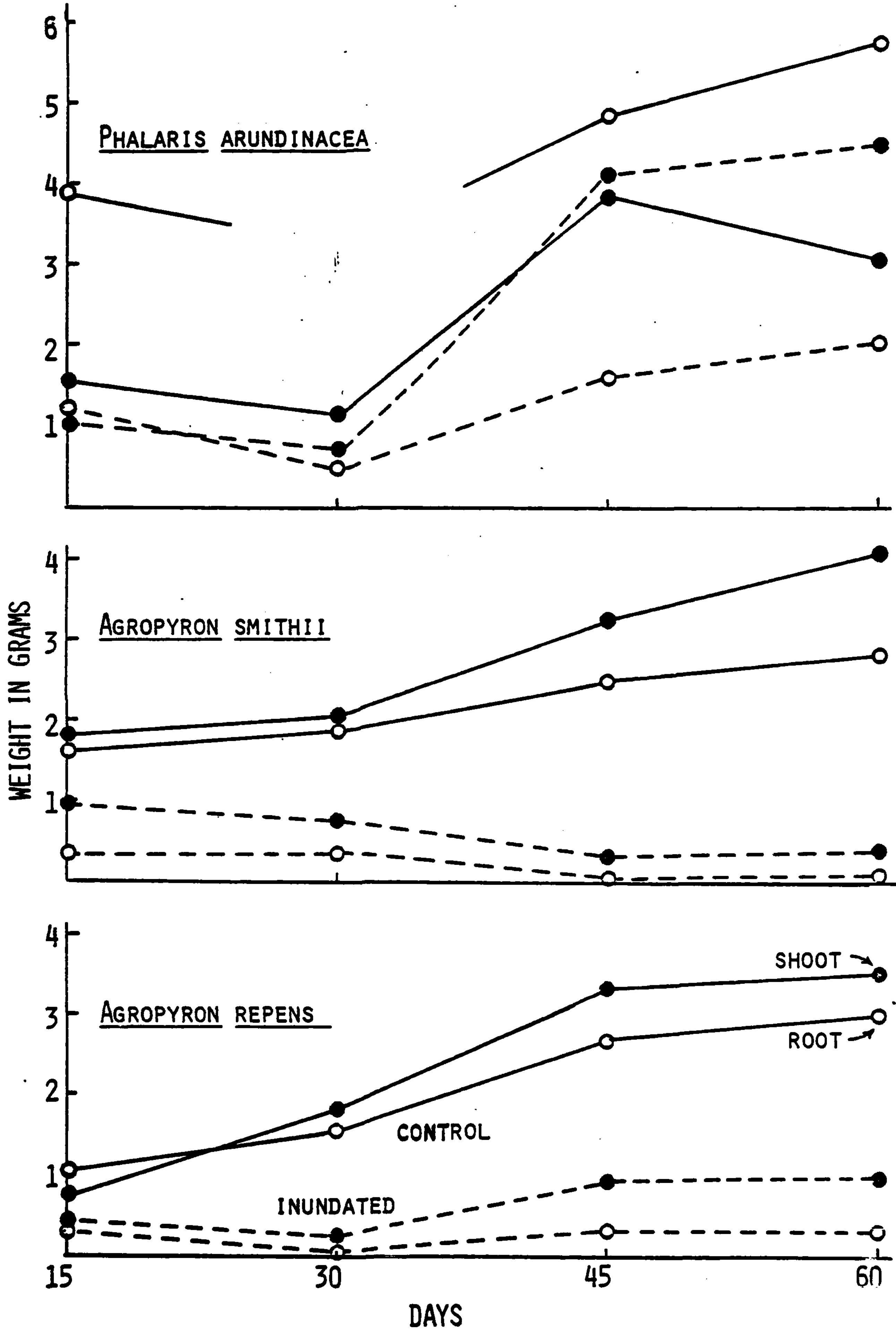
Finally, in interpreting results of Table 12, it is important that not all plants were equidistant from the shorelines on a given date in 1975; this alone yielded some variation in the results.

(2) Laboratory Experiments.---Five species tested were members of the ephemeral shore communities. *Agropyron repens* and *Agropyron smithii* were similar in their responses to inundation. Both species survived 60 days complete inundation in this experiment though flooding reduced dry matter production of both shoots and roots, compared to control plants (Fig. 10, Table F). The height and the number of shoots per pot were also much less in test plants compared to controls (Table F). When exposed to soil moisture of 2x field capacity for 30 days, shoots of *Agropyron repens* were only slightly less productive than control plants, though roots were more greatly reduced (Table F). For *Agropyron smithii*, exposure to soil moisture of 2x field capacity resulted in greater shoot production and only slightly less root production than control plants (Table F).

Plants of *A. smithii* considered to be a possible "wetland" ecotype survived 30 days complete inundation no better than "normal" ecotypes of *A. smithii*, though exposure to soil moisture of 2x field capacity did result in considerably more growth of the test plants compared to controls (Table F).

If it is not inundated *Alopecurus aequalis* normally grows less than 0.5 m tall in our region. When inundated, it elongates its culms and can extend above water about 1 m deep. In this experiment it also elongated its culms to maintain a limited number of leaves just above the water surface. While some plants survived, 60 days of inundation took its toll in

Fig. 10. Dry weights of roots and shoots of grasses inundated for various lengths of time. Solid lines are control plants; dashed lines are inundated plants. Solid circles are shoots, open circles are roots.

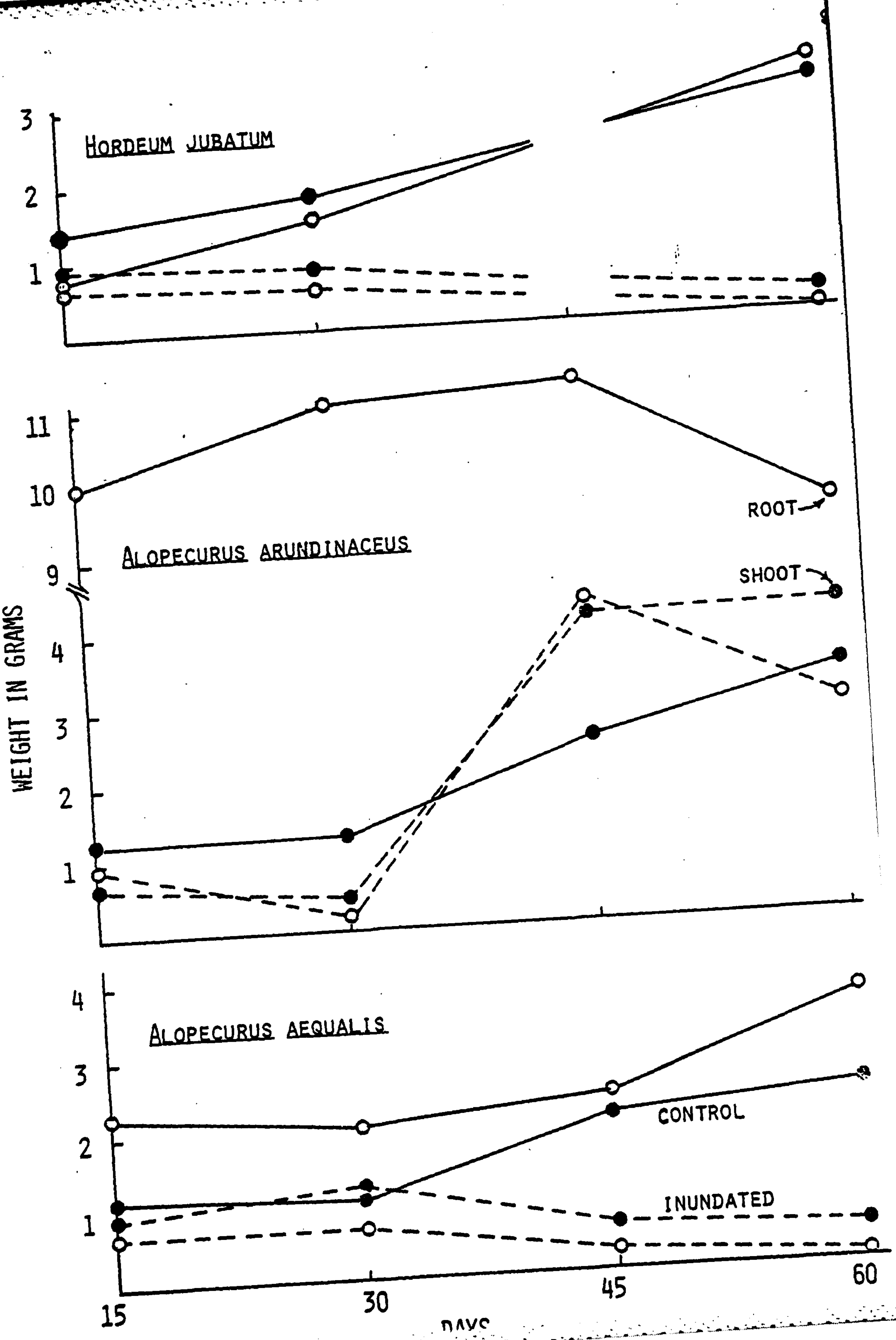


PHALARIS ARUNDINACEA
AGROPYRON SMITHII
AGROPYRON REPENS
WEIGHT IN GRAMS
SHOOT
ROOT
CONTROL
INUNDATED
DAYS

both numbers of plants and in dry matter produced (Fig. 11, Table 13). After about 30 days inundation, all plant tissue under water appeared dead, though green leaves occurred above the water level. During the 20 days recovery period following inundation, new leaves were produced from rhizomes. When exposed to soil moisture of 2x field capacity for 30 days, the plant produced more stems and greater dry matter than control plants (Table F).

Alopecurus arundinaceus also elongated rapidly when inundated to maintain leaves above the water level. As shown in Table 13 the dry weight of the shoots of plants inundated for 60 days followed by a 20 day recovery period was nearly twice that of control plants of the same age. The root weight however, of the control plants was much greater than that of inundated plants. An arbitrary decision to weigh all underground plant parts, including rhizomes, with roots resulted in the inflated value for roots of control plants. Much of that plant material was in fact rhizome which in the inundated plants elongated vertically and was weighed with shoot material (Fig. 11). More significantly, however, is the fact that the plants survived 60 days of inundation and in the field it has survived even longer periods of inundation. Survival of A. arundinaceus was threatened when the leaves above the water level were clipped off. As shown in Table F, this treatment which accompanied 45 days inundation resulted in only 3 live shoots per pot and very little production. While the species can withstand considerable inundation for prolonged periods, it seemingly must have leaves above the water

Fig. 11. Dry weights of roots and shoots of grasses inundated for various lengths of time. Solid lines are control plants, dashed lines are inundated plants. Solid circles are shoots, open circles are roots.



HORDEUM JUBATUM
ALOPECURUS ARUNDINACEUS
ALOPECURUS AEQUALIS
ROOT
SHOOT
CONTROL
INUNDATED
WEIGHT IN GRAMS
15
30
45
60
DAYS

Table 13. Summary of results of inundation experiment. Plants were inundated for 60 days followed by 20 days recovery in a growth chamber.[a]

Plant Species	Mean Shoot Height, cm	Mean Shoot Number	Mean Dry Wt of Shoots	Mean Dry Wt of Roots
Agropyron repens				
60 Days Inundation	24.2	8	0.92 g	0.30 g
Control Plants	61.2	33	3.50	3.04
Agropyron smithii				
60 Days Inundation	26.0	8	0.46	0.08
Control Plants	53.1	15	4.10	2.85
Alopecurus aequalis				
60 Days Inundation	30.4	5	0.50	0.10
Control Plants	27.4	47	2.38	3.57
Alopecurus arundinaceus				
60 Days Inundation	46.5	14	4.19	2.81
Control Plants	24.3	28	2.37	9.49
Beckmannia syzigachne				
60 Days Inundation	42.4	12	3.05	1.30
Control Plants	28.1	30	2.16	2.53

Table 13, cont'd.

Plant Species	Mean Shoot Height, cm	Mean Shoot Number	Mean Dry Wt of Shoots	Mean Dry Wt of Roots
Bromus inermis				
60 Days Inundation	25.9	10	0.68 g	0.56 g
Control Plants	33.4	18	2.15	7.01
Hordeum jubatum				
60 Days Inundation	---	--	0.23	0.02
Control Plants	50.6	24	3.10	3.27
Phalaris arundinacea				
60 Days Inundation	90.4	23	4.44	2.05
Control Plants	45.9	24	3.07	5.69
Poa pratensis				
60 Days Inundation	28.9	25	1.20	0.57
Control Plants	39.3	23	2.93	7.90
Puccinellia nuttalliana				
60 Days Inundation	---	--	0.12	0.01
Control Plants	49.2	42	3.38	2.85
Stipa viridula[b]				
30 Days Inundation	---	--	0.06	0.04
Control Plants	12.5	22	0.34	0.38

[a]Complete data are presented in Table F, Appendix.

level. Finally, the plant survived very well in soil at 2x field capacity (Table F). Under these conditions there were more shoots per pot and greater shoot weight than control plants. Root weight, however, was less than that of control plants.

Beckmannia syzigachne is an annual which also tolerates considerable inundation if the leaves are above water. When the leaves were clipped off just below water level the plant died (Table F). In this experiment, when _Beckmannia_ leaves did emerge above the water level, shoot biomass was equal to or greater than that of the control plants, but root biomass was considerably less than controls. Finally, it is significant in view of the mesic habitats occupied by this species, that plants exposed to soil moisture of 2x field capacity for 30 days produced more shoots per pot and greater root biomass than control plants; shoot biomass values were the same as those of control plants (Table F). While this species withstands considerable inundation, and does well in wet soils, it is an annual and must reseed each year. This could be a factor of some importance in considering the future management of the shore communities.

Bromus inermis is an introduced species and is frequently seeded along roadsides in our region. As indicated above, _Bromus inermis_ tolerated up to 19 days of surface water in 1975. In this laboratory experiment it tolerated 60 days inundation but the number of shoots and the biomass produced was significantly less than that of control plants (Table 13).

When exposed to soil at 2x field capacity for 30 days, the plants produced more shoots and more shoot biomass than control plants, but root biomass was less than that of the controls (Table F).

Hordeum jubatum did not survive the 60 day inundation treatment. The very small biomass values given in Table 13 are for shoots and roots that failed to recover during the 20 day recovery period. No 45 day inundation was given this species; it did survive 30 days inundation (Table F). Inundation did result in more shoots per pot than in the controls (Table F). As shown in Fig. 11 inundation also resulted in marked decrease in dry matter produced. Plants in soil with moisture at 2x field capacity for 30 days produced essentially tha same number of shoots as control plants, slightly less shoot biomass than controls, and only half as much root biomass (Table F). _Hordeum jubatum_ is an important species in shore communities; yet is quite intolerant to inundation. We did not observe it to have survived the high water of 1975, and in the laboratory it failed to survive 60 days inundation. Its importance on the shore suggests further investigation into its autecological requirements might be a rewarding endeavor.

Phalaris arundinacea is another species that responds to inundation by elongating its culms and producing leaves just above the surface of the water. As indicated above, it survived prolonged inundation along the lake shores in 1975. In this laboratory experiment it survived 60 days inundation. Compared to control plants it produced more shoot biomass but less root biomass after 60 days inundation. As in the case of Alopecurus arundinaceus the very large root weight of control plants of Phalaris included rhizomes, most of which were included among the elongated culms of the plants that had been inundated (Table 13). Phalaris plants exposed to soil moisture of 2x field capacity for 30 days produced twice as many shoots as control plants, and also more shoot and root biomass than control plants. A comparison of root and shoot biomass of both control and inundated plants is shown in Fig. 10. Phalaris shoots that were kept below the surface of the water by clipping showed after 45 days much less biomass in both shoots and roots than in the controls (Table F).

Poa pratensis survived all the inundation treatments, including 60 days. Like Bromus inermis it does not elongate culms when flooded; it does lose much chlorophyll when flooded, along with leaf and stem mechanical tissue. However, when removed from the water and placed into the growth chamber for a recovery period, it did recover. After 60 days inundation followed by the recovery period the shoot and root biomass were less than those of the control plants (Table 13). Plants exposed to soil moisture of 2x field capacity for 30 days produced significantly more shoot biomass than did control plants. Root biomass of this treatment was significantly less than that of control plants. In fact root biomass was significantly less among all treated plants than that of controls (Table F).

<u>Puccinellia</u> <u>nuttalliana</u> is quite intolerant of flooding. It began showing adverse effects after only 5 days inundation. After 15 days inundation, little sign of life remained in any of the treatment pots, though there was some recovery after the plants were taken from the inundation tank. After 30 days inundation most of the plants had died and none survived either 45 or 60 days inundation (Tables 13, F). Inundation even for 5 days resulted in significantly less shoot and root biomass than that of control plants. Interestingly, plants exposed to soil moisture of 2x field capacity did survive and produced somewhat fewer shoots per pot than the controls, but shoot and root biomass values of this treatment were unchanged from those of control plants (Table F).

<u>Stipa</u> <u>viridula</u> is another species that fails to survive inundation. After just 15 days inundation the plants were drowned. The small biomass values reported in Table F for shoots and roots are for plants that failed to recover following just 15 days inundation. <u>Stipa</u> seedlings grew rather rapidly to about 12 cm in height, but remained that size through the duration of the experiment. Plants exposed to soil moisture of 2x field capacity produced the same number of shoots and the same shoot and root biomass as those of the controls.

While the experimental conditions of this experiment are quite unlike those encountered in the field, most results were not inconsistent with observations made in the field.

Of the 11 species tested 8 survived 60 days inundation. In the field we have observed only _Agropyron smithii_ and _A. repens_ actually survive longer than 60 days complete inundation. However, for larger species, like _Phalaris arundinacea_, which in this experiment elongated to produce leaves above the water level, we have observed it to survive 106 days of surface water (Table 12).

The results of the experiment permitted a ranking of the species in relation to inundation tolerance, as follows, in order of decreasing tolerance:

1. _Phalaris arundinacea_
2. _Alopecurus arundinaceus_
3. _Beckmannia syzigachne_
4. _Agropyron smithii_
5. _Agropyron repens_
6. _Poa pratensis_
7. _Bromus inermis_
8. _Alopecurus aequalis_
9. _Hordeum jubatum_
10. _Puccinellia nuttalliana_
11. _Stipa viridula_

It is clear also that species like _Phalaris arundinacea_, _Alopecurus arundinaceus_ and _Beckmannia syzigachne_ survive inundation because in part they elongate their culms to have leaves above the level of water. These species are not _aquatic_ species, rather they are _amphibious_.

Cattle Grazing

Cattle grazing is a major enterprise in western North and South Dakotas. Along Lakes Oahe and Sakakawea cattle have ready access to both shore vegetation and water. While it has been recognized for many years that cattle grazing can decrease significantly the shore vegetation of ponds, lakes and reservoirs (Gill and Bradshaw 1971, Kelting and Penfound 1950, Magadza 1970, Tiemeier 1951), the effects of cattle grazing on shore vegetation of any Missouri River reservoirs has not been studied previously. Field observations indicated quite clearly that cattle grazing was to some extent a limiting factor in shore vegetation development. The present collection of data was aimed at determining how much of a limiting factor grazing represented.

On the Federally-controlled land immediately surrounding Lake Sakakawea a six month grazing period, 1 May to 31 October, is permitted. On improved pastures the stocking rate allowed is one animal unit/15 acres, and on native grassland the rate is one animal unit/30 acres. Additionally, for a maximum sustained production of the vegetation, one half the year's plant growth must remain after the grazing season. The stated regulations for grazing around Lake Oahe are somewhat different. Here the grazing period is 1 May to 1 November, and winter grazing is permitted in lieu of summer grazing. Though stocking rates are not specifically stated, grazers are requested to comply with state regulations, strive to improve the grazing lands, conform to all principles of good husbandry and overgrazing is not allowed (Operations Division, Corps of Engineers, Omaha District, personal communication).

Stated guidelines are obviously worthwhile for grazers. Parts of any grazed area will be more heavily utilized than others, and because of access to water, reservoir shores are areas of intense use. Because the shores are inundated regularly and the vegetation there is subject to drowning, it is somewhat more difficult to judge the impact of grazing. The ephemeral nature of the shore vegetation also makes it quite distinct from the upland steppe for which the grazing guidelines were actually written.

Methods

As indicated above, the shore vegetation is a mosaic composed primarily of alien species that have survived for various periods between high water. Source of disseminules, tolerance to inundation and timing of water level fluctuations all influence vegetation development. We studied shore communities in 1976, following the record high water levels of 1975. Thus, most of the shore species encountered in our study became established late in 1975 after recession of high water, or during the spring of 1976. Doing the study in 1976 provided some measure of uniformity among the sites in as much as all the shore was quite depleted of species during 1975.

The study was done at the following exclosure sites (Fig. 9):

Minnconjou
Moreau
Grand River
Kenel
Hazen
Garrison
New Town

Cattle have ready access to all the area around each exclosure.

At each sampling site (Fig. 9) we estimated plant canopy coverages within 2 x 5 dm plots (Daubenmire 1959). We sampled 30 plots at meter intervals along a tape parallel to the shoreline inside the exclosure. A duplicate set of plots was analyzed along a tape outside the exclosure and the same distance from the shoreline. Where canopy coverages were estimated, we also collected plant materials for biomass estimates. These were done by clipping at ground level all living vegetation rooted within 10 - 0.1 m^2 plots inside each exclosure and the same number of plots outside each exclosure. For shrubs, only current year twigs and leaves were collected. These plots were spaced 2 m apart along the same tapes used for coverage estimates. All plant material collected was placed in paper sacks and air-dried in the field. In the laboratory the material was dried further at 70°C for 48 hr, then weighed to the nearest 0.1 g.

