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Possible Relationships Between Surface Water Chemistry and Aquatic Plants in the Northern Great Plains

Kristin K. Sletten

POSSIBLE RELATIONSHIPS BETWEEN SURFACE WATER CHEMISTRY AND AQUATIC PLANTS IN THE NORTHERN GREAT PLAINS

by

Kristin K. Sletten

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POSSIBLE RELATIONSHIPS BETWEEN SURFACE

WATER CHEMISTRY AND AQUATIC PLANTS

IN THE NORTHERN GREAT PLAINS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Advisor　　　　Date

Head, Biology Department　　　　Date

ABSTRACT

The possibility of establishing relationships between surface water chemistry and the occurrence of certain aquatic plant species was investigated on 281 wetland sites throughout the northern Great Plains. Ninety-seven species of aquatic plants were selected for the study, selection being based on the direct association of plants with water and on the number of sites at which the plants were found. The ranges and means of surface water conductivity, total alkalinity and pH values were determined on a species by species basis.

Of the three chemical parameters measured, conductivity of surface water appeared to have the greatest influence on the presence or absence of certain aquatic plants. Five species were found strictly in fresh water while eleven others were found to tolerate subsaline conditions. Most species tolerated great variation in alkalinity, while 22 species were found strictly in highly alkaline waters. Little relationship was found between pH and aquatic plant occurrence, although the highest pH readings occurred in subsaline waters and the lowest readings in fresh waters.

ACKNOWLEDGEMENTS

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This would not be complete without acknowledging my two coworkers in the field. Thanks to Steve Van Sickle for his help in organizing the project. Special thanks to Ken Kanaan, whose constant encouragement and good humor helped keep me going through those long, hot days.

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INTRODUCTION

Wetlands of the northern Great Plains are now regarded as important natural resources. While critical as wildlife habitat and brood areas for waterfowl, wetlands also perform other necessary functions. Horwitz (1978) believes that water retention leading to reduced flooding is one of the most vital functions of wetlands. Studies by Hann and Johnson (1968) in Iowa, Moore and Larson (1979) in Minnesota and Dybvig and Hart (1977) in Saskatchewan showed that wetland drainage can have an effect on flooding. Although not well understood at present, it is known that there is a relationship between prairie wetlands and the water table (Meyboom 1963, Sloan 1972). Studies are underway to determine the role played by wetlands in ground water recharge (Winter and Carr 1980). Other studies have suggested that wetlands play a role in maintenance of water quality in that they are capable of removing nutrients as well as non-point pollutants from runoff (Jones et al. 1976, Boto and Patrick 1979, and Davis et al. 1981). Wetlands, being very productive systems, can also be used for forage production. Boyd (1978) has shown that most emergent wetland plants produce adequate forage and can possess high protein content. Finally, wetlands are essential for recreation as the number of sportmen demonstrates.

Unfortunately, the number of wetlands has been reduced in past years through drainage for agriculture and, to a much lesser extent, the process of strip mining. With this reduction has come the loss of valuable cover, shelter, food and breeding habitat for numerous animal species that utilize wetlands. This loss has been partially offset by the creation of artificial wetlands such as livestock-watering impoundments and ponds formed in the process of strip mine reclamation. These artificial wetlands, if developed and managed properly, can serve as habitat comparable to natural wetlands (Olson 1979) and can provide for waterfowl production (Lokemoen 1973).

In order to create proper habitat in artificially formed wetlands, suitable aquatic vegetation must be established and maintained. Some plants provide better habitat or food sources than others and each plant species has its own ecological requirements. The ecological factors influencing wetland plants include physical characteristics of the aquatic environment as well as water quality. Both can greatly affect the composition of wetland vegetation. To establish beneficial plants in newly formed wetlands, information on the taxonomy, ecology and present distribution of wetland plants must be available from the region affected by new water development.

The objectives of this study were 1) to determine occurrence and distribution of aquatic plants on wetland sites throughout the northern Great Plains and 2) to determine pH, conductivity and total alkalinity values of waters where each of the species occurs in order to detect relationships between water chemistry and species occurrence.

LITERATURE REVIEW

Descriptive studies of the distribution of aquatic plant species throughout the northern Great Plains have been few and fairly localized. Several manuals and checklists of aquatic vascular plants of the United States have been published (Muenscher 1944, Fassett 1957, Hotchkiss 1967 and 1970, Prescott 1969 and Weldon et al. 1969). For the Great Plains region, several plant manuals treat vascular plants in general, including Rydberg (1932) for the entire region, and Winter (1936), Booth and Wright (1959), Porter (1962), Van Bruggen (1976) and Dorn (1977) for individual states.

Few publications have dealt strictly with the floristic composition of the Great Plains wetlands. Lindstrom (1968) has produced a taxonomic treatment of aquatic plants for the Great Plains region as a whole. Other taxonomic studies have been restricted to local areas or states. Larson (1979) performed an intensive taxonomic study on North Dakota aquatic flora. Stevens (1920) and Rudd (1951) described geographical affinities of aquatic plants in North Dakota and Metcalf (1931) described species of aquatic plants that serve as important duck foods in North Dakota. More localized studies include a vegetational survey of Nelson county, North Dakota (Dix and Smeins 1967), and a survey of the aquatic vegetation of the Turtle Mountains (Disrud 1968). Studies of aquatic plant distributions in Nebraska are limited and only a few have been performed in the vast Sandhills area (Poole 1914, Tolstead 1942). McCarraher (1977) includes a brief survey of aquatic vegetation as part of a broad limnological study of Sandhill lakes.

Although Martin (1965) has published a paper on aquatic monocots of South Dakota, little information on the occurrence and distribution of the aquatic plant species of Montana, South Dakota and Wyoming has been made available.

These descriptive studies, with emphasis on floristic composition, have led to more ecologically-oriented floristic investigations. Among these are studies dealing with the influence of surface-water chemistry upon species occurrence and distribution of aquatic plants. Many investigators have noted that water quality does indeed influence the distribution of some aquatic plant species (Ellis 1955, Moyle 1945, Stewart and Kantrud 1971).

Although making no attempt at correlation, some authors, in reporting aquatic plant distribution, also report water chemistry values for the waters in which the plants were found. Fassett (1930) and Wilson (1935), both working in Wisconsin, listed carbonate and pH values of the sampled lakes along with the plant species observed. McCarraher (1977) gave values for several chemical parameters while listing the submerged plants found within Nebraska Sandhill lakes.

Very little work has been done on the pH tolerance of aquatic plants. In a study in Saskatchewan, Jeglum (1971) determined several classes of pH and named plant indicators for each. He found that pH values as well as depth to water table were two important environmental factors correlated with vegetational variation in peatlands. Hicks (1932) described the pH tolerance of some of the members of the family Lemnaceae. Stewart and Kantrud (1972) found very little relationship between pH and the occurrence of indicator plant communities, although they indicated that pH values could be correlated with conductivity values. Wilson (1958) stated that pH values can be closely correlated with alkalinity values. In light of these findings, it may be difficult to distinguish effects of pH on plant occurrence from effects of either conductivity or total alkalinity.

Studies on alkalinity and aquatic plant occurrence are few. Ellis (1955), working in Louisiana, identified certain categories of waters by alkalinity values and listed a few dominant species in each category. He correlated total alkalinity with submerged and free floating aquatic plants and listed indicator species for low and high bicarbonate waters. He noted that while the medium bicarbonate waters had the greatest diversity of aquatic plants, waters that showed a great range of alkalinity values had much less diversity. Since this study was not performed in the Great Plains, where alkalinity readings are considerably higher, results could be much different in this area.