At each site mineral soil samples of the shore habitats were collected to 1 dm depth at 10 intervals along the tapes inside and outside the exclosures. The samples were air dried in the field; in the laboratory they were bulked and passed through a 2 mm screen before analyses. We measured pH on moistened soil using a glass electrode, particle size distribution using a modified Buoyoucos method, readily exchangeable phosphorus, potassium, calcium using "quick" soil tests, cation exchange capacity using a modified ammonium acetate extractable technique, calcium plus magnesium using EDTA in a pH 10 buffered solution and using eriochrome black

T dye, and percent nitrogen using the Kjeldahl method (Moodie and Koehler 1975). Field capacity of soil samples was determined by establishing hanging water columns in sealed cylinders 60 cm long and 4 cm in diameter. After 48 hr 2 cm increments of the moist soil were removed, weighed, oven-dried at 105°C for 48 hr, then reweighed. The average percent moisture based on oven-dry weight as 100% is an estimate of the field capacity.

Results

The shore vegetation around both Lakes Oahe and Sakakawea is a mosaic of ephemeral plant communities that survive one or more years usually being eliminated by a combination of high water and cattle grazing. At least part of the shore is inundated every year.

Minnconjou, Moreau and Grand River sites on Lake Oahe occur on Pierre Shale-derived substrate which weathers into heavy clays or clay loams (Table 14). The high clay content of these substrates results in high water-holding capacity following inundation, or precipitation, but the same substrates become very hard and cracked when dry. As shown in Table 14 soil pH is above 7.0 at all three sites, and cation exchange capacities (CEC) are nearly the same with calcium and magnesium dominating the exchange complex. Owing to variable amounts of organic matter in the shore substrates, the amounts of phosphorus and nitrogen are variable, and not especially high.

Table 14. Edaphic characteristics of shore substrates at sites where grazing and/or fertilization studies were done.

		Percentages of			Nutrient Characteristics						
		Sand	Silt	Clay	ppm of			meq/100 g of			Field
Site	pH	(textural name)			P	K	Ca	Ca + Mg	CEC[a]	% N	Capacity
Minnconjou	7.5	23	22	55	400	640	8000	23	31	.122	37
		(clay)									
Moreau	7.3	42	21	37	150	480	6000	22	29	.061	29
		(clay loam)									
Grand River	7.3	27	35	38	200	240	12000	24	29	.160	--
		(clay loam)									
Kenel	6.9	33	54	12	300	480	6000	16	23	.260	25
		(silt loam)									
Hazen	7.6	43	45	12	150	640	8000	15	20	.164	22
		(loam)									
Garrison	7.6	27	39	34	T[b]	640	16000	23	26	.239	28
		(clay loam)									
New Town	7.6	34	39	27	150	320	8000	24	24	.220	26
		(clay loam)									
Mobridge	7.9	53	28	19	50	160	16000	30	30	.051	19
		sandy loam)									

Table 14, cont'd.

Site	pH	Percentages of Sand	Silt	Clay	Nutrient Characteristics ppm of P	K	Ca	meq/100 g of Ca + Mg	CEC	% N	Field Capacity, %
		(textural name)									
Beaver Creek	7.6	72	18	10	250	240	8000	14	18	.057	17
		(sandy loam)									
Wolf Creek	7.2	64	32	4	150	640	8000	16	21	.228	21
		(sandy loam)									
Lost Bridge	7.8	34	54	12	25	320	12000	14	16	.048	20
		(silt loam)									
Hofflund Bay	7.8	25	41	34	50	160	16000	31	31	.174	28
		(clay loam)									

[a] CEC = Cation Exchange Capacity

[b] T = Trace

The edaphic characteristics of the three sites are sufficiently similar that vegetational differences among the sites are not directly related to substrate characteristics. The similarity of each pair of stands was calculated using the familiar coefficient of similarity (see p. 20):

$$C.S. = \frac{2W}{A + B} \times 100$$

where C.S. is the coefficient of similarity, A is the total number of species in one stand, B the total number of species in the second stand, and W the number of species shared by the two stands. The value is multiplied by 100 to express the index as a percentage. Using total floristic lists from the above three sites, the indexes of similarity are the following: Minnconjou and Moreau = 37%, Moreau and Grand River = 11%, and Minnconjou and Grand River = 10%. From ungrazed plots only, the indexes are the following: Minnconjou and Moreau = 40%, Moreau and Grand River = 34%, and Minnconjou and Grand River = 32%. From grazed plots only, the indexes are the following: Minnconjou and Moreau = 23%, Moreau and Grand River = 31%, and Minnconjou and Grand River = 27%.

Though chance is important in determining the composition of seral shore communities, there is considerable similarity among the three sites on Pierre Shale-derived substrates. Grazing reduced the similarities to some extent, as shown by the calculated indexes above. The Grand River site is the most heavily grazed of the three sites. It has the greatest abundance of Solanum rostratum and Grindelia squarrosa; both were more abundant on ungrazed plots at Grand River (Table 15). Important species on ungrazed plots at Grand River include Bromus japonicus, Chenopodium album, Helianthus annuus, Melilotus spp., Polygonum achoreum and Hordeum jubatum. All but Hordeum were less abundant on grazed plots. Total coverage on grazed plots at Grand River was only slightly less than on ungrazed plots (Table 15). Total biomass, however, was reduced by nearly 50% on grazed plots at this site (Table 16).

Rumex crispus often dominates shore vegetation the first year following high water. It germinates and establishes on the bare shore in late summer as the water level recedes, remains in rosette form overwinter, then forms dense stands the following growing season. Cattle do graze the species. At the Moreau site Rumex crispus had 47% and 10% coverage on ungrazed and grazed plots respectively. At Minnconjou it had 6% coverage on ungrazed plots and was absent from grazed plots (Table 15). At Moreau Hordeum jubatum, Atriplex rosea, Polygonum ramosissimum, Thlaspi arvense and Xanthium strumarium were also important on ungrazed plots and were reduced or absent on grazed plots. Contrary to results obtained at Grand River and Minnconjou, both Melilotus spp. and Polygonum achoreum were more abundant on grazed plots at Moreau. Total coverage at Moreau was 97% and 43% on ungrazed and grazed plots respectively. Biomass at Moreau was 720 g m^{-2} and 173 g m^{-2} on ungrazed and grazed plots respectively (Table 16).

Table 15. Average percent canopy coverages of plants in grazed (G) and ungrazed (U) plots along the shores of Lakes Oahe and Sakakawea. Only those species are included that had an average coverage of at least 1% at one site.

	Sites and Percent Canopy Coverages													
	Minnconjou		Moreau		Grand River		Kenel		Hazen		Garrison		New Town	
Species	G	U	G	U	G	U	G	U	G	U	G	U	G	U
GRASSES:														
<u>Agropyron</u> <u>repens</u>										1			5	64
<u>Agropyron</u> <u>smithii</u>		1					1							1
<u>Agrostis</u> <u>hyemalis</u>													4	
<u>Alopecurus</u> <u>arundinaceus</u>			1											
<u>Beckmannia</u> <u>syzigachne</u>													1	
<u>Bromus</u> <u>japonicus</u>					2	19								
<u>Echinocloa</u> <u>crusgalli</u>			2											
<u>Hordeum</u> <u>jubatum</u>			3	5	8	6	8	26	12	17	7	26	26	11

Table 15, cont'd.

Species	Minnconjou G	Minnconjou U	Moreau G	Moreau U	Grand River G	Grand River U	Kenel G	Kenel U	Hazen G	Hazen U	Garrison G	Garrison U	New Town G	New Town U
	Sites and Percent Canopy Coverages													
Panicum capillare			1										1	
Poa palustris									1	5				
Poa pratensis									1					1
Sphenopholis obtusata										9				
SHRUBS AND FORBS:														
Achillea millefolium									1					
Amaranthus albus		4				2								
Amaranthus graecizans		1												
Artemisia biennis									3	2				
Artemisia frigida									1					
Atriplex rosea		8		7					1					

Table 15, cont'd.

Species	Minnconjou G	Minnconjou U	Moreau G	Moreau U	Grand River G	Grand River U	Kenel G	Kenel U	Hazen G	Hazen U	Garrison G	Garrison U	New Town G	New Town U
	Sites and Percent Canopy Coverages													
<u>Chenopodium album</u>			3	2	1	6	48	27		25		1	27	10
<u>Chenopodium hybridum</u>							5	18						
<u>Cirsium undulatum</u>												1		
<u>Conyza canadensis</u>								1	2	4				
<u>Descurainia sophia</u>	1	1							1	5				
<u>Grindelia squarosa</u>					37	18					1			
<u>Hedeoma hispida</u>									1					
<u>Helianthus annuus</u>		1			2	6								1
<u>Iva xanthifolia</u>										3			23	30
<u>Kochia scoparia</u>	2	2					9	27					1	
<u>Lactuca serriola</u>						1								
<u>Lepidium densiflorum</u>		1			1	3			2					

Table 15, cont'd.

Species	Minnconjou G	Minnconjou U	Moreau G	Moreau U	Grand River G	Grand River U	Kenel G	Kenel U	Hazen G	Hazen U	Garrison G	Garrison U	New Town G	New Town U
	Sites and Percent Canopy Coverages													
Medicago lupulina											1			
Melilotus spp.[a]	2	7	6	1	2	13			1	47		2	4	
Plantago eriopoda					3	1								
Plantago major													3	
Polygonum achoreum			5	2	4	6		1	33	1	2		9	4
Polygonum convolvulus												1		
Polygonum lapathifolium			1	1			1		5	28	10	97	4	2
Polygonum ramosissimum		1	2	9			2	1				1	2	3
Potentilla norvegica									5	3	1	2	20	1
Ratibida columnifera									1					
Rumex crispus		6	10	47	3	1	3	12	1		2	6		

Table 15, cont'd.

Species	Minnconjou G	Minnconjou U	Moreau G	Moreau U	Grand River G	Grand River U	Kenel G	Kenel U	Hazen G	Hazen U	Garrison G	Garrison U	New Town G	New Town U
	Sites and Percent Canopy Coverages													
<u>Rumex maritimus</u>										1			11	
<u>Salsola iberica</u>				3				3						
<u>Sisymbrium altissimum</u>										3				
<u>Solanum rostratum</u>	2	1			22	6								
<u>Sonchus arvensis</u>										1				
<u>Thlaspi arvense</u>	4	11	6	9										
<u>Verbena bracteata</u>			1											
<u>Xanthium strumarium</u>		9	2	11										
TOTAL COVER, PERCENT	11	54	43	97	82	87	77	116	72	155	24	137	141	128
TOTAL NUMBER OF SPECIES	8	16	18	14	14	15	11	13	25	20	11	13	17	13

[a]Included here are <u>Melilotus albus</u> and <u>M. officinalis</u>.

Table 16. Biomass present in grazed and ungrazed plots of shore vegetation.

Condition of Plots	Sites and Biomass in grams meter^{-2}						
	Minnconjou	Moreau	Grand River	Kenel	Hazen	Garrison	New Town
Grazed	19	173	259	210	85	15	474
Ungrazed	378	720	458	606	478	1766	911

Minnconjou was the least productive site judged by both coverage and biomass estimates. Total coverage was 54% and 11% on ungrazed and grazed plots respectively; and biomass was 378 g m^{-2} and 19 g m^{-2} on ungrazed and grazed plots respectively. Atriplex rosea, Amaranthus albus, Rumex crispus and Xanthium strumarium were all important on ungrazed plots, and absent on grazed plots at Minnconjou. Melilotus spp. and Thlaspi arvense were also important on ungrazed plots, and were considerably reduced by grazing. No species encountered at Minnconjou was more abundant on grazed than ungrazed plots.

The Kenel site occurs on a loess-derived substrate that has weathered into a relatively fertile silt loam soil. That the Kenel soil is quite fertile is attested to by not only soil analyses but also by the lack of response in production following addition of nitrogen, phosphorus and potassium (see below). Hordeum jubatum, Chenopodium album, C. hybridum, Kochia scoparia and Rumex crispus were all abundant on ungrazed plots. Total plant coverage was 116% and 77% on ungrazed and grazed plots respectively at Kenel (Table 15). Biomass estimates were 606 g m^{-2} and 210 g m^{-2} on ungrazed and grazed plots respectively. Chenopodium album was much more abundant on grazed than ungrazed plots and accounted for more than 50% of the coverage and biomass on grazed plots.

The three sites on Lake Sakakawea shore occur on glacial till-derived substrates having textures of loam at Hazen and clay loam at both Garrison and New Town. Floristic similarities among the three sites, lumping data from grazed and ungrazed plots and calculating as above for Lake Oahe sites, yielded the following: Hazen and Garrison = 36%, Hazen and New Town = 41% and Garrison and New Town = 24%. The same indexes representing only grazed plots were the following: Hazen and Garrison = 28%, Hazen and New Town = 24% and Garrison and New Town = 29%. Similarity indexes representing only ungrazed plots were Hazen and Garrison = 32%, Hazen and New Town = 42% and Garrison and New Town = 30%. Floristically, ungrazed plots were more similar than grazed plots, consistent with results obtained from the Lake Oahe sites.

Important species on ungrazed plots at Hazen were *Hordeum jubatum*, *Sphenopholis obtusata*, *Poa palustris*, *Chenopodium album*, *Descurainia sophia*, *Melilotus spp.* and *Polygonum lapathifolium* all of which were less abundant or absent on grazed plots. *Polygonum achoreum* was much more abundant on grazed plots with 33% coverage compared to only 1% coverage on ungrazed plots (Table 15). *Potentilla norvegica* was also somewhat more abundant on grazed than ungrazed plots. Total plant coverage at Hazen was 155% and 72% on ungrazed and grazed plots respectively (Table 15). Biomass was 478 g m^{-2} and 85 g m^{-2} on ungrazed and grazed plots respectively (Table 16).

Important species on ungrazed plots at Garrison were *Hordeum jubatum*, *Polygonum lapathifolium* and *Rumex crispus*. All three species were much less abundant on grazed plots. Small amounts of *Grindelia squarrosa*, *Medicago lupulina* and *Polygonum achoreum* were present on grazed plots only at Garrison. Total plant coverages at Garrison were 137% and 24% on ungrazed and grazed plots respectively. Biomass was

1766 g m^{-2} on ungrazed plots and 15 g m^{-2} on grazed plots. Polygonum lapathifolium accounted for much of the coverage and biomass on the ungrazed plots.

New Town was the only site at which total plant coverage was greater on grazed than ungrazed plots, though the difference was slight. Biomass, however, exhibited the same trend as that of other sites; there were 911 g m^{-2} and 474 g m^{-2} on ungrazed and grazed plots respectively. Agropyron repens dominated the ungrazed plots along with Hordeum jubatum, Chenopodium album and Iva xanthifolia. Of these both Hordeum and Chenopodium were considerably more abundant on grazed plots (Table 15). Potentilla norvegica, Iva xanthifolia, Chenopodium album, Hordeum jubatum and Polygonum achoreum were all dominants on the grazed plots.

Cattle grazing is a variable that influences and can limit shore vegetation. While shore vegetation is intended for cattle grazing, at least in part, as well as for wildlife habitat, fish spawning habitat, erosion control and aesthetic value to the shore environment, a balance must be reached whereby the various uses of the shore do not finally negate one another. There are areas of shore where definite over-grazing has occurred; and a plan for management of the shore will have to include controls on excessive grazing by cattle. If the guidelines for grazers do include leaving at least one half the year's plant growth, this is hardly being followed over much of the reservoir shores.

Soil Nutrients

Much of the lake shore substrates is parent material and as such contains limited supplies of N and P, particularly at Mobridge, Moreau and Beaver Creek (Table 14). From soil tests it appeared that of the basic cations measured, Ca and Mg are not limiting. The status of K is somewhat questionable but our tests indicate it might be low. At study sites, described above, many plants survived for longer than one year if they were neither drowned nor grazed excessively. If nutrients are indeed limiting, it can best be determined by observing plant responses following additions of nutrients. While promoting plant growth along the lake shores, there is the risk that nutrient additions washing into the lakes will speed the eutrophication process. For this reason it was decided to do relatively small scale experiments initially. If plants responded favorably to fertilizer additions there was the possibility that greater tolerance to inundation would also result and shore vegetation development would be enhanced.

Methods

Field Experiment.---Field nutrient experiments were done at the following sites (Fig. 9):

Mobridge
Moreau
Beaver Creek
Minconjou
Kenel
Wolf Creek
New Town

We used an N:P:K fertilizer of the following ratio: 50N:50P:33K (P expressed at P_2O_5 and K expressed as K_2O) at the rate of 623 kg/ha spread evenly onto 625 m^2 plots using a hand-operated spreader. Adjacent equal areas were not fertilized and served as a check on the effects of the fertilizer. Preliminary studies under laboratory conditions indicated that N, P and K were the most limiting elements in most of the shoreline substrates. To obtain a quantitative measure of vegetation response to fertilizer additions we estimated plant canopy coverages inside and outside the fertilized plot using a coverage estimation technique described above. Coverage of each species was estimated in fifteen 0.1 m^2 plots systematically placed along a tape through the center of each fertilized and unfertilized stand. Additionally, we clipped all plants at ground level within five 0.1 m^2 plots in each fertilized and unfertilized stand. Clippings were air-dried in paper sacks in the field then oven-dried at 70° C for 48 hr before they were weighed to the nearest gram.

Laboratory Experiment.---We collected large samples of upper 1 dm mineral soil from the following experimental sites (Fig. 9):

Minnconjou
Kenel
Mobridge
Beaver Creek
Wolf Creek
Hazen
Lost Bridge
Hofflund Bay

Soils were taken to the laboratory where they were gently ground in a mortar, then passed through a 2 mm sieve to remove gravel. Soils analyses were done as described on pages 73-74.

All pot culture tests were done using 1 kg of soil in tinned cans which were lined with plastic to prevent direct root contact with the metal. The cans were painted with aluminum paint on the outside to insure uniform reflection of radiant energy. Five one week old seedlings of Phalaris arundinacea were transplanted to each pot. Nutrients listed in Table 17 were added at the start of the experiment and again after 4 weeks. The treatments were the following:

1) complete nutrients added (see Table 17 for description of complete nutrients)
2) phosphorus, potassium and sulfur added, without nitrogen
3) nitrogen, potassium and sulfur added, without phosphorus
4) nitrogen, phosphorus and sulfur added without potassium
5) nitrogen, phosphorus and potassium added, without sulfur
6) control, with no nutrients added.

Each treatment was replicated 4 times. After plants and nutrients were in the pots, they were placed in identical plant growth chambers programmed for 16 hr daylight (1300 ft-c) at 21° C and 8 hr darkness at 10° C. We added deionized water every 3 days to bring soil moisture to field capacity. During the first nine days of the experiment plants that died were replaced with fresh seedlings of the original group. The experiment lasted 8 weeks during which time we noted any changes in vigor and color of the plants.

Table 17. Nutrients added to soil; values are ml of stock[a] solution/kg of soil.

Treatment	KNO_3	NH_4NO_3	KH_2PO_4	NH_2PO_4	H_2SO_4
Complete	1	4	1	1	2.25
-N	-	-	2	-	2.25
-P	2	4	-	-	2.25
-K	-	4	-	2	2.25
-S	1	4	1	1	-
Control	-	-	-	-	-

[a]All solutions are molar except H_2SO_4 which is 95%.

At the end of 8 weeks we photographed representative groups of plants of each treatment. Additionally, we measured the height of the tallest five plants in each pot, clipped all shoot material at soil level, washed all soil from the root material in each pot, dried all plant material at 70° C for 48 hr, then weighed roots and shoots of each pot.

Results

Field Experiment.--- The addition of nitrogen, phosphorous and potassium (N, P and K) fertilizer produced noticeable changes in both the coverage (Table 18) and biomass (Table 19) of naturally occurring shore species. Biomass increases ranged from .5% at Kenel to 106.7% at Mobridge. Coverage changes ranged from a complete change of the dominant species at Beaver Creek to much smaller changes at several sites.

Table 18. Coverage estimates of the major plant species on fertilized (F) and unfertilized (U) plots. Plots were fertilized in May, 1976, and coverages estimated in August, 1976.

	Plot locations and coverage estimates in percent area covered													
	Mobridge		Moreau		Beaver Creek		Wolf Creek		Minnconjou		Kenel		New Town	
Species	F	U	F	U	F	U	F	U	F	U	F	U	F	U
Salsola iberica	78	47	1	3			1	6			1	3		
Melilotus spp.[a]	19	47	3	1	17	87								
Atriplex patula	6	7							0	1				
Chenopodium album	6	2	11	2	75	0	90	65	2	0	55	27	77	10
Chenopodium hybridum	1	0									12	18		
Kochia scoparia	0	9					2	1	61	36	34	27		
Agropyron smithii	0	7	1	0	0	1							0	1
Atriplex rosea	0	1	10	7					1	20				
Hordeum jubatum	0	1	0	5	1	0	1	11			14	26	2	11
Rumex crispus			22	47	3	0	13	28	2	5	7	12		
Thlaspi arvense			22	9					0	1				
Polygonum achoreum			20	2							0	1	0	3

Table 18, cont'd.

Species	Mobridge F	Mobridge U	Moreau F	Moreau U	Beaver Creek F	Beaver Creek U	Wolf Creek F	Wolf Creek U	Minnconjou F	Minnconjou U	Kenel F	Kenel U	New Town F	New Town U
	Plot locations and coverage estimates in percent area covered													
Polygonum ramosissimum			17	9					7	20	0	1	0	3
Xanthium strumarium			10	11	28	14			2	3				
Rumex maritimus			2	0	6	0	0	4						
Polygonum lapathifolium			1	1			2	0					2	2
Helianthus annuus					0	2			7	26			0	1
Phalaris arundinacea							5	1						
Poa palustris							1	27						
Descurainia sophia							0	10						
Agropyron repens													46	64
Iva xanthifolia													41	30
All other species	1	0	1	0	1	0	1	15	1	4	0	0	1	2
Total coverage	111	121	121	97	131	106	115	168	83	116	123	115	169	128
Total number of species encountered	7	8	13	11	10	6	9	15	8	11	6	8	6	11

[a]Includes *Melilotus albus* and *M. officinalis*.

At the Mobridge site the substrate is exposed C horizon parent material, sandy loam in texture. Nitrogen, phosphorus and potassium contents are relatively low. At this site fertilization resulted in the largest change in biomass, 106.7% increase. Two taxa dominated the weed community here. Coverage of Salsola iberica increased from 47% to 78% with fertilization while that of Melilotus spp. dropped from 47% to 19%.

The Moreau substrate is also exposed C horizon but here the material is less weathered Pierre Shale. The nitrogen content here is low, but the phosphorus and potassium contents are about average. There was a 22.5% increase in biomass resulting from fertilization. A number of species shared dominance here. Some increased while others decreased in coverage following fertilization. It is unknown if the changes were a direct result of fertilization until more studies have been done. The largest change in coverage was an increase from 2% to 20% in Polygonum achoreum following fertilization. Chenopodium album increased from 2% to 11% and Rumex crispus decreased from 47% to 22%; these two species responded similarly at most other sites where they occurred.

The most dramatic results occurred at Beaver Creek where the dominant species changed from Melilotus spp. to Chenopodium album. The substrate here is C horizon sandy loam of exposed Foxhills sandstone. Nitrogen and potassium contents are well below the median for our sites, and phosphorus content is above average. In addition to the increase in coverage with fertilization of Chenopodium album, from 0% to 75%, and in

Xanthium strumarium, from 14% to 28%, Melilotus spp. decreased from 87% to 17%.

The substrate at the Minnconjou site is clay derived from Pierre Shale. The nitrogen content here is slightly below the median while phosphorus and potassium are above. Fertilization increased biomass 14.5%. The increase in biomass at this site was due to an increase in coverage of Kochia scoparia from 36% to 61%.

At Kenel the substrate is silt loam soil, developed on loess. Essentially no change in biomass resulted from fertilization; this soil contained above median amounts of nitrogen, phosphorus and potassium. Chenopodium album and Kochia scoparia increased in coverage with fertilization while Rumex crispus, Hordeum jubatum and Chenopodium hybridum decreased. Low biomass figures for this apparently rich soil were somewhat unexpected; low rainfall may have been responsible for the low biomass.

The Wolf Creek site is a sandy loam soil and has relatively large amounts of nitrogen, phosphorus and potassium, but here there was a 94.6% increase in biomass with fertilization. These results are in direct contrast to those obtained at Kenel; the explanation offered here is that greater precipitation at Wolf Creek enhanced the effects of fertilization. At Wolf Creek Chenopodium album increased in coverage from 65% to 95% with fertilization.

At New Town where the clay loam soil is about median in nutrient content, rainfall was adequate and biomass increased 70% on the fertilized plot. Large increases in the coverage of Chenopodium album and Iva xanthifolium account for most of the increased biomass. Fertilizer additions of nitrogen, phosphorous and potassium (N, P and K) produced some noticeable changes in the shore vegetation. Chenopodium album increased in coverage at every fertilized plot (Table 18). Kochia scoparia increased on three fertilized plots; and Thlaspi arvense and Polygonum achoreum both increased greatly at the Mobridge plot. Some species decreased noticeably on several fertilized plots. Melilotus spp. decreased at the Mobridge and Beaver Creek plots; and Rumex crispus decreased on four of the five plots where it occurred. Hordeum jubatum decreased on three plots where it occurred; on two other fertilized plots Hordeum jubatum was absent though it was present on the adjacent unfertilized plots. Polygonum ramosissimum increased greatly at the Mobridge plot but decreased significantly at the Minnconjou plot as did Helianthus annuus (Table 18). Agropyron repens and Iva xanthifolia both decreased noticeably on the fertilized plot at New Town where Chenopodium album increased tremendously. Salsola iberica increased greatly at the Mobridge plot but was relatively unimportant elsewhere.

Other species listed in Table 18 are important primarily in individual plots. Poa palastris, Agropyron repens and Iva xanthifolia were present in one location each where they were relatively important species.

As shown in Table 19 increases in biomass on fertilized plots varied considerably when compared to unfertilized

Table 19. Plant biomass production on fertilized and unfertilized plots. Plots were fertilized in May, 1976, and were clipped at ground level in August, 1976.

		Biomass, grams/ meter^2	
Location	Reservoir	Fertilized Plot	Unfertilized Plot
Mobridge	Oahe	1449	701
Moreau	Oahe	822	720
Beaver Creek	Oahe	1049	894
Minnconjou	Oahe	791	691
Kenel	Oahe	609	606
Wolf Creek	Sakakawea	1263	649
New Town	Sakakawea	1549	911

control plots, and when compared to other fertilized plots. Biomass values also are not well correlated with coverage estimates though this is not unexpected (Daubenmire 1968). Compared to control plots, the greatest increase in biomass occurred on the Mobridge fertilized plot, followed by the Wolf Creek and New Town plots. The remaining fertilized plots showed considerably less gain in biomass. There was essentially no difference in biomass production between fertilized and unfertilized plots at the Kenel site. Biomass increases resulted from relatively few species that were greatly stimulated by N, P and K additions. At the

Mobridge site Salsola iberica produced most of the biomass. At Beaver Creek and Wolf Creek the huge increases in biomass were produced by Chenopodium album. At New Town the large increase in biomass on the fertilized plot was due to both Chenopodium album and Iva xanthifolia. At the Moreau site the increase in biomass was due to Chenopodium album primarily; and at the Minnconjou site the increase in biomass was due to Kochia scoparia.

Though two-dimensional estimates do not account for the height of these shoreline species, they are valuable in estimating the potential of a given site to support vegetation, especially when biomass determinations are also made. Coverage and biomass data provide a basis from which to compare fertilized and unfertilized plots, as well as plots at different sites.

Edaphic characteristics of substrates, before fertilization, are shown in Table 14. Five of the seven substrates are C horizon material. Wolf Creek and Kenel substrates still exhibit characteristics of the A and B horizons though some erosion is evident at both sites. The higher than neutral reactions on six of the sites reflects the relatively high calcium and magnesium contents that dominate the cation exchange complexes. Soil textures ranged from sandy loam to clay, and the field capacities accordingly range from a low of 17% (sandy loams) to a high of 37% (clay). All nutrient concentrations, except for potassium, fall within the ranges expected for "normal" soils (Lyon, Buckman, Brady 1952). Potassium estimates in our substrates ranged from 160 ppm to

640 ppm and "expected" concentrations of potassium are given as 1,700 ppm to 33,000 ppm (Lyon, Buckman, Brady 1952). Though our soils data do not clarify the point, the substrates we worked with could possibly "fix" potassium. The soils are subject to alternate wetting and drying, they are mostly alkaline, and they have montmorillonitic colloids (Moodie and Smith 1955). Of the edaphic factors measured, N, P and K contents correlate somewhat with biomass increases. If N, P or K is a limiting factor for shoreline plants, then additions of these elements should produce noticeable responses in plant growth. In this preliminary study of fertilizer effects we observed the greatest biomass increases on substrates where N, P or K was initially low. Conversely least increases in biomass occurred on soils having higher amounts of these elements before fertilization.

Fertilizing shorelines has the potential of altering the composition of the natural vegetation and enhancing species that are planted. It is obvious from one season of data that the vegetation composition can be changed as a result of fertilization. We have shown above the significant changes that occurred in biomass production. One season of data is insufficient to fully judge the merits of shore vegetation. One should consider the consequences of changing the shore vegetation, possible addition of nutrients to lakes, and possibly changing the diversity of the shore communities. Presently I cannot comment on the effect of fertilization on inundation survival. Only one combination of nutrients was used and it is possible that varied combinations might enhance growth on certain substrates. The increased coverage and biomass resulting from fertilization can be beneficial to wildlife and this is important in our region where wildlife habitat has been significantly depleted.

Fertilized plots were visited again in July and August, 1977, to assess the effects after more than a year. At five of the sites---Mobridge, Minnconjou, Beaver Creek, Moreau and New Town---there were no obvious residual effects from the fertilization in 1976, either in species composition or in biomass present. At Kenel, Kochia scoparia and Chenopodium album were 2 - 3 dm tall in the plot that had been fertilized but only 1 - 1.5 dm tall in the unfertilized control plot. No other differences were apparent. At Wolf Creek the residual effects of fertilization were more apparent. Interestingly, only 9 species were encountered in the fertilized plot and 19 in the unfertilized plot. The dominants in the fertilized plot were Kochia scoparia and Salsola iberica with coverages of 39% and 13% respectively. In the unfertilized plot these two species had coverages of 2% and 1% respectively. The dominant species in the unfertilized plot were Poa palustris and Hordeum jubatum with coverages of 60% and 27% respectively. In the fertilized plot the coverages of these two species were 20% and 2% respectively. In terms of biomass produced the Kenel site showed no effects of fertilization in 1976 (Table 19) but plant coverage was somewhat greater in the fertilized plot (Table 18) than in the control plot. Of all seven sites in this experiment, Kenel and Wolf Creek had the most mature soil profiles; this might aid the explanation for obvious lingering effects of fertilization in 1977.

Laboratory Experiment.---The response of *Phalaris arundinacea* was determined in 8 shore substrates. Except for Hofflund Bay, *Phalaris* grew better in substrates to which complete nutrients (Table 17) were added. In substrates in which N and/or P were low (Minnconjou, Mobridge, Beaver Creek and Lost Bridge) *Phalaris* also responded favorably to all nutrient additions in which N and P were present (Table 20). In contrast to shoot growth, root growth was better in the absence of N in all substrates except Lost Bridge (Table 20). This is not readily explained except that in substrates in which N is limiting the root retains relatively more N than is transported to the shoot.

Minnconjou substrate is derived from Pierre Shale; it is clay in texture, and though it had considerable P content, and some N, *Phalaris* did respond favorably with the addition of both N and P. Even though the substrate is clay, and is subject to extremes of wetting and drying under field conditions, the constant soil moisture conditions of this experiment allowed *Phalaris* to produce as much dry matter in this substrate as in any other substrate tested. Shoot biomass was significantly greater than that of control plants in cultures receiving nutrients with N and P. Root biomass was significantly greater than that of controls only in -N cultures. Shoot height and number of culms correlated well with increased shoot biomass (Table 20).

Hofflund Bay substrate is a clay loam; it has more N but less P than Minnconjou. Phalaris was less productive in this substrate than in Minnconjou substrate (Table 20). In no treatment did root biomass significantly exceed that of the control plants. Only in -N cultures did shoot biomass exceed that of the controls. Height of plants and number of culms also did not exceed that of control plants in any treatment.

Though Lost Bridge and Kenel substrates are both silt loams, critical similarities end there. Lost Bridge substrate is recently deposited alluvium from the Little Missouri River and contains little N or P. Kenel substrate has both more N and P and is from a more mature soil (Table 14). Cation exchange capacity is considerably greater in Kenel than in Lost Bridge substrate. With the addition of no nutrients plant growth was minimal in Lost Bridge substrate. The addition of nutrients containing N resulted in significantly more root biomass than the controls. Shoot biomass was increased significantly by the addition of nutrients having both N and P (Table 20). The number of culms and shoot height correlated well with shoot biomass.

In the Kenel substrate Phalaris shoot height and biomass correlated positively with addition of N. While nutrients lacking either N or P stimulated significantly more shoot biomass than control cultures, even greater shoot biomass was produced in cultures having both N and P. Shoot height was inconsistently related to nutrient additions, and only the

Table 20. Results of pot culture nutrient experiment on height and biomass of <u>Phalaris arundinacea</u>. Plants were grown in shore substrates with or without the addition of complete nutrient solution or nutrient solution minus one element. Substrate location is given above each data set. Values are means with standard errors of the means in parentheses.

	Nutrient Treatments					
	Control	Complete	-N	-P	-K	-S
				Minnconjou		
Height, cm	44.1 (.38)	54.6 (2.7)^{a}	48.4 (2.0)	49.2 (2.7)	53.2 (2.0)^{a}	56.2 (3.1)^{a}
No. Culms	18 (.85)	30 (1.8)^{a}	19 (1.2)^{b}	21 (1.2)^{b}	29 (1.7)^{a}	32 (3.5)^{a}
Shoot Wt, g	1.35(.06)	4.00(.17)^{a}	1.60(.09)^{b}	1.69(.31)^{b}	3.40(.31)^{a}	3.36(.45)^{a}
Root Wt, g	1.72(.11)	1.74(.18)	2.24(.48)^{a}	0.92(.21)^{c}	1.46(.20)	1.64(.48)
				Mobridge		
Height, cm	29.2 (1.9)	52.9 (2.8)^{a}	40.6 (1.6)^{ab}	47.6 (1.5)^{a}	52.0 (1.2)^{a}	48.7 (2.7)^{a}
No. Culms	5 (.25)	19 (1.7)^{a}	12 (.48)^{ab}	9 (1.2)^{b}	21 (3.4)^{a}	20 (1.6)^{a}
Shoot Wt, g	0.16(.02)	1.32(.30)^{a}	1.10(.17)^{a}	0.85(.14)^{a}	2.12(.28)^{ad}	2.05(.30)^{ad}
Root Wt, g	0.20(.04)	0.89(.27)^{a}	1.58(.15)^{ad}	0.35(.05)^{b}	1.01(.17)^{a}	1.05(.23)^{a}
				Kenel		
Height, cm	48.2 (.72)	56.6 (1.7)^{a}	47.6 (1.3)^{b}	54.2 (1.3)^{a}	53.2 (1.1)	53.2 (4.2)
No. Culms	19 (.48)	22 (.71)^{a}	20 (.85)	23 (2.7)^{a}	23 (2.1)^{a}	21 (1.2)
Shoot Wt, g	1.99(.14)	3.78(.33)^{a}	2.65(.08)^{ab}	2.80(.36)^{ab}	3.82(.39)^{a}	3.38(.17)^{a}
Root Wt, g	1.60(.26)	1.61(.25)	2.84(.14)^{a}	2.00(.52)	1.91(.37)	1.34(.09)

Table 20, cont'd.

	Nutrient Treatments					
	Control	Complete	-N	-P	-K	-S
				Beaver Creek		
Height, cm	41.2 (3.4)	49.0 (2.2)	47.1 (1.7)	44.3 (1.1)	50.6 (2.5)	---
No. Culms	10 (.29)	21 (.65)^{a}	14 (.48)^{b}	14 (1.5)^{b}	24 (1.4)^{a}	
Shoot Wt, g	0.84(.05)	2.17(.19)^{a}	1.25(.06)^{b}	1.19(.15)^{b}	2.65(.30)^{a}	---
Root Wt, g	0.92(.06)	1.29(.15)	2.30(.20)^{ad}	1.21(.17)	1.77(.16)^{a}	---
				Wolf Creek		
Height, cm	46.0 (1.4)	44.2 (1.4)	47.8 (1.0)^{d}	44.9 (1.4)	45.6 (1.6)	47.4 (1.5)
No. Culms	19 (0.5)^{b}	25 (0.5)^{a}	21 (1.1)^{b}	19 (1.1)^{b}	23 (0.6)^{ab}	20 (1.1)^{b}
Shoot Wt, g	1.86(.11)	2.39(.36)^{a}	2.39(.06)^{a}	1.54(.16)	2.41(.14)^{a}	2.33(.21)^{a}
Root Wt, g	1.87(.48)	1.17(.30)	1.25(.17)	1.03(.20)	0.94(.14)	2.33(.21)
				Hazen		
Height, cm	31.5 (1.9)	37.4 (2.2)	39.5 (1.6)^{a}	20.2 (2.0)^{bc}	35.5 (1.4)	35.2 (3.7)
No. Culms	9 (0.5)	12 (1.5)	18 (1.2)^{ad}	4 (0.3)^{bc}	7 (0.4)^{b}	9 (2.6)
Shoot Wt, g	0.43(.03)	1.41(.48)^{a}	1.27(.03)^{a}	0.13(.02)^{bc}	0.56(.08)^{b}	0.52(.26)^{b}
Root Wt, g	0.44(.07)	0.46(.13)	1.02(.06)^{ad}	0.14(.04)^{bc}	0.32(.07)	0.47(.15)

Table 20, cont'd.

	Nutrient Treatments					
	Control	Complete	-N	-P	-K	-S
				Lost Bridge		
Height, cm	24.7 (0.8)[b]	48.0 (1.6)[a]	24.2 (1.0)[b]	26.7 (1.5)[b]	44.7 (2.2)[a]	46.5 (1.9)[a]
No. Culms	6 (0.5)[b]	21 (1.3)[a]	8 (0.3)[ab]	6 (0.9)[b]	19 (1.4)[a]	23 (0.6)[a]
Shoot Wt, g	0.20(.01)[b]	2.02(.17)[a]	0.28(.03)[b]	0.17(.08)[b]	1.65(.17)[a]	1.92(.22)[a]
Root Wt, g	0.20(.02)[b]	0.93(.11)[a]	0.34(.02)[ab]	0.08(.01)[bc]	0.65(.08)[a]	0.86(.09)[a]
				Hofflund Bay		
Height, cm	45.4 (1.8)	40.0 (2.6)	49.4 (1.4)[d]	35.8 (1.9)[c]	39.1 (2.0)[c]	45.8 (2.0)
No. Culms	19 (1.2)	19 (2.5)	20 (1.4)	15 (1.9)	15 (1.5)	19 (2.5)
Shoot Wt, g	1.56(.15)	1.35(.27)	2.12(.20)[a]	0.71(.13)[c]	1.17(.25)	1.61(.24)
Root Wt, g	0.74(.16)	0.48(.09)	0.93(.16)[d]	0.45(.13)	0.52(.17)	0.76(.18)

[a]Significantly greater than the mean of the control.

[b]Significantly less than the mean of the complete.

[c]Significantly less than the mean of the control.

[d]Significantly greater than the mean of the complete.

complete and the -P cultures showed greater height growth than control cultures. Only -N cultures had significantly greater root biomass than the controls (Table 20).

Hazen substrate was the only loam used in this experiment. Plants in control cultures produced little root or shoot biomass and only -N cultures yielded root biomass greater than that of the control cultures. Only complete and -N cultures yielded shoot biomass greater than the controls.

Beaver Creek, Wolf Creek and Mobridge substrates were all sandy loams. Of the three only Wolf Creek had a substantial N content. Phalaris in Wolf Creek substrate also responded minimally to N additions. In no case was root biomass greater than that in control cultures. Shoot biomass was greater than that of control cultures in all but -P cultures; but shoot height was not increased significantly over controls in any of the treatments. Beaver Creek substrate had little N content. Shoot biomass in complete and -K cultures was significantly greater than that of control plants. We did not have -S cultures in this test. Only in -N cultures was root biomass greater than that of the controls. There was no significant differences among the heights of Phalaris among the treatments and only in complete and -K cultures were there significantly more culms than in the controls. Mobridge substrate also had little N and P contents. Phalaris root and shoot biomass reflected nutrients added. Shoot biomass and shoot height were significantly greater than control plants in all treatments except -P.

Again, the greatest root biomass was in the -N cultures. The number of culms was significantly greater than controls in all but -N and -P cultures.

While useful in determining plant responses to nutrient additions under the conditions of the experiment, this approach to plant responses to nutrient additions has certain shortcomings. In this experiment soil moisture was maintained at or near field capacity throughout the experiment. In the field soil moisture varies greatly which in turn affects the availability of certain nutrients. Additionally, we tested only one plant species against only four plant nutrients. Obviously there are many other combinations of plants and nutrients that could have been tested. Though <u>Phalaris arundinacea</u> is one of the most important species along the lake shores, other species may have responded differently to the same set of experimental conditions. The fact remains, however, that this experiment did reveal a lack of N and P in some of the substrates judged by the increased growth in <u>Phalaris</u> when N and P were added.

Nutrient additions in the field resulted in increased plant growth, except at Kenel; but changes in species dominance at fertilized sites also occurred. Additionally, fertilization had only temporary effects; thus prolonged effects would require fertilization periodically. This is not unexpected but long term additions of fertilizer elements to these lakes may be less than desirable. From the results of the field and laboratory experiments we suggest that limited additions of fertilizer elements, particularly N and P, in conjunction with seeding a species like Phalaris arundinacea could be useful to stimulate establishment and growth of this species.

RECOMMENDATIONS FOR MAXIMIZING SHORE VEGETATION

Because the mainstem Missouri River dams and reservoirs are for multiple use, various demands are placed on the water resource. An important question from the standpoint of the current study is whether shore vegetation can be enhanced in the face of so many other demands that directly or indirectly influence shore vegetation.

Currently the shore vegetation of Lakes Oahe and Sakakawea is a mosaic of primarily ephemeral species that respond to fluctuating water levels. Each year most of the shore vegetation is eliminated by a combination of high water and cattle grazing, though there are certainly other factors that limit the vegetation also. Each year the vegetation reestablishes or survives the water/grazing stresses.

Shore vegetation provides food and cover for a number of animal species, provides preferred spawning habitat for several important fish species, helps reduce erosion of the shores and adds positively to the aesthetics of the shore environment. How to maintain shore vegetation is a somewhat intractable problem.

Recommendations to aid in solving this problem that have developed during the course of this study are the following.

Because there are six mainstem Missouri River reservoirs having considerable volume for annual flood control, it seems feasible to manage water levels within the total system of reservoirs to maximize for shore vegetation along one reservoir at a time. Within a given reservoir, water level fluctuations should be minimized and their timing should closely coincide with the phenologic activities of plant species occupying the shores.