Investigations that relate water quality to species occurrence seem to show that conductivity is the factor that most influences plant species composition and distribution. Sloan (1970) stated that the species composition of wetland vegetation is closely related to the conductivity of surface water. A study in Saskatchewan by Rawson and Moore (1944) identified Potamogeton pectinatus and Ruppia maritima as being two of the most common species occurring in waters of high conductivity. Stewart and Kantrud (1972) found that the conductivity of surface waters in North Dakota was very closely related to differences in species composition of plant communities found within the principal vegetation types they described. Dix and Smeins (1967) reported a higher frequency of Scirpus paludosus and Hordeum jubatum in North Dakota wet meadows that had high conductivity values. In a study of sloughs in Saskatchewan, Walker and Coupland (1968) found some aquatic plant species restricted to a very narrow range of conductivity. In a similar Saskatchewan study, Walker and Wehrhahn (1971) found that conductivity was one of the most variable of measured environmental factors and state that this could explain the varied ranges of conductivity apparently tolerated by aquatic plants.

The influence of conductivity on the occurrence of aquatic plant species has played a role in the classification of both wetlands and wetland plants. Metcalf (1931) formulated a general classification of lakes and sloughs in North Dakota based partially on conductivity readings and their correlation to plant communities. Rawson and Moore (1944) used tolerance to increasing salinity as a basis of classifying common rooted aquatic plants of Saskatchewan.

As indicated, a relatively small amount of work relating the occurrence of aquatic plant species to water chemistry has been accomplished in the northern Great Plains. Studies of this type have been performed in other areas of the United States as well as Europe and Asia.

MATERIALS AND METHODS

A total of 281 wetland sites, including lakes, ponds, mine ponds, impoundments, seepage wetlands, rivers and streams, was sampled in North Dakota, South Dakota, Nebraska and eastern Montana and Wyoming. Sites were selected from private and public lands on the basis of accessibility. Aquatic plant specimens were collected and plant species lists were made for each study site. Water samples were obtained and tested for pH, conductivity and alkalinity.

Determining the composition of wetland vegetation was accomplished by a walking and wading survey of the site area, including wet meadow, shallow marsh, emergent and submergent zones. Each identifiable species was recorded along with its habitat of occurrence. Collections of the recorded species were made to facilitate proper laboratory verification of the specimens.

Surface water samples were obtained from each site in a one-liter bottle, each sample being collected from approximately 3 cm beneath the water surface. From this one-liter sample, three 50-ml subsamples were taken and analyzed separately for pH, conductivity and total alkalinity. Conductivity readings were measured in micromhos/cm on a conductivity meter. Total alkalinity in mg/l $CaCO_3$ was determined by titration to a pH of 4.5 using 1.600 $\pm$ 0.005N sulfuric acid and a Hach digital titrator calibrated for 100-ml samples. Most water samples collected were relatively high in alkalinity. In order to save time and conserve acid, 50-ml samples were tested. Total alkalinity values based on the 50-ml samples were then doubled to adjust the values.

Ninety-seven species of aquatic plants were studied to determine any relationships between their occurrence in a particular wetland and the chemical characteristics of surface waters. Selection was based on 1) the direct association of the plants with surface water and 2) on sample size. Species were selected only if they normally occur as submergent or emergent plants and only if they were encountered in three or more sites. The ranges and means of conductivity, total alkalinity and pH values of surface waters were then calculated for each species based upon the values obtained from sites of their occurrence.

RESULTS

The 97 aquatic plant species that were selected are alphabetically ordered within their respective families. The families are arranged according to the phylogenetic system of Cronquist (1981). Habitat and range descriptions are provided for each species. Sample size (n), or the number of sites at which each species was found, is indicated along with the mean, the standard error of the mean ($S\bar{x}$), and the ranges for the values of pH, conductivity and total alkalinity. Conductivity was measured in micromhos/cm and alkalinity in mg/l $CaCO_3$.

Maps showing the distribution of each of the species throughout the northern Great Plains are included. Each dot represents at least one collection of that plant in the county indicated. Distribution information is from <u>The Atlas of the Flora of the Great Plains</u> (McGregor et al. 1977), the <u>Aquatic and Wetland Vascular Plants of North Dakota</u> (Larson 1983) and information gathered in this study.

Polypodiaceae, the Polypody Family

<u>Thelypteris palustris</u> Schott -- Marshfern

Boggy, marshy soil; marshes, fens and stream margins.
Nearly cosmopolitan, in Am. from Newf. to Man., s to GA and OK.

n=3	mean	$S\bar{x}$	range
pH	8.07	0.58	7.69-8.79
conductivity	147.77	22.99	103.00-179.00
alkalinity	73.07	7.06	60.00-85.00

Marsileaceae, the Marsilea Family

<u>Marsilea vestita</u> Hook. & Grev. -- Pepperwort

Ponds, streams or ditches and sometimes in temporary potholes.
MN to B.C., s to AR, TX, Mex. and CA; intro. in FL.

n=4	mean	$S\bar{x}$	range
pH	7.48	2.28	7.00-8.40
conductivity	525.50	158.27	186.00-945.00
alkalinity	145.30	15.95	112.60-180.00

Nymphaeaceae, the Water Lily Family

<u>Nuphar luteum</u> Sibth. & Sm. -- Spatterdock

Ponds, lakes and slow-moving streams, in shallow to deep water.
Newf. to the Yukon, s to DE, n OH, n IL, IA, NE and MT.

n=4	mean	$S\bar{x}$	range
pH	7.84	0.72	7.49-8.69
conductivity	779.23	137.64	486.30-1147.00
alkalinity	291.40	28.24	232.60-366.00

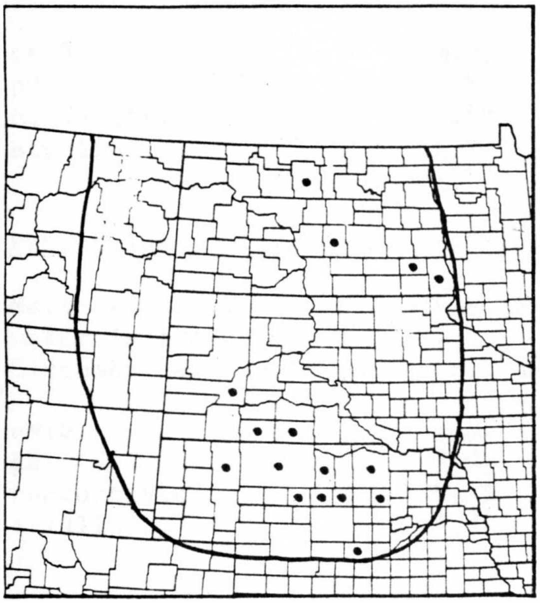
Ceratophyllaceae, the Hornwort Family

<u>Ceratophyllum demersum</u> L. -- Coontail

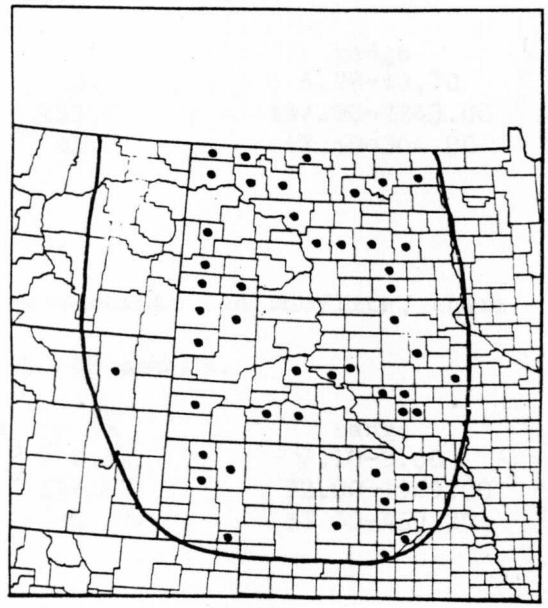
Fresh to moderately brackish water of quiet lakes, ponds, marshes and slow moving streams.
Southern Canada, throughout the U.S. to S.Am.

n=75	mean	$S\bar{x}$	range
pH	7.89	0.26	7.10-11.00
conductivity	1008.68	151.22	98.00-2820.00
alkalinity	195.88	22.62	46.00-486.00