During the year of minimum fluctuations the water level would best be maintained at a level lower than the maximum for the reservoir, but not as low as the lowest level during a "normal" year. I must be somewhat tentative at this point simply because the water levels have never been managed as suggested and we have empirical data based on seven consecutive years during which water level fluctuations were never the same two successive years. The low water level, however, would allow considerable shore vegetation to develop during that one year. During the following year water in that same reservoir should be raised more rapidly than normal to inundate some of the shore vegetation, thus allowing fish like the northern pike to spawn among the standing live and/or dead shore vegetation. This particular fish spawns early in the spring, so it is necessary for water to inundate shore vegetation early in the year. The above suggestion assumes that the remaining five reservoirs have the capacity to take up the volume of water that would normally go into the reservoir in question, and that output to the downstream portion of the River could be adjusted somewhat also to aid in this management plan. If the minimal water fluctuations for the reservoir could be carried out over a two-year period, considerably more shore vegetation would develop with the possibilities of surviving the inundation the third year greatly enhanced.

Along with this plan would have to be some more control over where cattle have access to the reservoir shores. We have documented that cattle grazing indeed do limit shore vegetation development; unless more stringent guidelines are set up and maintained regarding cattle grazing of the shore vegetation, the water level fluctuation plan would likely not succeed anyway. It is my belief that, regarding shore vegetation which was the focus of this study, the guidelines drawn up for grazers are not being followed at the present time. I also know this is a difficult problem simply because on broad expanses of arid rangeland cattle will congregate and impact more greatly near sources of water. I suspect, however, that corridors clearly marked and fenced if necessary could be established for cattle to have access to the reservoir water and the shore vegetation could be provided considerably more protection than at present.

The program of managing water level fluctuations within a given reservoir could be rotated among the various reservoirs to maximize for shore vegetation development around one reservoir at a time. Over a period of twelve years, assuming all reservoirs are involved in this program, all six reservoirs would benefit from the program. If, however, it were decided to allow two years of shore vegetation development before it was inundated, the time span for all six reservoirs would be six years longer. It is also possible that certain of the reservoirs are more critical than others in terms of this suggested management plan, and perhaps one or two of the reservoirs may not be included. From our experience along Lakes Oahe and Sakakawea, and a brief period during which we examined most of the shore around Fort Peck Reservoir, I would suggest that these three reservoirs should indeed be involved in some kind of program to enhance shore vegetation development.

From our limited studies on the effects of fertilizing shore vegetation, I would suggest this be combined with a seeding program. Simply fertilizing shore vegetation did increase production; but it also resulted in altered species compositions and dominants among the shore plant communities. There was insufficient time to determine if these changes were favorable for the longer term development of shore vegetation, or whether the new communities were more or less tolerant to inundation than those before fertilizing. In our seeding studies, we found that certain plant species were seemingly adapted to the shore environment, discounting, of course, the effects of inundation and cattle grazing. Plants like *Phalaris arundinacea*, *Phragmites australis*, *Typha latifolia*, *Agropyron smithii*, *Scirpus validus* and *Alopecurus arundinaceus* and *Alopecurus aequalis* all do quite well when planted along the lake shores. In fact, they have spread in certain areas and there is a possibility that they will be "permanent" members of the shore communities, within the constraints imposed on all species of the shores. Fertilizing newly planted or seeded areas of some of these may well be the best use of fertilizers along these lake shores. As nearly as we can tell from the nutrient studies done, nitrogen and phosphorous are the two most limiting elements. This is not totally unexpected in view of the shore substrates being mainly parent material that has been little altered by organisms. A final point to consider in fertilizing any shore vegetation is the long-term effect on eutrophication of the lakes. Very likely, small additions of fertilizer elements to the lake shores will affect the aging of the lake minimally or not at all. Continuous long-term additions of fertilizer elements over much of the lake shore could indeed speed the aging process.

The above suggestions are made based on observations and data obtained during the course of this study. In making the suggestions for enhancing shore vegetation development, I also must add that the possibilities are remote for shore vegetation that will remain indefinitely in a given area. Only if there were no water fluctuations, or only if water fluctuations were minimal could one expect any semblance of permanent vegetation. At the same time, I suggest that even if it is not permanent, shore vegetation development can be enhanced and the mosaic of shore communities that shift and change in composition in relation to factors of the environment can itself be considered a permanent part of the shore environment. The concept of a shifting and changing yet permanent mosaic of plant communities should be given every consideration in the overall management of fluctuating water level reservoirs. I am also assuming in making the above suggestions that in fact shore vegetation is desirable and is a priority item in the overall management of the system of Missouri River reservoirs. It is extremely easy to destroy shore vegetation along fluctuating water level reservoirs; but it is equally difficult to maintain shore vegetation along the same reservoirs.

SUMMARY

Major findings of the present study can be summarized as follows:

1. Fluctuating water level reservoirs ordinarily exhibit a shore mainly devoid of macrovegetation. Vegetation temporarily establishes on the shore between periods of high water.

2. Lakes Oahe and Sakakawea are mainstem Missouri River reservoirs that occur in a climate which normally supports steppe vegetation. Growing seasons are short in the vicinity of Lake Sakakawea, somewhat longer southward along Lake Oahe. The natural vegetation of the region is steppe on the uplands and woodlands along the protected ravines of the Missouri River "breaks". Much of the substrate around both lakes shows signs of past glaciation, though erosion has exposed Tertiary- and Cretaceous-aged shales and sandstones over much

of the area close to the lakes. Alluvium and gravel of Pleistocene or Recent times are present to a limited extent along the shores.

3. Natural vegetation around Lake Oahe is distinguishable into two zones; zone one vegetation is upland and has not been inundated, and zone two vegetation is shore vegetation that is inundated, at least in part, during most years. The shore vegetation is dominated by *Agropyron smithii*, *Hordeum jubatum*, *Rumex crispus*, *Kochia scoparia*, *Lactuca serriola* and others. Shore vegetation around Lake Oahe is a mosaic of shifting plant communities that responds to yearly water level fluctuations and other limiting factors. *Rumex crispus* usually dominates the shore vegetation the first year after high water. The second year after high water *Rumex* is replaced by *Hordeum jubatum* as a dominant species.

4. Vegetation at Lake Sakakawea is discernible into three zones. Upland vegetation is zone one and is not inundated. Zone two is shore vegetation intermediate in position along the shore. It is dominated by *Agropyron smithii*, *Hordeum jubatum*, *Poa pratensis*, *Rumex crispus* and *Phalaris arundinacea*. Zone three vegetation is that closest to the water and is dominated by *Polygonum lapathifolium* along with *Phalaris arundinacea*, *Rumex crispus* and *Hordeum jubatum* as co-dominants. Shore vegetation around Lake Sakakawea also changes yearly exhibiting responses to water level fluctuations and cattle grazing.

5. Numerous species can be established along the lake shores either by seeding or transplanting. The longevity of

established species depends on tolerance to flooding, if protected from grazing. Record-high levels in 1975 killed most species that had been planted in 1973 and 1974. The only survivors in 1975 of planted stock were Phalaris arundinacea, Alopecurus arundinaceus, Phragmites australis, Typha latifolia, Scirpus validus and Salix alba. Many species did survive at least two years of "normal" water level fluctuations.

6. Record-high water levels in 1975 also allowed us to document inundation tolerances of numerous naturally occurring species. Shrubs are quite intolerant to flooding. Among trees, Salix amygdaloides was most tolerant to flooding, Celtis occidentalis and Ulmus spp. were least tolerant. Among herbaceous species Phalaris arundinacea, Phargmites australis, Scirpus validus, Typha latifolia and Agropyron smithii were most tolerant.

7. In a laboratory experiment on inundation tolerance among common grasses encountered in the study region, Phalaris arundinacea was most tolerant, along with Alopecurus arundinaceus, Beckmannia syzigachne, Agropyron smithii and A. repens. Stipa viridula, Puccinellia nuttalliana and Hordeum jubatum were least tolerant.

8. Cattle grazing significantly decreased both plant coverage and plant biomass along both lake shores. Grazing also decreased floristic similarities between grazed and ungrazed plots.

9. Fertilizing shore plant communities with N, P and K fertilizer increased vegetation coverage and production on sites where the substrate was parent material and low in N

and/or P. Where these elements were present in adequate concentrations fertilizer did not increase production. Laboratory experiments were done using seven of the shore substrates and testing the responses of <u>Phalaris arundinacea</u> to additions of nutrients containing N, P, K and S. Results verified the lack of N and P and the increased plant growth with additions of these elements.

10. Recommendations for management of a fluctuating water level reservoir that could materially aid shore vegetation development and reproduction of certain fish species include drastic reduction of shore area being grazed by cattle and/or sheep. Additionally, water level fluctuations should be minimized for one or two years to permit development of considerable shore vegetation. During the following year water levels should be raised early in the spring to permit spawning of such prized game fish as northern pike. A program of minimal fertilization with N and P following seeding with such species as <u>P. arundinacea</u>, <u>A. arundinaceus</u> and <u>Agropyron smithii</u> would enhance development of stands of these species. By rotating among the lakes the regimen for enhancing shore vegetation development and fish reproduction, the benefits could be spread among the reservoirs of the mainstem Missouri River. Additional benefits would include greater shore vegetation for wildlife habitat and added aesthetic value to the shore environment.

11. In any given location along the lake shores the vegetation is not permanent. But shore vegetation over the entire shore area is a shifting mosaic of plant communities

of various composition. It is this mosaic that is permanent and can be sustained over an indefinite period of time.

REFERENCES CITED

Ackermann, W. C. et al. 1973. Summary and recommendations, pp. 3-40, IN W. C. Ackermann et al., eds., Man-made lakes: their problems and environmental effects. Amer. Geophys. Union, Geophys. Monogr. No. 17, 847 pp.

Ahlgren, C. E. and H. L. Hansen. 1957. Some effects of temporary flooding on coniferous trees. Jour. For. 55: 647-650.

Beard, J. B. and D. P. Martin. 1970. Influence of water temperature on submersion tolerance of four grasses. Agron. Jour. 62: 257-259.

Benson, N. G. 1968. Review of fishery studies on Missouri River main stem reservoirs. U.S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife Res. Rept. 71, 61 pp.

Bolton, J. L. and R. E. McKenzie. 1946. The effect of early spring flooding on certain forage crops. Sci. Agric. 26: 99-105.

Burgess, R. L. et al. 1973. Vegetation of the Missouri River floodplain in North Dakota. No. Dak. Water Resources Res. Institute Mimeo. Report, 162 pp.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northw. Sci. 33: 43-64.

______________. 1968. Plant Communities, a textbook of plant synecology. Harper & Row, Publ., New York, 300 pp.

Davis, A. G. and B. F. Martin. 1949. Observations on the effect of artificial flooding on certain herbage plants. Jour. Brit. Grassl. Soc. 4: 63-64.

Fels, E. and R. Keller. 1973. World register of man-made lakes. pp. 43-49 IN W. C. Ackermann et al., eds., Man-made lakes their problems and environmental effects. Amer. Geophys. Union, Geophys. Monogr. No. 17, 874 pp.

Finn, B. J. et al. 1961. Effects of different soil moisture tensions on grass and legume species. Can. Jour. Soil Sci. 41: 16-23.

Flint, R. F. 1955. Pleistocene geology of eastern South Dakota. U.S. Geol. Survey Prof. Paper 262, 173 pp.

Gill, C. J. and A. D. Bradshaw. 1971. The landscaping of reservoir margins. Jour. Inst. Landscape Arch. 95: 31-34.

Green, W. E. 1947. Effect of water impoundment on tree mortality and growth. Jour. For. 45: 118-120.

Hanson, H. and W. Whitman. 1938. Characteristics of major grassland types in western North Dakota. Ecol. Monogr. 8: 57-114.

Hosner, J. F. 1960. Relative tolerance to complete inundation of fourteen bottomland tree species. For. Sci. 6: 246-251.

Kelting, R. W. and W. T. Penfound. 1950. The vegetation of stock pond dams in central Oklahoma. Amer. Midl. Nat. 44: 69-75.

Küchler, A. W. 1964. Potential vegetation of the conterminous United States. Amer. Geog. Soc. Spec. Publ. No. 36, 116 pp. + map.

Leonard, A. G. 1930. The geology of North Dakota. Univ. No. Dak. Bull. No. 11.

Lyon, T. L. et al. 1952. The nature and properties of soils. The MacMillan Co., New York, 591 pp.

Magadza, D. H. D. 1970. A preliminary survey of the vegetation of the shore of Lake Kariba. Kirkia 7: 253-267.

Moodie, C. D. and H. W. Smith. 1955. Syllabus for soil fertility. Dept. of Agron., Wash. St. Univ., Pullman, Wn., 249 pp.

____________. and F. E. Koehler. 1975. Laboratory manual for soil fertility. Dept. Agron. and Soils, Wash. St. Univ., Pullman, Wn., 206 pp.

____________. et al. 1963. Laboratory manual for soil fertility. Dept. Agron. and Soils, Wash. St. Univ., Pullman, Wn., 198 pp.

Nelson, J. R. 1961. Woody plant communities in the badlands of western North Dakota. No. Dak. Acad. Sci. 15: (Abst.)

Omodt, H. W. et al. 1968. The major soils of North Dakota. No. Dak. Agr. Exp. Sta. Bull. No. 472, 60 pp.

Orloci, L. 1967. An agglomerative method for classification of plant communities. Jour. Ecol. 55: 193-206.

Patterson, D. D. et al. 1968. Soil survey report, county general soil maps, North Dakota. No. Dak. Agr. Exp. Sta. Bull. No. 473, 150 pp.

Porterfield, H. G. 1945. Survival of buffalo grass following submersion in playas. Ecology 26: 98-100.

Rhoades, E. D. 1967. Grass survival in flood pool areas. Jour. Soil and Water Cons. 22: 19-21.

Sheard, J. W. and M. E. Jonescu. 1974. A multivariate analysis of the distribution of lichens on Populus tremuloides in west-central Canada. The Bryol. 77: 514-530.

Silker, T. H. 1948. Planting of water-tolerant trees along margins of fluctuating-level reservoirs. Iowa State Coll. Jour. Sci. 22: 431-447.

Sokal, R. R. and P. H. A. Sneath. 1963. Principles of Numerical Taxonomy. W. H. Freeman and Co., San Francisco, 359 pp.

Thornbury, W. D. 1954. Principles of Geomorphology. John Wiley and Sons, Inc., New York, 618 pp.

Tiemeier, O. 1951. Studies on Kanopolis reservoir in 1950. Kans. Acad. Sci. Trans. 54: 175-189.

U. S. Army Corps of Engineers. 1971. Garrison project area-capacity tables. Omaha District (mimeo. report), 12 pp.

______________________________. 1972. Oahe project area-capacity tables. Omaha District (mimeo. report), 12 pp.

U. S. Dept. of Commerce Weather Bureau. 1959. Climatography of the United States No. 60-32, 16 pp.

______________________________. 1960. Climatography of the United States No. 60-39, 16 pp.

Van Bruggen, T. 1976. The vascular plants of South Dakota. Iowas State Univ. Press, Ames, Iowa, 538 pp.

Vanderveen, B. and G. R. Hoffman. 1973. The shoreline vegetation of Lake Oahe, a man-made fluctuating water level reservoir of the upper Missouri River basin. Mimeo Report, 75 pp.

Waddington, D. V. and G. H. Baker. 1965. Influences of soil aeration on the growth and chemical composition of three grass species. Agron. Jour. 57: 253-258.

Weaver, J.E. 1942. Competition of western wheat grass with relict vegetation of prairie. Amer. Jour. Bot. 29: 366-372.

Westin, F. C. et al. 1967. Soils of South Dakota. So. Dak. Agr. Expt. Sta. Soil Survey Series No. 3, 32 pp.

Whittaker, R.H. 1962. Classification of natural communities. Botan. Rev. 28: 1-239.

APPENDIX

Table A. Percentage cover (CV), average frequency (AF), and constancy (CN) of each species in zone one around Lake Oahe from 1972 to 1976.

Species	1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Agropyron smithii	48	75	95	29	50	76	24	48	71	24	50	77	27	50	69
Bromus japonicus	13	26	49	10	24	47	15	32	53	.12	32	63	7.7	19	47
Melilotus officinalis	5.7	12	30	+	0.2	2.7	+	.1	2.7	1.7	5.8	29	2.1	6.4	19
Bromus inermis	5.6	9.1	19	5.8	9.7	19	8.2	13	24	3.4	5.7	14	7.9	11	19
Agropyron cristatum	5.0	7.5	11	5.1	7.9	13	5.4	9.1	21	8.1	12	17	8.2	13	19
Symphoricarpos occidentalis	4.0	8.5	14	3.2	8.7	19	1.6	7.2	16	3.0	8.5	23	4.1	10	16
Rumex crispus	3.8	11	38	0.8	2.6	11	+	0.2	2.7	0.3	1.3	5.8	0.6	3.5	16
Carex eleocharis	3.4	8.1	11							0.9	3.2	5.8	1.2	3.0	6.3
Poa pratensis	3.1	11	30	1.9	5.5	13	4.0	11	29	2.7	7.3	26	0.7	3.5	13
Lactuca oblongifolia	3.1	12	35	0.5	3.9	21	0.2	1.7	19	0.9	5.8	19	0.3	2.3	9.4
Sonchus arvensis	2.9	5.4	5.5	2.0	4.5	5.3	1.7	5.0	5.3	1.9	4.2	5.8			
Hordeum jubatum	2.4	10	33	1.9	5.9	21	0.9	4.2	21	1.5	6.6	34	0.2	1.3	9.4
Stipa spartea	2.2	9.0	14	1.4	3.5	11	1.1	2.8	5.3				0.1	0.6	3.2
Aster ericoides	2.2	5.7	14	5.7	17	32	3.4	15	40	1.0	4.7	26	1.2	5.0	16
Lactuca serriola	2.0	11	22	1.3	4.3	16	0.9	4.0	16	1.8	10	40	0.2	0.9	6.3
Kochia scoparia	2.0	4.2	16	1.6	3.9	13	1.6	2.9	11	3.0	6.9	12	1.9	4.1	9.4

Table A, Contd.

Species	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Plantago patagonica	0.5	1.6	2.8							0.2	1.3	5.8			
Andropogon scoparius	0.5	1.5	5.5	0.1	0.6	2.7	0.4	0.9	2.7				0.2	0.7	3.2
Xanthium strumarium	0.5	2.8	8.2							+	0.3	2.9			
Convolvulus sepium	0.5	1.4	2.8				0.4	2.6	2.7	0.5	3.2	5.8	0.9	2.4	3.2
Conyza canadensis	0.5	1.3	8.2	0.1	0.7	11	+	0.4	2.7	0.3	1.8	8.6	+	0.5	6.3
Artemisia dracunculus	0.5	3.6	11	0.2	1.1	2.7	0.2	0.9	5.3				0.1	0.3	3.2
Tragopogon dubius	0.5	4.4	27	0.1	0.9	11	0.3	2.6	24	0.3	2.2	20	0.2	2.1	16
Festuca ovina	0.4	2.2	2.8												
Bidens frondosa	0.4	1.1	5.5												
Salsola iberica	0.4	0.5	2.8	0.1	1.2	5.3	+	0.5	5.3	1.1	2.7	8.6	0.5	2.5	9.4
Aristida longiseta	0.4	1.4	5.5	0.6	2.0	5.3	0.5	1.2	5.3	0.3	1.0	2.9	0.2	0.7	3.2
Polygonum ramosissimum	0.4	2.1	5.5	0.1	1.1	11	+	0.2	2.7	0.6	3.9	17	+	0.3	3.2
Polygonum achoreum	0.4	3.2	5.5							0.2	1.7	2.9	+	0.5	3.2
Chenopodium album	0.4	2.8	16	0.1	0.7	7.9	0.1	0.9	11	0.6	0.9	14	0.1	1.3	9.4
Bidens cernua	0.4	1.1	5.5												
Physalis virginiana	0.4	0.5	2.8	+	0.2	2.7									
Medicago sativa	0.3	0.9	2.8	0.2	0.7	2.7	0.1	1.3	2.7	0.9	2.2	8.6			

Table A, Contd.

Species	1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Aster hesperius	0.3	0.9	2.8				0.4	1.2	2.7						
Lygodesmia juncea	0.3	2.1	5.5	0.2	1.8	7.9	0.1	1.8	7.9	0.1	1.2	2.9	0.2	1.7	6.3
Juncus bufonius	0.3	0.8	2.8												
Rosa blanda	0.3	2.6	8.2	0.4	2.6	11	0.2	2.1	7.9	0.1	0.9	2.9			
Gaura coccinea	0.3	1.6	5.5	0.4	2.4	13	0.1	1.4	7.9						
Rhus aromatica	0.3	1.6	2.8	0.2	0.9	5.3	0.1	0.2	2.7	0.1	0.3	2.9	0.3	0.9	6.3
Polygonum convolvulus	0.3	1.8	2.8												
Melilotus albus	0.3	0.8	5.5							0.3	0.8	8.6			
Potentilla rivalis	0.3	1.1	2.8												
Verbena bracteata	0.2	0.7	5.5										+	0.2	3.2
Urtica dioica	0.2	1.5	5.5							0.3	0.3	2.9	0.5	3.1	3.2
Erigeron pumilus	0.2	2.2	8.2												
Medicago sp.	0.2	0.8	5.5							0.1	0.8	2.9			
Distichlis spicata	0.2	0.6	5.5							0.5	1.2	2.9			
Tradescantia bracteata	0.2	1.7	5.5												
Grindelia squarrosa	0.2	1.4	11	0.5	2.0	7.9	0.6	1.8	7.9	0.2	1.3	5.8	1.4	5.3	25
Petalostemon purpureum	0.2	1.4	5.5	0.1	1.4	2.7	0.1	0.6	2.7	0.3	1.8	5.8	0.1	0.7	3.2

Table A, Contd.