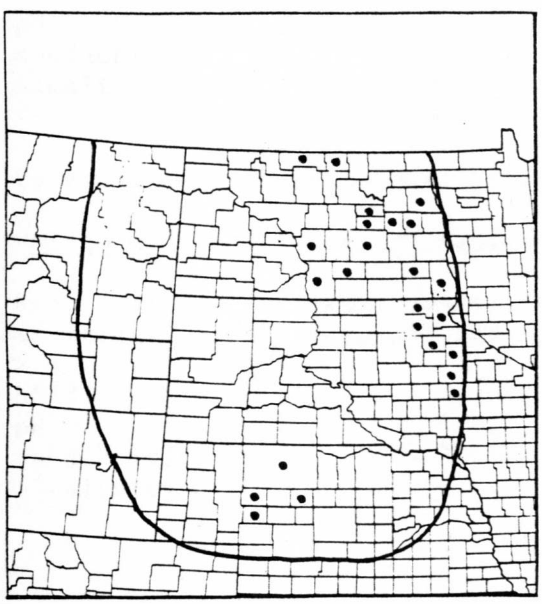
Thelypteris palustris Schott



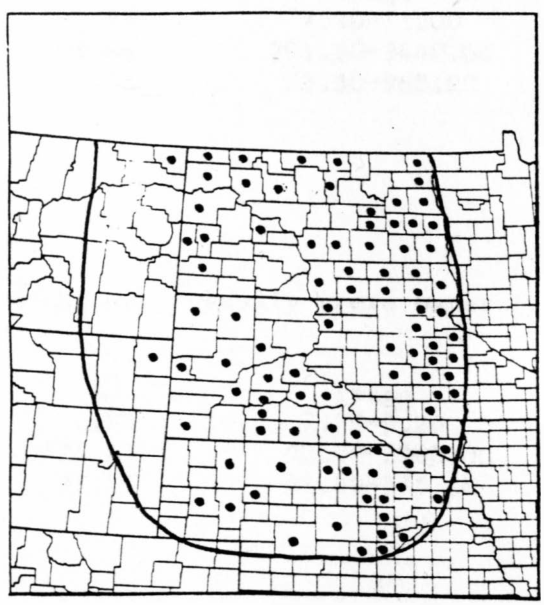
Marsilea vestita Hook. & Grev.



Nuphar luteum Sibth. & Sm.



Ceratophyllum demersum L.



Ranunculaceae, the Buttercup Family

Ranunculus longirostris Godr. -- White water crowfoot

Calcareous water of streams, ponds, marshes and water-filled ditches. Que. to Sask., s to DE, TN, AL, AR, TX, NM, ID and NV.

n=33	mean	$S\bar{x}$	range
pH	7.85	0.46	6.98-10.70
conductivity	712.89	123.81	137.00-2243.00
alkalinity	163.97	12.77	48.60-304.00

Ranunculus sceleratus L. -- Cursed crowfoot

Marshes, ditches, wet meadows, shores, streambanks and mudflats, where water is fresh to brackish.
Circumboreal, in Am., s to FL, AR, LA, TX, NM and CA.

n=16	mean	$S\bar{x}$	range
pH	7.83	0.54	7.10-9.60
conductivity	908.35	138.67	92.00-1969.00
alkalinity	249.74	30.37	53.00-459.30

Ranunculus subrigidus W. B. Drew -- White water crowfoot

Ponds, slow-moving streams, lakes, marshes and water-filled ditches. Que. to N.W. Terr. and B.C., s to MA, MI, IA, TX, n Mex. and CA.

n=19	mean	$S\bar{x}$	range
pH	8.12	0.33	7.30-11.00
conductivity	2360.64	885.68	291.60-3440.00
alkalinity	236.08	48.48	73.30-968.00

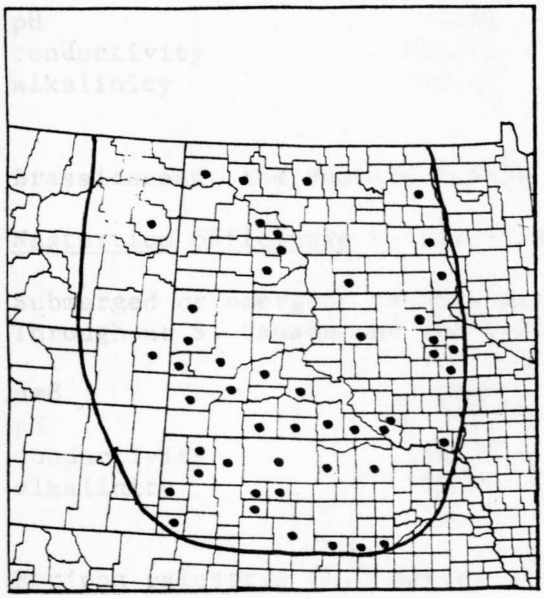
Polygonaceae, the Buckwheat Family

Polygonum amphibium L. -- Water smartweed

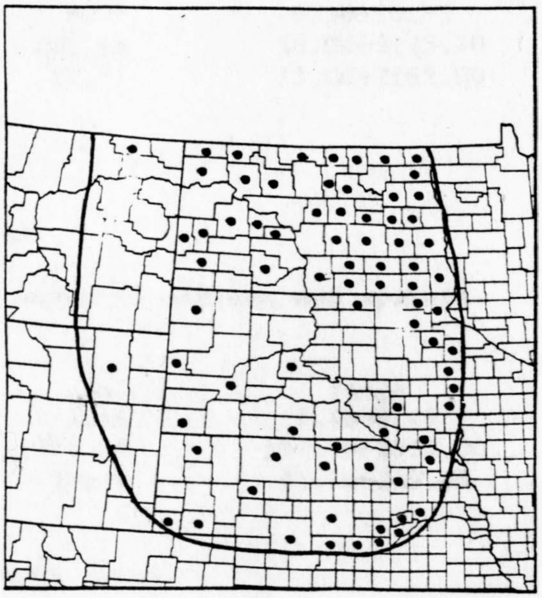
Fens, springs, streams, ponds, lakes and marshes, usually where water is fresh. Nearly cosmopolitan.

n=33	mean	$S\bar{x}$	range
pH	8.02	0.26	7.39-9.20
conductivity	1373.65	625.43	92.00-2900.00
alkalinity	244.44	37.59	61.30-575.30

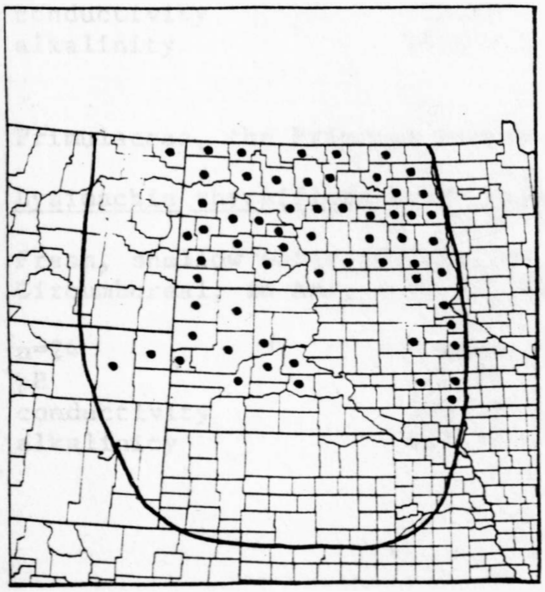
Ranunculus longirostris Godr.



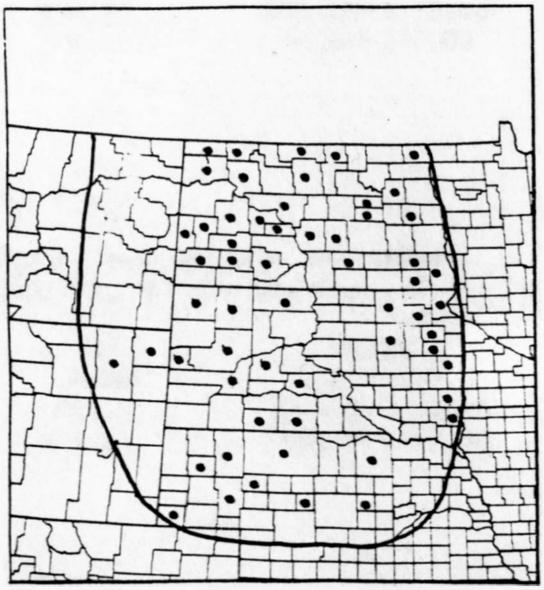
Ranunculus sceleratus L.