Species	1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Psoralea argophylla	0.2	1.5	8.2	0.1	0.4	5.3	+	0.4	2.7	0.1	0.5	2.9			
Stipa comata	0.2	0.7	2.8	0.4	2.5	7.9	2.2	6.7	16	0.1	1.0	8.6	2.3	6.7	19
Polygonum lapathifolium	0.2	1.9	8.2												
Amorpha canescens	0.2	1.1	2.8	0.2	0.7	2.7	0.3	0.9	2.7						
Lathyrus polymorphus	0.1	2.2	11												
Solidago missouriensis	0.1	0.5	5.5	0.2	1.3	7.9	0.2	1.3	5.3						
Agropyron repens	0.1	0.9	2.8	0.1	0.4	2.7									
Elymus canadensis	0.1	1.8	8.2	0.7	2.8	11	0.1	0.9	5.3	0.1	0.9	2.9			
Andropogon gerardi	0.1	1.4	2.8	+	0.2	2.7				0.1	0.5	2.9			
Potentilla norvegica	0.1	0.3	2.8	0.2	1.1	5.3							0.4	2.4	3.2
Dalea enneandra	0.1	0.9	8.2										0.1	0.3	3.2
Agrostis hyemalis	0.1	0.3	2.8	+	0.2	2.7				0.4	1.4	5.8			
Koeleria pyramidata	0.1	0.8	8.2	0.1	0.8	5.3	0.3	1.9	7.9	+	1.2	2.9	0.1	0.5	3.2
Descurainia sophia	0.1	0.9	8.2	0.1	0.3	2.7	0.4	2.1	7.9	0.2	1.6	17	0.2	1.0	3.2
Achillea millefolium	0.1	1.0	5.5	+	0.2	2.7	0.1	0.7	5.3	0.1	0.4	5.8	0.2	0.6	3.2
Potentilla paradoxa	0.1	0.2	2.8												
Potentilla arguta	0.1	0.8	2.8	+	0.5	2.7	+	0.7	2.7	+	0.2	2.9	0.1	0.6	3.2

Table A, Contd.

Species	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Hordeum pusillum	0.1	0.6	5.5							+	0.2	2.9			
Asclepias pumila	0.1	0.5	5.5												
Taraxacum officinale	0.1	3.2	11				+	0.3	2.7	0.3	1.9	12	0.3	2.1	3.2
Puccinellia nuttalliana	0.1	1.1	8.2							0.1	0.3	2.9			
Polygala alba	0.1	0.8	2.8	+	0.2	2.7									
Echinacea angustifolia	0.1	1.0	8.2				+	0.5	5.3						
Ratibida columnifera	0.1	0.9	5.5	0.7	5.9	32	0.9	3.1	16	0.1	1.2	12	0.4	4.3	19
Menthe arvensis	0.1	0.4	2.8				+	0.2	2.7						
Euphorbia podperae	+	0.6	5.5												
Lycopus americanus	+	0.3	2.8												
Calamovilfa longifolia	+	0.3	2.8	0.2	0.6	5.3	+	0.2	2.7	0.1	0.7	5.8	0.1	1.0	3.2
Chenopodium glaucum	+	0.3	2.8												
Cirsium flodmani	+	0.4	5.5												
Lactuca ludoviciana	+	0.2	2.8												
Opuntia fragilis	+	0.2	2.8												
Cirsium arvense	+	0.2	2.8							+	0.1	2.9			
Apocynum cannabinum	+	0.2	2.8												

Table A, Contd.

Species	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Solidago rigida	+	0.4	2.8	0.2	0.4	2.7	+	0.3	2.7						
Liatris punctata	+	0.2	2.8												
Ambrosia psilostachya	+	0.2	2.8												
Helianthus maximiliana	+	0.2	2.8				0.1	0.7	2.7						
Plantago elongata	+	0.7	2.8												
Panicum capillare	+	0.6	5.5							+	0.1	2.9	+	0.6	3.2
Oxalis stricta	+	0.7	2.8							0.1	0.5	2.9			
Rumex mexicanus	+	0.7	2.8	1.0	3.2	7.9	0.1	2.0	7.9	0.5	1.3	5.8			
Viola spp.	+	0.5	2.8												
Euphorbia marginata	+	0.5	5.5							0.1	0.9	2.9			
Opuntia compressa	+	0.4	2.8	+	0.2	2.7	+	0.2	2.7	0.2	1.3	12	+	0.2	3.2
Buchloe dactyloides	+	0.3	2.8							0.5	0.9	5.8			
Erysimum asperum	+	0.3	2.8												
Lepidium densiflorum	+	0.3	2.8	0.1	1.0	7.9	0.4	3.2	19	0.2	1.7	12	+	0.3	3.2
Rumex maritimus	+	0.2	2.8												
Collomia linearis	+	0.2	2.8	+	0.3	2.7				0.2	1.5	5.8			
Cleome serrulata	+	0.2	2.8	0.4	1.3	2.7									

Table A, Contd.

Species	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Rosa arkansana	+	0.2	2.8				+	0.4	2.7				0.3	2.1	6.3
Rosa woodsii	+	0.2	2.8	+	0.2	2.7				0.2	1.2	12			
Linum rigidum	+	0.2	2.8												
Carex filifolia				3.4	7.3	19	2.5	6.6	7.9	0.5	1.3	2.9			
Poa arida				0.7	2.9	7.9									
Aster simplex				0.7	1.9	5.3									
Carex laeviconica				0.6	0.9	2.7	0.9	1.5	5.3						
Atriplex patula				0.5	1.5	5.3	1.0	2.5	5.3	2.2	5.2	12			
Artemisia ludoviciana				0.3	2.0	7.9	0.3	1.4	11	0.3	1.9	8.6	0.4	3.7	13
Agropyron caninum				0.3	1.0	5.3	0.9	2.8	5.3	0.1	0.6	2.9			
Helianthus petiolaris				0.2	0.6	2.7	0.1	0.3	2.7	0.5	2.2	8.6	0.1	0.6	6.3
Elymus virginicus				0.1	0.8	2.7				+	0.3	2.9	0.1	0.7	3.2
Lactuca biennis				0.1	0.8	5.3									
Lesquerella ludoviciana				0.1	0.8	5.3	+	0.2	2.7	+	0.6	5.8			
Cirsium undulatum				0.1	0.7	2.7				0.1	0.4	5.8	0.1	0.3	3.2
Glycyrrhiza lepidota				0.1	0.3	2.7									
Artemisia absinthium				+	0.6	2.7									

Table A, Contd.

Species	1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Ambrosia artemisiifolia				+	0.3	2.7				0.4	1.8	12			
Toxicodendron rydbergii				+	0.3	2.7	+	0.3	2.7	+	0.2	2.9	0.1	0.4	3.2
Solidago graminifolia				+	0.4	2.7									
Populus deltoides				+	0.3	2.7									
Rorippa palustris				+	0.2	2.7	0.1	0.9	2.7						
Polygonum arenastrum							0.1	0.3	2.7	0.2	0.2	2.9	0.2	0.9	3.2
Lomatium foeniculaceum							0.1	1.3	5.3						
Allium spp.							0.1	0.5	5.3	+	0.6	5.8	+	0.7	3.2
Epilobium adenocaulon							+	0.3	2.7						
Sisymbrium altissimum							+	0.2	2.7	0.1	0.5	5.8	0.1	0.6	3.2
Rumex occidentalis							+	0.2	2.7	+	0.1	2.9			
Panicum oligosanthes							+	0.4	2.7						
Malva neglecta							+	0.4	2.7						
Vicia americana							+	0.4	2.7	0.1	0.7	5.8	+	0.6	6.3
Prunus spp.							+	0.3	2.7						
Penstemon sp.							+	0.2	2.7						
Lappula redowskii							+	0.2	2.7	+	0.2	2.9			

Table A, Contd.

Species	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Erigeron lonchophyllus							+	0.2	2.7						
Sporobolus cryptandrus										0.6	2.3	8.6			
Carex spp.										0.5	2.3	8.6	0.9	3.0	6.3
Unknown spp.										0.4	1.7	14	0.5	5.0	9.4
Atriplex rosea										0.2	0.7	2.9			
Silene cucubalis										0.1	0.9	2.9	0.6	1.3	3.2
Salix exigua										0.1	0.2	2.9			
Lolium perenne										0.1	0.8	5.8			
Solidago spp.										0.1	0.5	2.9			
Euphorbia geyeri										0.1	0.4	5.8			
Nepeta cataria										0.1	0.4	2.9			
Teucrium canadense										0.1	0.4	2.9	+	0.6	3.2
Anemone canadensis										0.1	0.4	2.9			
Cirsium arvense										+	0.3	2.9			
Stellaria crassifolia										+	0.3	2.9			
Amorpha nana										+	0.4	2.9	0.1	0.6	3.2
Hedeoma hispida										+	0.4	2.9			

Table A, Contd.

Species	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Asclepias speciosa										+	0.2	2.9			
Bidens spp.										+	0.2	2.9			
Linum spp.										+	0.2	2.9			
Fraxinus pennsylvanica										+	0.2	2.9			
Schedonnardus paniculatus													0.2	1.2	3.2
Polygonum spp.													0.2	1.0	3.2
Lomatium orientale													+	0.2	3.2
Bouteloua curtipendula													+	0.2	3.2
Comandra umbellata													+	0.7	3.2
Phalaris arundinacea													+	0.6	3.2
Cyperus erythrorhizos													+	0.4	3.2
Erigeron strigosus													+	0.3	3.2
Psoralea esculenta													+	0.2	3.2

Table B. Percentage cover (CV), average frequency (AF), and constancy (CN) of each species in zone two around Lake Oahe from 1972 to 1976.

Species	1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Rumex crispus	30	50	71	17	37	74	4.6	17	71	0.8	5.1	24	22	48	86
Agropyron smithii	25	54	87	8.8	23	66	13	31	84	16	42	74	4.2	13	58
Hordeum jubatum	6.9	22	50	9.2	22	76	10	30	84	1.9	11	41	7.5	29	81
Rumex maritimus	4.6	17	47	2.4	7.3	34							1.3	5.8	36
Rumex mexicanus	4.4	12	37	2.0	5.3	21	2.1	6.9	24	0.7	4.2	27	0.2	0.9	14
Carex laeviconica	2.7	3.1	5.3	1.0	1.4	5.3	0.9	1.9	13				0.8	1.4	5.6
Helianthus annuus	2.3	12	45	1.2	5.7	34	0.9	4.5	37	0.4	2.6	15	2.3	8.1	36
Scirpus americanus	2.3	5.0	13	0.6	1.6	5.3	+	0.3	2.7	0.5	1.5	3.0	+	0.1	2.8
Populus deltoides	2.2	6.6	26	1.2	3.2	29	1.5	2.8	21	2.9	6.4	21	0.8	2.6	22
Thlaspi arvense	2.2	5.2	19	0.4	1.6	11	2.9	9.7	29	0.7	1.9	8.9	1.7	8.1	22
Potentilla norvegica	2.0	5.4	24	0.9	4.5	29	0.3	2.2	19	+	0.2	3.0	0.4	2.8	28
Bidens cernua	1.9	7.3	37	+	0.4	5.3									
Lactuca serriola	1.7	5.7	34	2.9	12	63	6.4	20	63	2.5	8.4	35	0.3	2.8	36
Ambrosia trifida	1.7	7.2	21	0.4	2.7	11	+	0.1	2.7	0.1	0.9	5.9	0.3	1.0	5.6
Polygonum ramosissimum	1.7	8.5	32	3.3	10	61	0.3	1.6	21	0.7	5.8	21	1.2	6.7	33
Poa pratensis	1.7	5.1	21	0.1	0.8	11	3.6	8.9	37	1.1	3.7	24	0.4	1.4	11

Table B, Contd.

	1972			1973			1974			1975			1976		
Species	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Iva axillaris	1.7	2.6	5.3												
Bromus japonicus	1.6	8.7	23	1.4	5.1	32	3.7	11	45	1.9	10	44	2.4	8.3	42
Kochia scoparia	1.5	3.1	24	4.4	9.0	34	7.7	16	42	0.1	0.8	5.9	7.6	20	67
Bidens frondosa	1.3	3.8	19	+	0.1	2.7									
Echinochloa crusgalli	1.2	4.2	13	0.5	3.2	21	+	0.3	7.9	0.1	0.8	3.0	0.3	2.5	22
Xanthium strumarium	1.2	4.8	29	0.9	2.4	19	0.5	2.0	7.9				2.8	7.7	31
Distichlis spicata	1.2	2.6	5.3				0.3	0.7	5.3	0.6	1.5	3.0			
Carex brevior	1.2	3.5	21	0.2	0.7	7.9	+	0.3	5.3	0.5	2.5	8.9	0.2	0.7	5.6
Aster ericoides	1.2	1.8	2.7	0.2	0.8	16	0.5	2.0	13	1.1	3.3	8.9			
Chenopodium album	1.1	6.1	29	1.0	5.0	40	0.5	2.3	21	1.9	5.4	15	3.5	17	83
Typha latifolia	1.1	2.3	5.3	0.7	2.2	5.3	0.2	1.5	5.3	0.1	1.1	5.9	0.1	0.6	5.6
Lycopus americanus	0.9	3.1	16	0.1	0.4	2.7									
Conyza canadensis	0.9	5.0	13	1.0	4.9	37	0.3	3.0	34				0.7	4.4	28
Glycyrrhiza lepidota	0.8	2.2	2.7	0.4	0.9	2.7	0.2	0.9	2.7	0.4	1.5	3.0			
Rorrippa palustris	0.8	4.8	24	1.5	5.2	21	0.2	0.9	7.9				0.1	1.0	11
Tragopogon dubius	0.8	3.5	11	+	0.3	5.3	0.1	0.9	16	0.2	1.5	15			
Potentilla paradoxa	0.7	5.1	24	0.6	1.6	5.3	1.1	3.5	16				+	0.3	5.6

Table B. Contd.

Species	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Salix spp.	0.7	2.9	24	0.5	1.6	19	0.4	1.7	24	3.8	6.1	24	0.6	1.7	20
Sonchus arvensis	0.7	1.8	5.3	0.3	1.2	2.7	1.7	4.0	11	1.5	4.2	12	+	0.1	2.8
Polygonum lapathifolium	0.6	3.3	24	0.5	1.7	19	0.1	1.0	16	0.1	0.4	3.0	3.0	11	47
Mentha arvensis	0.6	2.8	13	0.1	0.1	2.7	0.1	0.7	5.3	0.7	1.5	3.0			
Aster hesperius	0.6	1.3	2.7	0.1	0.2	2.7	0.2	0.8	2.7	0.6	2.0	5.9			
Convolvulus arvensis	0.6	2.6	5.3	0.2	1.3	11	0.5	1.9	7.9	0.1	0.5	5.9	0.3	1.0	11
Panicum capillare	0.6	3.6	24	1.0	3.7	16	+	0.3	5.3				0.8	3.9	33
Phalaris arundinacea	0.5	1.2	5.3	0.4	0.7	5.3	0.5	1.0	5.3	1.9	3.4	8.9	0.5	1.3	2.8
Apocynum cannabinum	0.5	0.8	2.7	+	0.1	2.7	0.1	0.3	2.7	+	0.3	3.0			
Ellisia nyctelea	0.5	3.5	11												
Spartina pectinata	0.5	2.0	5.3	+	0.3	5.3	0.1	0.2	5.3	0.2	0.5	3.0	+	0.1	2.8
Verbena bipinnatifida	0.4	1.3	2.7												
Melilotus spp.	0.4	2.4	13	0.2	1.7	16	1.5	6.4	32	1.8	5.7	24	3.9	13	47
Melilotus officinalis	0.4	3.0	21	+	0.1	2.7	1.7	5.1	26	0.2	1.6	8.9	2.1	5.7	11
Symphoricarpos occidentalis	0.4	1.3	2.7	0.0	0.3	5.3							0.3	0.7	8.4
Verbena bracteata	0.3	1.7	13	0.7	1.6	7.9	0.4	2.0	11	+	0.4	3.0	0.3	2.0	20
Bromus tectorum	0.3	1.5	11				0.3	1.4	7.9	0.3	1.1	5.9			

Table B, Contd.

Species	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Grindelia squarrosa	0.3	1.2	13	0.5	1.9	16	0.5	2.1	21	+	0.2	3.0	+	0.2	5.6
Agropyron cristatum	0.3	0.5	5.3	+	0.2	5.3	0.1	0.2	5.3				0.7	1.8	8.4
Bromus inermis	0.2	0.8	7.9										+	0.1	2.8
Aster falcatus	0.2	0.8	5.3												
Agastache foeniculum	0.2	0.6	2.7												
Leersia oryzoides	0.2	0.9	5.3												
Polygonum convolvulus	0.2	0.4	2.7												
Scirpus validus	0.2	0.2	2.7				0.1	0.2	2.7						
Teucrium canadense	0.2	0.4	2.7	0.1	0.6	7.9	0.1	0.6	2.7	+	0.3	3.0	+	0.1	2.8
Lactuca oblongifolia	0.1	1.9	16	0.1	0.8	11	0.2	1.8	21	0.4	2.9	12	0.4	1.3	8.4
Sagitteria latifolia	0.1	1.1	5.3												
Stachys palustris	0.1	0.7	2.7												
Eleocharis macrostachya	0.1	0.5	2.7										+	0.2	2.8
Setaria viridis	0.1	0.8	2.7	0.1	0.3	2.7							0.1	0.3	2.8
Euphorbia serpens	0.1	1.7	7.9	0.1	1.3	5.3									
Artemisia cana	0.1	1.2	2.7	+	0.5	2.7	+	0.1	2.7	0.1	0.2	3.0			
Ambrosia psilostachya	0.1	0.6	5.3	+	0.1	2.7							0.1	0.3	2.8

Table B, Contd.

Species	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Convolvulus sepium	0.1	0.4	2.7												
Chenopodium glaucum	0.1	0.2	2.7	1.5	3.7	19	+	0.1	2.7				1.8	7.1	39
Elymus canadensis	0.1	0.5	5.3							+	0.2	3.0			
Salix exigua	0.1	0.9	11	0.1	0.6	11	0.3	1.1	11	0.7	2.9	8.9	0.1	0.4	8.4
Lotus purshianus	0.1	0.4	2.7				0.3	0.9	5.3	0.1	0.4	3.0	0.1	0.7	2.8
Agropyron repens	0.1	0.2	2.7	0.5	1.8	7.9	0.1	0.4	5.3	+	0.1	3.0	0.4	1.2	11
Lepidium densiflorum	0.1	1.8	11	+	0.1	2.7	0.2	1.0	7.9	+	0.2	3.0	0.2	1.5	20
Amaranthus retroflexus	0.1	1.1	5.3	0.2	1.3	11	+	0.4	2.7				+	0.4	5.6
Descurainia sophia	0.1	0.7	5.3	0.1	1.1	13	0.5	2.2	21				0.7	5.1	39
Beckmannia syzgachne	0.1	0.4	5.3	0.1	0.4	5.3	+	0.1	2.7				0.1	0.4	5.6
Psor.lea argophylla	0.1	0.4	2.7												
Camelina microcarpa	+	1.2	2.7												
Collomia linearis	+	0.7	5.3	+	0.1	2.7	+	0.3	2.7				+	0.2	2.8
Cyperus erythrorhizos	+	0.1	2.7												
Artemisia frigida	+	0.6	5.3	+	0.2	2.7	0.1	0.7	5.3				0.1	0.4	5.6
Euphorbia podperae	+	0.5	2.7												
Solanum rostratum	+	0.4	5.3	0.5	2.1	7.9	0.1	1.1	5.3				0.5	3.2	17

Table B, Contd.

Species	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Fraxinus pennsylvanica	+	0.3	2.7	+	0.2	2.7	+	0.1	2.7	+	0.5	3.0	+	0.1	2.8
Euphorbia marginata	+	0.4	5.3	+	0.1	2.7							+	0.1	2.8
Hordeum pusillum	+	0.2	2.7							+	0.2	3.0			
Malva neglecta	+	0.3	5.3				+	0.1	2.7				+	0.2	2.8
Plantago elongata	+	0.8	5.3										+	0.1	2.8
Festuca octoflora	+	0.9	2.7												
Lemna minor	+	0.1	2.7												
Schedonnardus paniculatus	+	0.5	2.7				+	0.2	2.7						
Plantago patagonica	+	0.5	5.3	+	0.2	2.7									
Erysimum asperum	+	0.4	2.7												
Taraxacum officinale	+	0.3	2.7										+	0.2	2.8
Polanisia dodecandra	+	0.2	2.7												
Artemisia biennis	+	0.2	2.7	0.1	0.7	7.0	+	0.3	2.7				0.4	3.3	22
Astragalus drummondii	+	0.2	2.7												
Ratibida columnifera	+	0.2	2.7				+	0.1	2.7				+	0.4	8.4
Nepeta cataria	+	0.2	2.7												
Stipa spartea	+	0.2	2.7	0.1	0.2	2.7	0.1	0.2	2.7						

Table B, Contd.

Species	1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Lappula echinata	+	0.2	2.7												
Lactuca ludoviciana	+	0.2	2.7												
Oenothera biennis	+	0.1	2.7	+	0.2	2.7	0.1	0.4	5.3						
Atriplex rosea				0.7	1.9	11	0.4	0.9	2.7				0.3	1.6	17
Atriplex patula				0.5	2.3	21	1.3	4.9	26	0.5	2.0	8.9	2.0	8.7	39
Rosa woodsii				0.4	0.7	5.3							+	0.1	2.8
Salsola iberica				0.4	1.4	13	0.9	4.9	24	0.3	1.4	8.9	3.8	13	47
Agropyron caninum				0.3	0.9	2.7	0.2	0.9	13	0.2	1.3	5.9			
Amaranthus albus				0.3	1.2	7.9	0.1	0.3	2.7						
Amaranthus graecizans				0.3	0.8	5.3	0.1	0.4	2.7				0.2	0.8	5.6
Iva xanthifolia				0.2	0.8	2.7							0.1	0.6	8.4
Polygonum arenastrum				0.2	0.6	2.7	0.3	1.1	5.3				0.9	2.6	11
Helianthus petiolaris				0.1	0.3	2.7							0.1	0.7	8.4
Sisymbrium altissimum				0.1	0.4	7.9	0.1	0.5	11	0.2	1.1	5.9	0.5	1.9	22
Aster simplex				0.1	0.4										
Potentilla rivalis				0.1	0.2	2.7									
Bouteloua gracilis				0.1	0.1	2.7				0.3	1.1	5.9			

Table B, Contd.

Species	1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Chenopodium leptophyllum				0.1	0.5	5.3							0.1	0.5	5.6
Lycopus asper				+	0.1	2.7									
Aristida longiseta				+	0.5	2.7	0.1	0.2	2.7						
Ambrosia artemisiifolia				+	0.4	2.7				0.2	1.5	3.0			
Epilobium adenocaulon				+	0.1	2.7	+	0.1	2.7						
Hedeoma hispida				+	0.3	2.7	+	0.4	2.7				0.1	0.4	5.6
Lesquerella ludoviciana				+	0.2	2.7							+	0.2	2.8
Portulaca oleracea				+	0.2	5.3									
Bidens spp.				+	0.2	2.7	0.1	0.3	5.3				0.1	0.7	11
Polygonum coccineum				+	0.3	2.7	0.2	0.5	5.3	+	0.3	3.0			
Ulmus americana				+	0.3	5.3				+	0.2	3.0			
Poa arida				+	0.2	2.7									
Plantago major				+	0.2	2.7									
Carex eleocharis				+	0.2	2.7	0.1	0.3	2.7				0.2	0.9	5.6
Cleome serrulata				+	0.2	2.7									
Panicum oligosanthes				+	0.1	2.7									
Opuntia fragilis				+	0.1	2.7									

Table B, Contd.

Species	1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Poa palustris				+	0.3	2.7				0.1	0.7	8.9	0.5	1.4	8.4
Astragalus spp.				+	0.1	2.7									
Cirsium undulatum				+	0.1	2.7									
Cirsium arvense				+	0.1	2.7				0.6	1.5	3.0			
Typha angustifolia				+	0.2	2.7	0.1	0.1	2.7	0.6	1.5	3.0	0.2	0.6	2.8
Euphorbia geyeri				+	0.5	5.3							0.1	0.7	5.6
Stipa viridula				+	0.4	2.7				0.2	1.6	5.9			
Oxalis stricta				+	0.1	2.7									
Lactuca biennis				+	0.1	2.7									
Brassica nigra				+	0.1	2.7									
Lepidium perfoliatum							0.2	2.1	2.7						
Bidens vulgata							0.1	0.3	2.7						
Bidens comosa							0.1	0.3	2.7						
Melilotus albus							0.1	0.3	5.3	0.1	0.1	3.0			
Rumex occidentalis							0.1	0.4	2.7	0.3	1.1	8.9	0.2	1.1	2.8
Puccinellia nuttalliana							0.1	0.6	13				0.1	0.2	2.8
Solidago missouriensis							0.1	0.4	5.3						

Table B, Contd.

Species	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Artemisia ludoviciana							0.1	0.3	2.7	+	0.1	3.0	+	0.2	2.8
Poa compressa							0.1	0.2	2.7						
Stipa comata							0.1	0.3	5.3				+	0.3	2.8
Chenopodium berlandieri							+	0.6	2.7						
Equisetum spp.							+	0.2	2.7				+	0.2	2.8
Carex filifolia							+	0.2	2.7						
Ulmus pumila							+	0.1	2.7						
Elymus virginicus							+	0.1	2.7						
Polygonum achoreum							+	0.3	5.3	0.1	0.4	3.0	0.2	1.7	14
Salsola collina							+	0.2	2.7				0.1	0.4	5.6
Artemisia dracunculus							+	0.1	2.7						
Achillea [illegible]*llefolium*							+	0.1	2.7						
Carex spp.										0.7	2.0	3.0	+	0.3	2.8
Unknown spp.										0.4	2.1	12	0.4	2.4	20
Sphaeralcea coccinea										0.1	0.5	3.0			
Lappula redowskii										+	0.2	3.0			
Scirpus fluviatilis													0.7	0.9	2.8

Table B, Contd.

Species	1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Potentilla platensis													0.1	0.6	2.8
Amorpha canescens													0.1	0.5	2.8
Setaria glauca													0.1	0.5	2.8
Atriplex argentea													0.1	0.4	2.8
Plantago eriopoda													+	0.6	5.6
Leptochloa fascicularis													+	0.2	2.8
Anemone canadensis													+	0.2	5.6
Silene cucubalis													+	0.1	2.8
Solidago sp.													+	0.1	2.8
Sphenopholis obtusata													+	0.1	2.8

Table C. Percentage cover (CV), average frequency (AF), and constancy (CN) of each species in zone one around Lake Sakakawea from 1971 to 1976.

	1971			1972			1973			1974			1975			1976		
Species	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Agropyron smithii	18	49	71	39	59	73	29	48	64	19	36	64	20	48	67	15	42	68
Agropyron cristatum	11	12	18	9.5	14	14	9.8	16	25	8.6	15	25	12	20	24	7.4	13	18
Agropyron repens	3.9	12	24	9.4	23	50	5.3	11	25	3.1	6.7	21				6.7	9.0	18
Symphoricarpos occidentalis	5.4	12	24	9.0	18	27	4.4	8.0	21	6.3	15	39	4.9	16	33	3.3	9.8	23
Bromus inermis	1.0	3.8	12	5.8	9.2	18	7.9	11	25	8.9	14	32	4.3	4.8	4.8	2.3	4.6	9.1
Hordeum jubatum	2.0	8.5	18	5.6	14	18	1.0	4.4	18	1.2	5.1	21				0.1	0.8	4.5
Stipa viridula	0.8	6.8	29	5.0	12	27	3.2	9.7	25	3.2	9.9	25	3.0	14	43	2.8	8.0	32
Poa pratensis	1.3	4.7	18	4.1	15	46	3.6	8.7	29	5.6	11	39	2.3	9.5	24	4.9	14	27
Convolvulus arvensis	1.9	5.9	5.9	3.4	7.4	23	1.9	4.4	7.1	0.8	3.7	7.1	0.2	3.0	9.5			
Lactuca serriola	0.2	3.5	18	3.2	15	41	0.1	0.7	7.1	0.9	4.9	21				0.8	4.5	14
Agrostis hyemalis				2.9	6.5	27				+	0.5	3.6	0.5	2.0	4.8	0.2	1.6	14
Carex filifolia				2.8	5.5	9.1	0.2	0.8	3.6	0.3	0.9	7.1	0.6	3.4	9.5			
Lactuca oblongifolia				2.7	18	46	2.8	15	46	1.8	9.2	25	1.5	13	38	0.8	6.0	27
Aster ericoides	+	0.8	5.9	2.7	12	27	1.2	5.7	18	2.2	9.8	46	2.2	11	29	1.9	11	32
Cirsium arvense	+	0.3	5.9	2.6	11	32	4.6	12	32	4.5	15	29						

Table C, Contd.

Species	1971 CV	1971 AF	1971 CN	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Stipa comata	2.8	6.2	12	2.4	8.5	18	0.9	5.8	18	1.6	6.6	21	4.5	25	43	5.9	19	50
Artemisia dracunculus	+	0.5	5.9	2.1	6.5	23	0.9	5.8	25	1.3	5.7	21	2.7	14	38	1.1	7.0	32
Urtica dioica	0.3	1.9	5.9	1.9	3.0	4.5	2.4	2.7	7.1	0.4	1.2	3.6				+	1.1	4.5
Eleocharis obtusa				1.8	3.0	4.5												
Melilotus officinalis	0.4	6.5	18	1.7	6.8	18	4.2	12	21	0.6	2.5	14	3.4	8.4	14			
Rosa woodsii	1.2	5.9	5.9	1.7	4.9	9.1	1.1	3.5	7.1	2.7	4.4	7.1	2.0	6.3	9.5	1.0	1.9	9.1
Poa palustris				1.5	1.9	9.1	0.9	5.0	21	0.2	1.5	11	0.6	3.0	9.5	0.1	0.7	9.1
Tragopogon dubius	0.3	1.9	5.9	1.5	8.9	36	0.7	6.9	29	0.9	8.4	36	0.3	1.8	14	0.5	4.4	14
Artemisia frigida	0.2	4.4	24	1.5	8.5	32	2.7	11	29	0.4	3.8	21	2.3	14	48	2.4	19	50
Potentilla norvegica	0.7	5.7	29	1.4	5.2	23	+	0.3	3.6	+	0.8	3.6				+	0.5	4.5
Carex brevior	+	0.6	5.9	1.4	4.5	18	0.1	1.9	11							0.1	0.8	4.5
Puccinellia nuttalliana	0.3	4.1	18	1.3	2.6	14	0.5	1.8	7.1	2.2	12	36	0.8	2.8	4.8			
Gaura coccinea				1.1	2.0	4.5	0.6	1.5	7.1	0.3	1.0	7.1	0.4	2.8	9.5	0.1	1.0	4.5
Rosa arkansana	0.2	1.8	12	1.0	6.1	18	0.1	1.6	14	0.3	1.6	3.6	0.5	2.4	14	0.4	3.0	14
Artemisia ludoviciana	0.5	3.1	12	1.0	4.0	14	0.7	3.7	11	0.5	4.1	11	1.4	8.0	14	1.2	6.9	23
Koeleria pyramidata	1.1	6.8	18	1.0	5.7	9.1	0.3	2.1	14	1.0	5.5	18	2.8	15	43	3.0	13	36
Achillea millefolium	1.1	6.8	18	1.0	8.8	27	0.2	1.5	11	0.7	3.2	11	0.2	1.6	14	0.1	2.0	14

Table C, Contd.

Species	1971 CV	1971 AF	1971 CN	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
<u>Conyza canadensis</u>	0.6	11	29	1.0	3.8	23				0.1	1.0	11	0.3	1.8	9.5	0.7	5.1	32
<u>Psoralea argophylla</u>	0.3	3.5	12	0.9	4.4	14	1.2	4.9	14	0.4	3.5	14	1.8	8.7	24	1.2	6.8	18
<u>Vicia americana</u>				0.9	6.1	18	0.9	5.6	14	0.2	1.7	14	0.4	4.2	19			
<u>Solidago missouriensis</u>	0.4	2.4	5.9	0.8	2.2	9.1	0.7	2.8	14	0.2	1.0	7.1	0.5	3.4	4.8	0.1	0.4	4.5
<u>Melilotus</u> spp.	0.2	1.9	5.9	0.8	4.3	23	0.1	0.6	3.6	0.7	3.7	18	2.3	8.9	19	7.1	18	46
<u>Sonchus arvensis</u>				0.8	2.5	18	2.6	8.1	36	1.6	7.0	18						
<u>Ribes americanum</u>				0.7	1.0	4.5	0.1	0.5	3.6	0.1	0.5	3.6						
<u>Ratibida columnifera</u>	1.2	7.7	18	0.7	3.8	18	0.9	5.0	25	0.6	5.4	29	1.0	7.9	24	0.6	6.5	27
<u>Rumex occidentalis</u>	1.2	7.7	18	0.6	1.5	4.5				0.6	1.8	7.1						
<u>Convolvulus sepium</u>				0.5	2.0	9.1	0.1	0.9	7.1	0.3	2.3	7.1	0.1	1.3	9.5			
<u>Carex laeviconica</u>				0.4	2.3	9.1										0.4	1.9	4.5
<u>Brassica nigra</u>				0.4	0.9	4.5												
<u>Polygala alba</u>				0.4	0.8	9.1	+	0.6	7.1									
<u>Polygonum ramosissimum</u>				0.4	2.3	4.5							+	1.0	4.8	0.2	1.1	9.1
<u>Anemone canadensis</u>				0.4	3.2	14	0.5	2.1	7.1	0.4	2.4	11						
<u>Ambrosia psilostachya</u>				0.4	2.5	9.1	0.8	1.1	3.6	0.7	1.9	3.6						
<u>Bouteloua gracilis</u>	0.3	2.5	12	0.3	3.0	14	0.5	2.7	11				1.2	4.0	9.5	3.9	11	36

Table C, Contd.

Species	1971			1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Phalaris arundinacea	+	0.7	12	0.3	1.3	9.1	0.5	0.8	3.6	0.6	1.2	7.1						
Bouteloua curtipendula	0.1	2.4	5.9	0.2	1.5	4.5							0.1	0.5	4.8			
Rumex crispus	0.5	3.8	12	0.2	2.7	9.1	0.5	2.1	11	+	0.7	3.6	-			+	0.5	4.5
Aster oblongifolius				0.2	0.4	4.5												
Sisymbrium altissimum	0.8	2.9	5.9	0.2	0.8	9.1	0.1	0.8	7.1									
Verbena bracteata				0.2	1.1	4.5												
Plantago eriopoda	0.5	0.3	5.9	0.2	1.1	4.5												
Apocynum cannabinum				0.2	1.8	4.5												
Oenothera biennis	0.2	1.7	5.9	0.1	0.4	4.5							0.1	0.8	4.8	0.1	1.5	4.5
Monarda fistulosa				0.1	0.9	4.5							0.1	1.0	4.8			
Calamovilfa longifolia	0.7	4.9	5.9	0.1	1.5	4.5							0.9	4.1	4.8	2.2	5.5	18
Poa interior	+	0.8	5.9	0.1	1.4	9.1	0.3	1.8	3.6									
Oxalis stricta				0.1	0.8	4.5							0.1	1.3	4.8			
Aster hesperius	0.6	1.5	7.1	0.1	0.7	9.1	0.6	1.5	7.1	0.1	1.0	7.1						
Iva xanthifoila	0.3	2.4	5.9	0.1	0.8	9.1	0.6	0.7	3.6	0.1	0.4	3.6						
Ambrosia trifida				0.1	0.4	4.5				+	0.6	3.6				0.4	1.1	4.5
Polygonum lapathifolium	+	0.3	5.9	0.1	2.3	4.5												

Table C, Contd.

Species	1971			1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Heracleum sphondylium				0.1	0.4	4.5												
Taraxacum officinale				0.1	0.4	4.5												
Echinochloa crusgalli				+	1.1	4.5												
Erigeron lonchophyllus	1.9	4.5	11	+	0.8	4.5	1.9	4.5	11									
Senecio congestus				+	0.8	4.5												
Cirsium flodmani				+	0.5	4.5												
Ellisia nyctelea				+	0.5	4.5												
Epilobium adenocaulon				+	0.5	4.5												
Melililotus albus	0.6	3.1	5.9				2.0	6.9	21	2.1	4.9	11						
Ambrosia artemisiifolia							0.3	2.1	3.6				1.7	7.6	9.5	2.1	6.3	14
Lappula redowskii							0.2	0.4	3.6									
Euphorbia podperae							0.2	1.2	3.6	0.5	3.6	3.6						
Chenopodium album							0.2	1.1	7.1							0.4	1.6	9.1
Sphenopholis obtusata							0.1	0.4	3.6							0.1	0.9	4.5
Erigeron strigosus	0.2	1.0	5.9				0.1	0.6	3.6									
Elymus canadensis							+	0.3	3.6	+	0.3	3.6	0.6	4.0	9.5	0.4	3.2	4.5
Vitus riparia							+	0.3	3.6									

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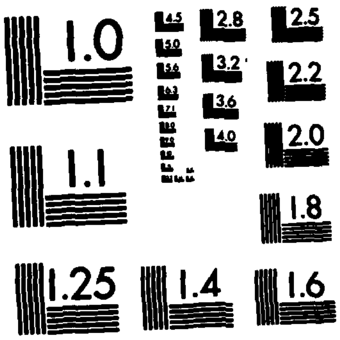

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Table C, Contd.

Species	1971			1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Arctium minus							+	0.3	3.6									
Echinacea angustifolia							+	1.6	11	+	0.6	3.6	0.3	2.0	9.5	0.4	2.7	14
Lygodesmia juncea							+	0.5	7.1	0.1	1.2	7.1	0.1	0.6	4.8			
Ranunculus sceleratus							+	0.9	3.6									
Bromus japonicus							+	0.3	3.6							0.1	0.5	4.5
Helianthus annuus	0.3	0.9	5.9				+	0.3	3.6				0.1	1.0	4.8			
Sphaeralcea coccinea							+	0.2	3.6									
Agropyron caninum										1.0	5.1	14	0.6	3.5	9.5	3.6	8.5	14
Spartina pectinata										0.5	0.6	3.6						
Andropogon gerardi										0.3	0.7	3.6				1.1	2.3	4.5
Aster simplex										0.2	1.5	3.6						
Glyceria grandis										0.2	0.8	3.6						
Cirsium undulatum										0.1	0.4	3.6				0.2	1.9	9.1
Malva neglecta										0.1	0.4	3.6						
Rumex maritimus										0.1	0.4	3.6						
Kochia scoparia	3.1	3.9	5.9							0.1	0.4	3.6				0.1	0.6	4.5
Medicago sativa										0.1	0.4	3.6				0.6	1.3	9.1

Table C, Contd.

Species	1971 CV	1971 AF	1971 CN	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Descurainia sophia										+	0.3	3.6				0.1	0.5	4.5
Prunus spp.										+	0.3	3.6						
Beckmannia syzigachne										+	0.3	3.6						
Lotus purshianus										+	0.6	3.6						
Plantago major										+	0.6	3.6						
Unknown spp.													2.9	7.3	14	0.6	2.3	9.1
Carex spp.													1.9	6.7	29	4.4	12	27
Solidago spp.													1.1	4.3	14	0.8	4.5	4.5
Comandra umbellata													0.6	3.7	9.5	0.6	4.6	23
Aristida longiseta													0.5	3.6	4.8	0.3	1.1	4.5
Elymus virginicus													0.4	3.1	4.8	0.8	2.3	4.5
Grindelia squarrosa	1.0	3.9	5.9										0.3	1.2	4.8	0.1	0.3	4.5
Linum spp.													0.2	1.8	4.8	+	0.9	4.5
Euphorbia geyeri													0.2	1.2	4.8			
Menthe arvensis	+	1.2	5.9										0.1	1.0	4.8			
Liatris punctata	0.1	2.2	12										0.1	0.8	4.8	0.1	0.3	4.5
Asclepias speciosa													0.1	0.7	4.8	0.1	1.1	4.5

Table C, Contd.

Species	1971			1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Setaria viridis	0.1	0.5	5.9										+	1.0	4.8			
Hedeoma hispida													+	0.6	4.8	0.2	2.9	9.1
Avena fatua	+	0.5	5.9										+	0.4	4.8			
Cicuta maculata																2.3	3.0	4.5
Fraxinus pennsylvanica																1.7	2.3	4.5
Artemisia cana																0.9	2.9	4.5
Carex eleocharis																0.8	4.5	4.5
Distichlis spicata																0.6	2.4	9.1
Acer negundo																0.4	0.8	4.5
Petalostemon purpureum																0.2	2.0	14
Polygonum convolvulus																0.2	1.1	4.5
Helianthus maximiliana																0.1	0.4	4.5
Chenopodium leptophyllum																0.1	1.5	4.5
Coryphantha vivipara																0.1	0.8	4.5
Psoralea esculenta																0.1	0.8	9.1
Potentilla pensylvanica																0.1	0.5	4.5
Lepidium densiflorum																0.1	0.5	4.5

Table C, Contd.

Species	1971			1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Anemone patens																0.1	0.5	4.5
Helianthus rigidus																0.1	0.5	4.5
Ulmus americana																0.1	0.4	4.5
Salsola iberica																+	1.1	4.5
Plantago patagonica																+	0.6	4.5
Amorpha nana																+	0.3	4.5
Erigeron lonchophyllus	0.7	6.1	24															
Solidago rigida	+	0.5	5.9															

Table D. Percentage cover (CV), average frequency (AF), and constancy (CN) of each species in zone two around Lake Sakakawea from 1971 to 1976.

Species	1971			1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Hordeum jubatum	11	41	75	24	60	90	12	31	77	7.8	28	71				8.2	29	74
Agropyron smithii	6.7	31	61	19	48	71	13	30	56	12	29	59	10	33	53	4.9	15	47
Poa pratensis	2.4	10	36	16	36	61	7.6	18	56	14	29	71	0.9	3.7	12	0.4	2.6	18
Puccinellia nuttalliana	5.2	25	57	11	25	61	0.4	2.3	5.9	5.5	20	59				0.3	1.3	2.9
Agropyron repens	4.1	13	36	6.7	23	58	7.1	19	44	4.7	11	27				2.4	8.5	33
Phalaris arundinacea	1.7	6.1	11	6.7	10	19	6.6	8.8	18	7.2	9.1	18				4.0	8.0	18
Poa palustris	+	0.1	3.6	6.2	17	45	7.5	21	53	1.4	5.2	18	0.2	1.6	12	5.3	18	62
Cirsium arvense	0.3	3.3	14	3.9	16	39	4.4	13	41	6.7	19	47	0.7	1.9	5.9	1.3	4.2	21
Rumex crispus	3.2	22	43	3.9	21	61	2.6	12	50	4.3	16	41				12	34	71
Polygonum lapathifolium	1.5	7.4	29	3.8	15	39	3.7	8.9	27	2.5	7.4	27				5.4	24	74
Agrostis hyemalis				2.8	6.9	23										0.8	2.8	8.8
Lactuca serriola	2.0	11	29	2.7	12	23	0.1	1.3	12	0.5	1.8	5.9				0.3	2.1	18
Carex laeviconica				2.6	5.1	13	1.9	4.5	18	3.0	6.1	18				0.2	0.5	5.9
Carex brevior				2.5	8.1	23	0.9	5.1	18	1.9	6.9	21	0.8	2.9	5.9			
Alopecurus aequalis				2.2	9.5	29	0.8	3.7	15							0.2	1.2	12
Potentilla norvegica	4.1	27	71	2.2	15	55	0.7	2.9	15	0.3	1.8	8.8				8.7	28	77

Table D, Contd.

Species	1971			1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Lactuca oblongifolia				2.1	13	45	1.1	5.9	21	1.4	7.6	35				+	0.3	2.9
Melilotus spp.	0.4	3.9	18	1.9	4.0	13				0.2	0.5	5.9				13	28	68
Sonchus arvensis	0.4	3.5	14	1.9	6.0	19	3.7	13	50	4.9	15	44				0.8	3.0	18
Helianthus annuus	0.5	3.3	7.1	1.7	6.3	16				0.1	0.9	2.9	0.2	1.2	5.9	2.6	10	29
Bromus inermis	0.2	0.5	3.6	1.7	7.4	19	4.0	8.9	24	2.9	9.5	29	3.9	7.5	12			
Agropyron cristatum	2.5	5.5	14	1.7	4.8	16	2.1	3.6	18	1.0	1.2	29	3.8	9.8	12	0.1	0.8	5.9
Artemisia dracunculus	0.4	3.4	14	1.5	6.0	19	+	0.8	5.9	+	0.2	2.9	0.7	4.4	5.9	0.1	0.7	2.9
Beckmannia syzigachne	+	0.6	3.6	1.2	2.3	9.7	0.7	3.0	21	0.3	1.9	8.8				0.5	2.6	18
Agropyron caninum				1.1	3.7	9.7	+	0.2	2.9	0.1	0.9	5.9	0.7	3.7	12	0.2	0.4	2.9
Eleocharis obtusa	0.3	0.9	3.6	1.1	7.1	16	1.2	2.2	5.9									
Xanthium strumarium	0.2	2.3	3.6	0.8	3.8	6.5	0.2	1.1	8.8	0.1	0.6	2.9				1.6	2.8	2.9
Ratibida columnifera	0.4	5.3	29	0.7	5.1	19	+	0.9	5.9	+	0.2	2.9				0.3	2.2	15
Rumex occidentalis	0.7	3.6	3.6	0.7	3.5	9.7	+	0.3	2.9	0.1	0.7	5.9				0.5	2.3	18
Brassica nigra	0.4	3.9	11	0.7	4.4	13	0.9	2.5	8.8	0.2	1.2	5.9						
Symphoricarpos occidentalis	0.1	1.9	7.1	0.6	6.8	19	0.8	2.7	8.8	0.4	1.2	8.8	7.9	14	24	2.4	4.6	12
Veronica peregrina				0.5	0.8	3.2												
Rumex maritimus	0.1	0.9	3.6	0.5	0.8	3.2				0.1	1.0	2.9				2.4	9.9	44

Table D, Contd.

Species	1971 CV	1971 AF	1971 CN	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Tragopogon dubius	+	1.2	3.6	0.5	4.9	19	0.2	0.8	5.9	0.2	1.2	8.8						
Aster hesperius				0.5	2.3	13	+	0.2	2.9							0.1	0.2	2.9
Rosa arkansana	+	1.5	7.1	0.5	2.9	6.5	0.1	0.6	5.9	+	0.6	5.9				0.2	1.9	8.8
Koeleria pyramidata	+	0.5	3.6	0.3	1.3	3.2	+	0.2	2.9	0.1	0.5	2.9				+	0.3	2.9
Lepidium densiflorum	0.4	7.0	18	0.3	3.7	13				0.1	0.6	5.9				0.7	4.6	27
Fraxinus pennsylvanica				0.3	1.8	3.2												
Melilotus officinalis	0.2	1.6	7.1	0.3	2.7	13	2.9	8.1	32	1.0	3.5	15	0.3	0.7	5.9			
Stipa viridula				0.3	1.1	3.2				0.1	0.4	5.9	0.6	3.8	12	0.2	1.2	2.9
Convolvulus arvensis				0.3	3.7	13	0.2	2.4	5.9	0.1	0.4	2.9				0.1	0.4	2.9
Aster ericoides				0.3	2.0	6.5	+	0.2	2.9	0.3	1.5	15						
Solidago rigida	+	0.3	3.6	0.2	0.6	6.5	0.1	0.4	2.9	+	0.4	2.9						
Bromus japonicus				0.2	0.9	3.2	+	0.4	2.9	0.1	0.4	5.9				0.2	0.7	5.9
Ambrosia trifida	0.1	0.7	7.1	0.2	1.2	6.5				0.1	0.4	2.9				0.4	2.1	12
Eleocharis macrostachya				0.2	1.9	6.5												
Rorippa palustris				0.2	2.5	16	0.2	0.6	2.9	0.6	2.5	8.8				1.1	4.9	27
Anemone canadensis				0.2	1.8	13	0.1	1.0	8.8	0.3	1.7	8.8	0.1	0.9	5.9	+	0.2	2.9
Urtica dioica	+	0.3	3.6	0.2	1.7	9.7	0.1	1.1	8.8	0.1	1.0	8.8	0.3	1.4	5.9	0.1	1.0	2.9

Table D, Contd.

Species	1971 CV	1971 AF	1971 CN	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Stellaria crassifolia				0.2	3.8	13												
Artemisia frigida	0.2	2.9	14	0.2	2.3	9.7	+	0.3	2.9				0.2	1.5	5.9	0.3	1.9	12
Polygonum ramosissimum	0.6	5.2	21	0.2	2.7	19	0.2	2.1	8.8	0.3	1.3	8.8	+	1.2	5.9	1.9	8.7	44
Melilotus albus	0.2	0.9	3.6	0.2	0.8	6.5	3.0	7.4	24	1.1	3.0	15						
Conyza canadensis	0.8	9.0	36	0.2	0.6	6.5				0.1	0.9	5.9				4.6	24	77
Vicia americana				0.2	1.5	6.5				0.1	0.4	2.9						
Polygonum coccineum				0.2	1.3	3.2	0.1	2.0	2.9	0.2	2.0	2.9				0.4	0.7	2.9
Elymus canadensis	+	0.5	3.6	0.2	1.1	6.5	0.1	1.1	8.8	+	0.2	2.9	0.6	4.4	12	+	0.2	2.9
Achillea millefolium	0.1	1.0	3.6	0.1	1.4	3.2	0.3	1.3	2.9	0.3	0.9	2.9				+	0.3	2.9
Erigeron lonchophyllus	0.3	3.6	18	0.1	0.4	3.2												
Plantago eriopoda				0.1	0.8	3.2												
Bidens vulgata				0.1	1.2	6.5												
Ambrosia psilostachya	0.6	0.9	3.6	0.1	1.2	9.7												
Artemisia ludoviciana				0.1	0.7	6.5				0.6	1.7	8.8				+	0.3	2.9
Ellisia nyctelea				0.1	1.2	9.7												
Iva xanthifolia	1.5	5.9	11	0.1	1.3	3.2	0.1	0.8	2.9							1.3	6.0	24
Atriplex patula				0.1	0.6	3.2										0.1	0.8	2.9

Table D, Contd.

Species	1971 CV	1971 AF	1971 CN	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Descurainia sophia				0.1	0.6	3.2	0.2	0.9	5.9	0.2	0.9	2.9				1.9	11	32
Oenothera biennis	0.1	1.4	7.1	0.1	0.8	6.5				0.1	0.4	2.9				0.2	1.1	8.8
Plantago major				0.1	0.5	3.2	+	0.4	5.9	0.1	0.4	2.9				+	0.3	2.9
Chenopodium album	0.1	4.3	18	0.1	1.2	6.5	0.2	1.5	8.8	0.2	1.3	8.8				9.3	31	82
Stipa comata				0.1	0.9	6.5							0.5	3.6	12			
Sisymbrium altissimum	1.1	7.3	14	0.1	1.8	13										0.8	3.2	15
Polygonum achoreum	0.1	0.5	3.6	0.1	0.9	9.7										+	0.3	2.9
Monarda fistulosa				0.1	0.4	3.2							0.2	1.2	5.9			
Carex lanuginosa				0.1	0.5	3.2												
Echinochloa crusgalli	1.9	6.3	18	0.1	0.6	3.2												
Menthe arvensis	0.1	0.5	3.6	0.1	1.0	6.5				0.2	1.1	5.9	0.2	1.1	5.9			
Taraxacum officinale				0.1	0.4	3.2				0.9	1.8	2.9						
Poa interior	0.2	1.4	3.6	0.1	0.8	6.5	0.3	1.7	12	+	0.2	2.9				0.1	0.4	2.9
Juncus balticus	0.1	0.5	3.6	+	0.3	3.2												
Hackelia deflexa				+	0.2	3.2												
Scirpus atrovirens				+	0.4	3.2												
Artemisia biennis	+	0.4	3.6	+	0.2	3.2										0.1	1.4	5.9

Table D, Contd.

Species	1971 CV	1971 AF	1971 CN	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Salsola iberica	0.1	0.9	3.6	+	0.8	3.2										1.6	6.3	27
Artemisia cana				+	0.5	3.2										0.2	0.9	2.9
Collomia linearis				+	0.5	3.2	+	0.6	5.9							+	0.3	2.9
Carex eleocharis				+	0.5	3.2	0.1	0.5								+	0.3	2.9
Convolvulus sepium				+	0.4	3.2	0.3	1.4	5.9	0.3	1.3	5.9						
Thlaspi arvense	0.1	1.1	3.6	+	1.6	3.2	0.1	0.8	2.9							0.1	0.7	2.9
Thalictrum sp.				+	0.4	3.2												
Prunus besseyi				+	0.4	3.2												
Plantago patagonica				+	o.4	3.2										0.1	0.4	2.9
Lappula redowskii				+	0.2	3.2	+	0.6	2.9	+	0.2	2.9						
Verbena bracteata				+	0.2	3.2										0.5	2.4	5.9
Cirsium undulatum	+	1.6	7.1	+	0.3	3.2	0.1	0.4	2.9									
Setaria glauca	0.1	0.9	3.6	+	0.2	3.2										0.4	3.0	30
Ulmus americana				+	0.2	3.2												
Glycyrrhiza lepidota				+	0.2	3.2												
Cornus stolonifera				+	0.2	3.2												
Medicago sativa	+	0.2	3.6				0.8	1.7	5.9	0.5	1.5	2.9				0.1	0.4	2.9

Table D, Contd.

Species	1971 CV	1971 AF	1971 CN	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Epilobium adenocaulon							0.7	2.9	18	1.3	5.0	27				0.1	0.4	2.9
Ambrosia artemisiifolia							0.6	1.5	8.8				0.8	3.5	5.9	1.0	2.9	12
Heracleum sphondylium							0.4	2.0	2.9									
Glyceria grandis							0.2	0.6	2.9									
Distichlis spicata							0.2	0.7	5.9	0.1	0.2	2.9				0.1	0.9	8.8
Poa compressa							0.2	0.6	2.9									
Arctium minus							0.2	0.8	2.9	0.2	1.3	2.9				+	0.3	2.[illegible]
Rosa woodsii							0.1	0.4	2.9	0.2	1.5	12				0.4	1.6	5.9
Typha latifolia							0.1	1.2	2.9	0.4	1.4	5.9						
Capsella bursa-pastoris							0.1	0.4	2.9	0.4	0.6	2.9						
Sphenopholis obtusata							0.1	1.1	5.9	0.1	0.4	2.9				0.1	1.1	5.9
Solidago missouriensis							0.1	0.4	2.9	0.1	0.6	2.9						
Panicum capillare							0.1	0.4	2.9									
Medicago lupulina							0.1	0.4	2.9									
Teucrium canadense							+	0.2	2.9									
Amaranthus graecizans							+	0.2	2.9									
Cicuta maculata							+	0.2	2.9									

Table D, Contd.

Species	1971			1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Spartina pectinata										0.3	0.6	2.9						
Psoralea argophylla										0.1	0.5	2.9	0.1	0.6	5.9			
Cirsium altissimum										+	0.5	2.9						
Carex gravida										+	0.5	2.9						
Euphorbia podperae										+	0.2	2.9				+	0.2	2.9
Elymus virginicus										+	0.2	2.9				+	0.2	2.9
Carex spp.													1.4	3.8	12	0.1	1.3	8.8
Lotus purshianus													0.2	1.5	5.9			
Kochia scoparia	0.1	1.2	3.6													1.5	7.2	38
Chenopodium leptophyllum																1.1	4.1	12
Polygonum convolvulus																0.9	3.8	21
Typha angustifolia																0.7	1.9	2.9
Hedeoma hispida																0.4	1.9	5.9
Setaria viridis	0.3	4.3	14															
Grindelia squarrosa	0.1	1.0	7.1															
Avena fatua	0.1	2.6	7.1															

Table E. Percentage cover (CV), average frequency (AF), and constancy (CN) of each species in zone three around Lake Sakakawea from 1971 to 1976.

Species	1971 CV	1971 AF	1971 CN	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
<u>Polygonum lapathifolium</u>	11	52	90	15	48	87	12	35	91	16	41	86				41	74	94
<u>Rumex crispus</u>	3.8	22	59	7.5	30	79	2.8	9.5	39	7.6	23	66	2.3	15	20	4.4	14	54
<u>Alopecurus aequalis</u>				6.7	25	50	0.2	0.6	6.1	0.1	0.8	5.7				0.2	1.2	11
<u>Phalaris arundinacea</u>	1.7	5.1	14	6.5	9.9	16	7.8	13	24	6.1	9.7	26	7.5	40	60	4.7	10	31
<u>Puccinellia nuttalliana</u>	0.4	3.1	24	4.6	15	55	1.1	5.4	27	1.8	7.9	43						
<u>Hordeum jubatum</u>	1.8	7.9	41	3.8	13	61	1.6	6.5	30	3.3	12	51				2.1	10	57
<u>Beckmannia syzigachne</u>	0.1	2.2	17	2.1	10	34	1.2	6.4	36	1.2	7.8	29				0.4	2.4	17
<u>Agropyron repens</u>	1.1	3.7	17	2.0	6.6	26	1.9	4.2	12	2.7	6.0	20				1.3	4.1	23
<u>Agropyron smithii</u>	0.3	1.6	17	1.3	5.4	26	0.3	1.7	12	0.3	0.6	5.7				+	0.2	2.9
<u>Polygonum ramosissimum</u>	0.9	4.3	24	1.1	5.6	40	0.2	1.5	3.0	0.2	2.0	14				0.8	4.3	26
<u>Veronica peregrina</u>				1.0	6.7	21												
<u>Carex laeviconica</u>	+	0.3	6.9	0.9	2.6	18	1.5	3.2	21	2.3	5.9	23						
<u>Poa palustris</u>				0.8	3.8	24	0.5	1.5	6.1	0.1	0.4	5.7				1.6	7.2	29
<u>Poa pratensis</u>	0.1	0.4	6.9	0.8	3.8	24	0.5	1.5	6.1	0.1	0.4	5.7				+	0.2	2.9
<u>Typha latifolia</u>	0.1	0.5	2.7	0.5	2.7	16	0.6	1.6	12	2.1	5.4	11	1.2	8.0	20			
<u>Potentilla norvegica</u>	0.2	1.8	14	0.4	5.1	37	+	0.5	6.1	+	0.2	2.9				0.9	2.0	17

Table E, Contd.

Species	1971 CV	1971 AF	1971 CN	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
<u>Carex lanuginosa</u>				0.4	1.3	2.6												
<u>Cirsium arvense</u>	+	0.3	3.5	0.3	1.0	5.3	0.1	0.4	3.0	0.1	0.7	5.7						
<u>Lappula redowskii</u>				0.3	1.7	7.9												
<u>Echinochloa crusgalli</u>				0.2	1.5	7.9	0.1	0.4	3.0	0.1	0.6	2.9				0.4	1.1	5.7
<u>Carex brevior</u>				0.2	0.7	13	+	0.2	3.0	+	0.2	2.9				0.1	0.4	5.7
<u>Stellaria crassifolia</u>				0.2	2.0	18												
<u>Rorippa palustris</u>	+	0.3	3.5	0.2	1.6	13	0.1	0.6	3.0	0.3	2.2	11				0.1	0.5	5.7
<u>Lactuca oblongifolia</u>				0.2	2.8	24												
<u>Brassica nigra</u>	0.1	0.4	6.9	0.2	2.4	37	0.6	2.3	9.1	+	0.2	2.9						
<u>Xanthium strumarium</u>	0.1	0.5	3.5	0.2	0.8	2.6				0.1	1.1	5.7				0.4	0.9	8.6
<u>Glyceria grandis</u>	0.1	0.2	3.5	0.1	0.3	2.6												
<u>Rosa woodsii</u>	0.1	0.2	3.5	0.1	0.8	2.6										0.5	1.6	2.9
<u>Potamogeton</u> spp.	0.1	0.4	5.3	0.2	0.8	3.0												
<u>Salix exigua</u>	+	0.6	3.5	0.1	0.3	2.6	0.1	0.4	3.0	0.2	0.6	5.7				0.1	0.6	2.9
<u>Hackelia deflexa</u>				0.1	0.8	2.6												
<u>Eleocharis macrostachya</u>				0.1	1.0	5.3				0.1	0.1	2.9				0.2	9.5	2.9

Table E, Contd.

Species	1971 CV	1971 AF	1971 CN	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Melilotus officinalis				0.1	0.6	7.9												
Eragrostis cilianensis				0.1	0.2	2.6												
Scirpus maritimus				0.1	0.5	5.3	0.2	0.3	3.0	0.1	0.4	2.9						
Verbena bracteata				0.1	0.6	5.3										1.3	2.1	2.9
Bidens vulgata				+	0.9	7.9												
Ranunculus sceleratus	+	0.2	3.5	+	1.1	7.9												
Sisymbrium altissimum	0.1	1.2	10	+	0.9	11	+	0.2	3.0							0.1	0.5	5.7
Lactuca serriola	+	0.1	3.5	+	0.4	2.6				+	0.3	2.9				+	0.3	2.9
Agropyron caninum				+	0.2	2.6												
Rosa arkansana				+	0.4	2.6												
Lepidium densiflorum	0.2	1.8	6.9	+	0.6	5.3										+	0.3	2.9
Glyceria lepidota				+	0.2	2.6												
Helianthus annuus	0.1	0.5	3.5	+	0.2	2.6										0.6	3.5	20
Aster hesperius				+	0.2	2.6												
Chenopodium album	+	0.3	3.5	+	1.2	11	0.1	0.5	6.1	0.1	0.8	5.7				2.6	9.3	51
Plantago eriopoda				+	0.2	2.6												
Collomia linearis				+	0.2	5.3												

Table E, Contd.

Species	1971 CV	1971 AF	1971 CN	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Rumex occidentalis	0.2	1.0	6.9	+	0.2	5.3	0.1	0.5	6.1	+	0.3	5.7						
Thlaspi arvense	+	0.2	3.5	+	0.1	2.6	+	0.2	3.0									
Polygonum achoreum	+	0.1	3.5	+	0.6	2.6										0.1	0.7	2.9
Capsella bursa-pastoris				+	0.2	2.6												
Scirpus atrovirens				+	0.1	2.6												
Prunus besseyi				+	0.6	2.6												
Eleocharis obtusa				+	0.1	2.6												
Bromus inermis				+	0.1	2.6	0.1	0.2	3.0									
Convolvulus arvensis	+	0.1	3.5	+	0.1	2.6												
Anemone canadensis				+	0.1	2.6												
Salix spp.				+	0.1	2.6												
Kochia scoparia				+	0.4	2.6										0.4	2.2	11
Salsola iberica	0.1	0.4	3.5	+	0.4	5.3										0.2	0.5	5.7
Carex eleocharis				+	0.4	2.6												
Festuca octoflora				+	0.2	2.6												
Ambrosia trifida				+	0.1	2.6										0.1	0.3	5.7
Fraxinus pennsylvanica				+	0.1	2.6												

Table E, Contd.

Species	1971 CV	1971 AF	1971 CN	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Poa interior	+	0.1	3.5	+	0.1	2.6										0.1	0.3	2.9
Populus deltoides				+	0.1	2.6				+	0.5	2.9				+	0.2	2.9
Ellisia nyctelea				+	0.2	2.6												
Melilotus spp.	0.1	0.5	6.9	+	0.2	3.0										1.3	5.3	26
Menthe arvensis				+	0.1	2.6				+	0.1	2.9						
Agrostis hyemalis				+	0.1	2.6				-	-	-				+	0.3	2.9
Polygonum coccineum							0.4	0.9	3.0	0.3	1.1	5.7				0.1	0.2	5.7
Epilobium adenocaulon							0.1	0.3	3.0	0.5	1.3	5.7						
Descurainia sophia							0.1	0.7	6.1	+	0.2	2.9				+	0.3	2.9
Melilotus albus	0.1	0.5	3.5				+	0.2	3.0									
Conyza canadensis							+	0.2	3.0							0.1	0.7	8.6
Oenothera biennis										+	0.2	2.9						
Sonchus arvensis										+	0.2	2.9				0.3	1.9	8.6
Carex gravida										+	0.2	2.9						
Rumex maritimus	0.1	0.3	3.5							+	0.1	2.9				0.2	1.9	11
Alopecurus arundinaceus										+	0.1	2.9						
Setaria viridis	+	0.1	3.5							+	0.2	2.9						

Table E, Contd.

Species	1971 CV	1971 AF	1971 CN	1972 CV	1972 AF	1972 CN	1973 CV	1973 AF	1973 CN	1974 CV	1974 AF	1974 CN	1975 CV	1975 AF	1975 CN	1976 CV	1976 AF	1976 CN
Scirpus americanus																0.5	1.2	2.9
Iva xanthifolia																0.3	1.1	8.6
Oxalis stricta																0.1	0.9	2.9
Setaria glauca																0.1	0.4	2.9
Ambrosia artemisiifolia																0.1	0.9	5.7
Symphoricarpos occidentalis	+	0.1	3.5													0.1	0.6	2.9
Typha angustifolia																0.1	0.6	2.9
Unknown spp.																0.1	0.5	2.9
Artemisia biennis																0.1	0.5	5.7
Polygonum convolvulus																0.1	0.4	2.9
Ranunculus cymbalaria																+	0.3	2.9
Plantago major																+	0.3	2.9
Taraxacum officinale																+	0.2	2.9
Achillea millefolium																+	0.2	2.9
Helianthus petiolaris																+	0.2	2.9
Carex spp.																+	0.2	2.9

Table E, Contd.

Species	1971			1972			1973			1974			1975			1976		
	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN	CV	AF	CN
Schedonnardus paniculatus																+	0.9	2.9
Atriplex rosea																+	0.1	2.9
Atriplex patula																+	0.1	2.9
Artemisia cana																+	0.1	2.9
Grindelia squarrosa	+	0.2	3.5															
Scirpus validus	+	0.1	3.5															
Erigeron lonchophyllus	+	0.1	3.5															
Agropyron cristatum	+	0.1	3.5															

Table F . Results of water tolerance experiments on grasses that commonly occur around Lake Sakakawea and/or Lake Oahe. All treatments were followed by a 20 day recovery period. Values given are means ± one standard error. Using a t-test mean shoot and root biomass data are compared for treated and control plants.

Treatment	Mean height in cm of shoots before expt.	Mean height in cm of shoots after expt.	Mean number of shoots per pot after expt.	Mean dry wt. in g of five shoots.	Calculated t values.	Mean dry wt. in g of five roots.	Calculated t values.	Root/shoot ratio.
			Agropyron repens (quack grass)					
15 days inundation	23.6 ± 1.0	22.1 ± 1.6	9.3 ± 1.8	.35 ± .0	1.5[c]	.27 ± .1	5.5[a]	.8
Control[b]	23.7 ± .8	32.5 ± 1.9	13.3 ± 2.3	.70 ± .2		1.04 ± .1		1.5
30 days inundation	25.1 ± 1.4	13.0 ± 2.2	5.3 ± 1.8	.25 ± .1	11.0[a]	.20 ± .0	6.9[a]	.8
30 days at 2x F. C.	23.1 ± 1.5	37.3 ± 2.7	13.3 ± 1.5	1.40 ± .2	1.2[c]	.90 ± .0	3.6[c]	.6
Control	25.4 ± 1.2	40.8 ± 2.5	12.3 ± 2.4	1.70 ± .1		1.60 ± .2		.9
45 days inundation	43.7 ± 1.2	26.2 ± 2.3	16.3 ± 2.2	.89 ± .1	14.1[a]	.32 ± .0	12.5[a]	.4
Control	41.6 ± 1.1	60.9 ± 1.6	27.3 ± 3.0	3.30 ± .2		2.67 ± .2		.8
60 days inundation	43.8 ± 1.7	24.2 ± 3.8	8.0 ± 4.4	.92 ± .3	9.5[a]	.30 ± .1	17.0[a]	.3
Control	41.9 ± 1.9	61.2 ± 2.0	33.0 ± 4.7	3.50 ± .1		3.04 ± .1		.9
			Agropyron smithii (western wheatgrass) (possible upland ecotype)					
5 days inundation	38.7 ± 1.0	39.1 ± 1.5	7.3 ± .9	1.08 ± .1	4.4[a]	.73 ± .0	7.7[a]	.7
Control[f]	39.6 ± 1.8	45.0 ± 1.6	8.5 ± .5	1.49 ± .1		1.23 ± .0		.8

Table F, Contd.

Treatment	Mean height in cm of shoots before expt.	Mean height in cm of shoots after expt.	Mean number of shoots per pot after expt.	Mean dry wt. in g of five shoots.	Calculated t values	Mean dry wt. in g of five roots	Calculated t values	Root/shoot ratio
15 days inundation	37.1 ± 1.8	29.2 ± 2.3	8.3 ± 1.2	.82 ± .2	4.5[a]	.37 ± .1	4.6[a]	.5
Control	38.5 ± .8	44.1 ± 1.1	8.5 ± .5	1.83 ± .1		1.62 ± .4		.9
30 days inundation	36.8 ± 1.5	29.5 ± 2.2	11.6 ± .3	.71 ± .0	17.1[a]	.37 ± .1	21.4[a]	.5
30 days at 2x F. C.	39.9 ± .5	45.7 ± 1.5	17.0 ± 1.5	2.44 ± .1	4.2[a]	1.64 ± .1	2.4[c]	.7
Control	37.8 ± .8	43.2 ± 1.6	10.3 ± .3	2.00 ± .1		1.88 ± .0		.9
45 days inundation	31.1 ± 1.2	21.6 ± 1.9	6.7 ± .7	.23 ± .0	7.1[a]	.10 ± .1	4.5[a]	.4
Control	26.6 ± 1.6	52.0 ± 2.4	11.5 ± 1.5	3.28 ± .4		2.52 ± .5		.8
60 days inundation	31.6 ± 1.1	26. ± 2.3	7.7 ± .3	.46 ± .1	11.9[a]	.08 ± .0	5.7[a]	.2
Control	30.1 ± .8	53.1 ± 2.2	15.3 ± .9	4.10 ± .3		2.85 ± .5		.7
Agropyron smithii (western wheatgrass) (possible wetland ecotype)								
30 days inundation	36.6 ± 2.5	28.6 ± 1.6	12.0 ± 1.0	.84 ± .1	8.7[a]	.39 ± .1	14.2[a]	.5
30 days at 2x F. C.	39.3 ± 2.4	49.2 ± 3.2	9.5 ± 2.5	2.82 ± .1	1.8[c]	2.08 ± .1	3.2[c]	.7
Control[f]	35.5 ± 2.1	46.7 ± 2.5	5.5 ± .5	2.24 ± .1		1.79 ±		.8
Alopecurus aequalis (shortawn foxtail)								
5 days inundation	33.0 ± 1.3	39.0 ± 2.1	36.7 ± 2.0	1.62 ± .1	3.9[a]	1.13 ± .1	4.7[a]	.7
Control	29.8 ± 1.1	38.9 ± 2.1	37.3 ± 1.3	1.21 ± .1		1.71 ± .1		1.4

Table F. Contd.

Treatment	Mean height in cm of shoots before expt.	Mean height in cm of shoots after expt.	Mean number of shoots per pot after expt.	Mean dry wt. in g of five shoots.	Calculated t values.	Mean dry wt. in g of five roots.	Calculated t values.	Root/shoot ratio.
30 days inundation	20.9 ± 1.9	8.2 ± 5.0	4.5 ± 1.5	.38 ± .1	.8[c]	.18 ± .1	10.2[a]	.5
30 days at 2x F. C.	20.2 ± 2.0	28.6 ± 1.4	17.6 ± 1.2	1.65 ± .2	1.4[c]	9.74 ± 3.4	2.1[c]	5.9
Control[f]	22.9 ± 2.6	28.3 ± 5.4	12.0 ± 6.0	1.22 ± .2		11.09 ± 1.9		9.1
45 days inundation	44.4 ± 1.4	24.3 ± 1.1	13.3 ± 1.3	4.19 ± .8	2.2[c]	4.30 ± .8	3.0[c]	1.2
Control	44.9 ± 1.6	32.7 ± 1.0	21.3 ± 2.7	2.47 ± .1		11.18 ± 2.2		4.5
45 days inundation, leaves clipped	37.0 ± 1.7	25.3 ± 2.2	3.0 ± 2.1	.53 ± .2	9.4[a]	.16 ± .1	14.6[a]	.3
Control	43.9 ± 1.8	31.6 ± 1.1	25.7 ± 2.0	3.30 ± .3		7.29 ± .5		2.2
60 days inundation	45.3 ± 1.6	46.5 ± 8.1	14.3 ± 1.2	4.19 ± .5	3.8[c]	2.81 ± .2	4.4[a]	.7
Control	47.5 ± .9	24.3 ± 1.1	28.3 ± 2.7	2.37 ± .1		9.49 ± 1.5		4.0
Beckmannia syzigachne (american sloughgrass)								
5 days inundation	35.8 ± .8	36.4 ± 1.4	22.0 ± 2.3	1.77 ± .0	.3[c]	1.66 ± .1	3.7[a]	.9
Control[f]	37.5 ± 1.5	35.8 ± .6	18.5 ± .5	1.74 ± .2		4.14 ± .9		2.4
15 days inundation	34.1 ± .9	40.7 ± 1.8	18.0 ± 1.5	1.63 ± .1	2.2[c]	1.02 ± .1	7.0[a]	.6
Control[f]	34.9 ± .8	35.1 ± 1.3	19.0 ± 2.0	2.05 ± .1		3.20 ± .4		1.6

Table F, Contd.

Treatment	Mean height in cm of shoots before expt.	Mean height in cm of shoots after expt.	Mean number of shoots per pot after expt.	Mean dry wt. in g of five shoots.	Calculated t values	Mean dry wt. in g of five roots.	Calculated t values.	Root/shoot ratio.
30 days inundation	36.8 ± .8	72.8 ± 4.4	22.0 ± 2.0	2.17 ± .3	1.0[c]	.99 ± .1	5.0[a]	.5
30 days at 2x F. C.	35.8 ± 1.1	41.5 ± 1.2	22.3 ± .7	2.52 ± .1	.4[c]	8.90 ± 1.	1.2[c]	3.5
Control	35.8 ± 1.4	38.7 ± 2.5	16.3 ± 1.5	2.57 ± .1		5.90 ± .7		2.3
45 days inundation	43.0 ± 1.0	38.7 ± 1.9	12.7 ± 1.2	2.82 ± .2	.3[c]	1.27 ± .1	6.1[a]	.5
Control	42.4 ± 1.1	26.4 ± 2.1	34.7 ± 2.7	2.89 ± .1		2.84 ± .2		1.0
45 days inundation, leaves clipped	34.5 ± .8	---[d]	---	.30 ± .1	8.9[a]	.06 ± .1	13.2[a]	.2
Control	39.4 ± 1.0	45.7 ± 2.4	19.7 ± 2.9	3.67 ± .4		2.67 ± .2		.7
60 days inundation	41.0 ± 1.0	42.4 ± 4.1	12.3 ± 1.5	3.05 ± .2	2.7[c]	1.30 ± .3	2.8[a]	.4
Control	44.3 ± 1.0	28.1 ± 2.5	30.3 ± 5.5	2.16 ± .2		2.53 ± .3		1.2
		Bromus inermis (smooth brome)						
5 days inundation	32.6 ± 1.5	32.5 ± 1.2	5.7 ± .7	.96 ± .1	.9[c]	1.40 ± .1	1.9[c]	1.5
Control	30.8 ± 1.2	30.5 ± 1.2	6.0 ± .6	.85 ± .1		2.30 ± .5		2.7
15 days inundation	30.5 ± .9	30.6 ± 1.2	7.3 ± 1.2	.76 ± .1	1.6[c]	.96 ± .2	5.2[a]	1.3
Control	31.5 ± 1.9	33.1 ± 1.8	6.3 ± .9	.93 ± .1		2.96 ± .3		3.2

Table F, Contd.

Treatment	Mean height in cm of shoots before expt.	Mean height in cm of shoots after expt.	Mean number of shoots per pot after expt.	Mean dry wt. in g of five shoots	Calculated t values	Mean dry wt. in g of five roots.	Calculated t values.	Root/shoot ratio.
30 days inundation	27.2 ± 1.9	25.7[d] ± 1.1	6.3 ± 2.2	.53 ± .1	2.9[a]	.39 ± .1	3.4[a]	.7
30 days at 2x F. C.	31.1 ± 1.1	28.3 ± 1.1	15.7 ± .7	1.22 ± .0	6.6[a]	1.84 ± .1	1.3[c]	1.5
Control	30.7 ± 1.5	29.6 ± 1.6	6.7 ± .3	.93 ± .0		2.72 ± .7		2.9
45 days inundation	37.5 ± 1.5	29.0 ± 1.4	13.7 ± 1.2	1.03 ± .1	13.3[a]	.67 ± .1	8.6[a]	.7
Control	39.1 ± 2.2	39.7 ± 1.9	16.3 ± .9	2.38 ± .0		9.83 ± 1.1		4.1
60 days inundation	37.5 ± 1.8	25.9 ± 1.4	10.3 ± 2.3	.68 ± .2	5.2[a]	.56 ± .1	7.4[a]	.8
Control	37.0 ± 2.1	33.4 ± 2.5	17.7 ± .3	2.15 ± .2		7.01 ± .9		3.3
		Hordeum jubatum (foxtail barley)						
5 days inundation	34.2 ± 1.6	52.7 ± 1.8	11.3 ± .3	1.09 ± .0	1.4[c]	.48 ± .1	.9[c]	.4
control	33.7 ± 1.1	53.2 ± 1.8	8.7 ± 1.5	1.32 ± .2		.57 ± .1		.4
15 days inundation	32.1 ± 1.5	44.2 ± 2.2	13.3 ± 1.9	.96 ± .0	5.4[a]	.67 ± .2	.5[c]	.7
Control	35.1 ± 1.5	52.3 ± 1.9	7.0 ± 1.2	1.37 ± .1		.75 ± .1		.6
30 days inundation	33.7 ± 1.7	37.2 ± 1.8	16.3 ± .9	.86 ± .0	1.5[c]	.56 ± .1	1.5[c]	.7
30 days at 2x F. C.	31.6 ± 1.3	44.2 ± 2.7	11.3 ± .7	1.46 ± .2	1.3[c]	.71 ± .1	1.2	.5
Control	34.4 ± 2.2	49.7 ± 2.4	10.0 ± 2.1	1.75 ± .6		1.44 ± .6		.8

Table F, Contd.

Treatment	Mean height in cm of shoots before expt.	Mean height in cm of shoots after expt.	Mean number of shoots per pot after expt.	Mean dry wt. in g of five shoots.	Calculated t values.	Mean dry wt. in g of five roots.	Calculated t values.	Root/shoot ratio
60 days inundation	27.4 ± 1.3	---	---	.23	20.9[a]	.02 ± .0	3.6[c]	.1
Control	29.8 ± .5	50.6 ± 1.2	23.6 ± 2.3	3.10 ± .1		3.27 ± .9		1.3
Phalaris arundinacea (reed canary grass)								
5 days inundation	27.3 ± 1.7	35.5 ± 1.7	15.0 ± 1.0	1.07 ± .3	.4[c]	1.84 ± .7	1.3[c]	1.7
Control	29.1 ± 1.3	32.9 ± 1.6	11.7 ± 1.2	1.21 ± .1		2.79 ± .3		2.3
15 days inundation	28.6 ± 1.4	35.7 ± 1.9	14.3 ± 1.8	.94 ± .1	5.1[a]	1.01 ± .1	6.0[a]	1.1
Control	31.7 ± 1.2	36.4 ± 1.5	16.0 ± 1.2	1.47 ± .1		3.93 ± .5		2.7
30 days inundation	29.0 ± 1.1	31.2 ± 1.9	11.6 ± 1.5	.67 ± .1	5.8[a]	.45 ± .1	8.2[a]	.7
30 days at 2x F. C.	28.7 ± 1.2	32.8 ± 1.8	23.0 ± 1.7	1.60 ± .2	.2[c]	2.72 ± .4	.8[c]	1.7
Control[f]	20.7 ± 1.6	32.3 ± 2.5	11.7 ± 1.9	1.21 ± .4		1.87 ± .5		1.5
45 days inundation	47.1 ± 1.6	75.6 ± 4.7	20.3 ± 1.4	4.13 ± .4	.6[c]	1.67 ± .2	7.0[a]	.4
Control	45.6 ± 1.6	47.1 ± 1.3	22.3 ± .3	3.90 ± .1		4.89 ± .4		1.3
45 days inundation, leaves clipped	42.0 ± 1.0	23.7 ± 5.2	24.3 ± 2.2	.89 ± .2	12.3[a]	.57 ± .1	7.2[a]	.6
Control	38.4 ± .7	38.4 ±	9.0 ± 4.4	4.02 ± .1		6.26 ± .8		1.6
60 days inundation	46.2 ± 1.2	90.4 ± 6.8	23.3 ± 1.2	4.44 ± .2	.8[c]	2.05 ± .2	16.0[a]	.5
Control	45.3 ± 1.8	45.9 ± 1.6	23.6 ± 2.3	3.07 ± .8		5.69 ± .1		1.9

Table F, Contd.

Treatment	Mean height in cm of shoots before expt.	Mean height in cm of shoots after expt.	Mean number of shoots per pot after expt.	Mean dry wt. in g of five shoots.	Calculated t values.	Mean dry st. in g of five roots.	Calculated t values.	Root/shoot ratio.
Poa pratensis (kentucky blue grass)								
5 days inundation	26.2 ± 1.1	26.8 ± 1.0	21.7 ± 1.2	1.04 ± .1	1.8[c]	1.30 ± .2	6.2[a]	1.2
Control	26.1 ± .5	28.5 ± .8	20.7 ± 4.4	.79 ± .1		2.99 ± .1		3.8
15 days inundation	27.2 ± 1.2	29.1 ± 1.0	23.3 ± 2.7	.98 ± .1	.7[c]	.63 ± .1	7.5[a]	.6
Control	27.7 ± .9	30.6 ± .9	18.7 ± 1.5	1.09 ± .1		11.02 ± 1.		10.2
30 days inundation	26.4 ± 1.1	24.5 ± .7	20.3 ± 3.2	.93 ± .1	2.2[c]	.64 ± .0	7.0[a]	.7
30 days at 2x F. C.	27.1 ± 1.3	30.1 ± .8	21.0 ± 1.7	1.51 ± .0	2.9[a]	2.05 ± .3	3.4[a]	1.4
Control	27.5 ± 1.3	29.8 ± 1.1	17.3 ± .7	1.20 ± .1		3.86 ± .5		3.2
45 days inundation	34.1 ± .9	29.3 ± .8	22.7 ± 3.5	1.23 ± .2	3.0[c]	.47 ± .1	10.7[a]	.4
Control	36.2 ± 1.2	41.4 ± 1.1	27.3 ± 4.1	3.20 ± .6		4.08 ± .5		1.3
60 days inundation	33.3 ± .9	28.9 ± 1.6	24.7 ± 2.6	1.20 ± .1	11.5[a]	.57 ± .1	11.1[a]	.5
Control	36.3 ± 1.3	39.3 ± 9.5	22.7 ± 3.5	2.93 ± .1		7.90 ± .7		2.7
Puccinellia airoides (nuttall alkali grass)								
5 days inundation	33.7 ± 1.3	45.3 ± 3.9	20.7 ± 1.5	1.10 ± .2	4.5[a]	.22 ± .0	6.9[a]	.2
Control	34.6 ± .9	48.6 ± 1.8	25.3 ± 3.2	2.13 ± .2		.83 ± .1		.4

Table F, Contd.

Treatment	Mean height in cm of shoots before expt.	Mean height in cm of shoots after expt.	Mean number of shoots per pot after expt.	Mean dry wt. in g of five shoots.	Calculated t values.	Mean dry wt. in g of five roots.	Calculated t values.	Root/shoot ratio.
15 days inundation	35.5 ± 1.1	22.6[d] ± 2.6	13.7 ± 1.3	.47 ± .1	22.9[a]	.09 ± .0	5.3[a]	.2
Control	34.6 ± 1.0	57.5 ± 3.2	23.7 ± 3.2	2.82 ± .1		1.25 ± .2		.4
30 days inundation	34,7 ± 1.4	25.8[d] ± 2.2	9.3 ± 9.3[e]	.50 ± .2	10.1[a]	.09 ± .0	5.5[a]	.2
30 days at 2x F. C.	31.5 ± 1.5	58.4 ± 2.7	32.0 ± 4.2	3.07 ± .3	.7[c]	2.30 ± .5	.1[c]	.8
Control	33.0 ± 1.5	55.5 ± 1.5	37.7 ± 3.3	3.28 ± .2		2.24 ± .4		.7
45 days inundation	35.2 ± 1.6	---	---	.09 ± .0	9.5[a]	.01 ± .0	17.8[a]	.1
Control	36.9 ± .8	47.9 ± 2.7	39.0 ± 4.2	3.19 ± .3		1.25 ± .1		.4
60 days inundation	33.9 ± 2.4	---	---	.12 ± .0	11.0[a]	.01 ± .0	3.1[c]	.1
Control	38.5 ± 1.1	49.2 ± 2.0	42.0 ± 5.9	3.38 ± .3		2.85 ± .9		.8
Stipa viridula (green needlegrass)								
5 days inundation	13.4 ± .5	13.3 ± .4	15.0 ± .6	.23 ± .0	.1[c]	.26 ± .2	1.3[c]	1.1
Control	13.6 ± .5	13.6 ± .6	20.3 ± 1.2	.22 ± .1		.32 ±		.5
15 days inundation	12.5 ± .5	---	---	.08 ± .0	10.1[a]	.06 ± .1	2.8[a]	.7
Control	12.3 ± .4	12.1 ± .4	21.3 ± .3	.27 ± .0		.29 ± .1		1.1

Table F, Contd.

Treatment	Mean height in cm of shoots before expt.	Mean height in cm of shoots after expt.	Mean number of shoots per pot after expt.	Mean dry wt. in g of five shoots.	Calculated t values.	Mean dry wt. in g of five roots.	Calculated t values.	Root/shoot ratio.
30 days inundation	12.4 ± .5	---	---	.06 ± .0	9.3[a]	.04 ± .0	10.5[a]	.8
30 days at 2x F. C.	12.3 ± .6	12.1 ± .5	20.3 ± 1.3	.34 ± .0	.1[c]	.31 ± .0	1.6[c]	.9
Control	12.6 ± .5	12.5 ± .5	22.3 ± 1.2	.34 ± .0		.38 ± .0		1.1

[a]Significant at the .05 level.

[b]Control plants were maintained at field capacity.

[c]Not significant at the .05 level.

[d]Only living stems were measured.

[e]There were 28 stems in one pot and none in the other two.

[f]Only two control pots were used instead of the usual three.

END