Ranunculus subrigidus W. Drew



Polygonum amphibium L.



Polygonum coccineum Muhl. -- Water smartweed

Meadows, streams, ponds, lakes and marshes, often forming extensive colonies. Que. and N.S. to B.C., s to NC, TN, TX and CA.

n=110	mean	$S\bar{x}$	range
pH	7.68	0.50	6.30-10.79
conductivity	912.72	103.58	59.00-9125.70
alkalinity	230.19	23.51	13.00-2282.00

Brassicaceae, the Mustard Family

Nasturtium officinale R. Br. -- Watercress

Submerged or emergent in shallow, clear water of streams and springs. Throughout S. Canada and the U.S.

n=8	mean	$S\bar{x}$	range
pH	7.52	1.18	7.10-8.49
conductivity	1152.02	391.09	137.00-2937.00
alkalinity	183.44	20.54	53.00-249.30

Rorippa palustris (L.) Besser -- Bog yellow cress

Marshes, streambanks, lake shores, ditches and other wet places. Lab. to AK, s to n S. Am.

n=17	mean	$S\bar{x}$	range
pH	7.95	0.37	7.30-10.79
conductivity	739.59	140.97	108.00-2103.60
alkalinity	183.41	16.55	44.60-277.00

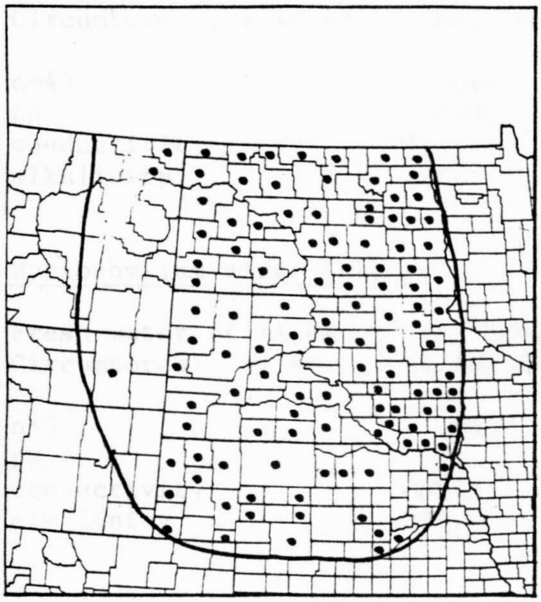
Primulaceae, the Primrose Family

Lysimachia thyrsiflora L. -- Tufted loosestrife

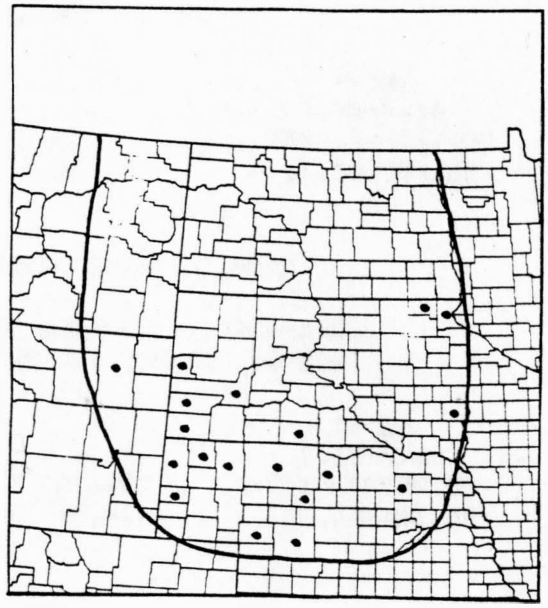
Fresh, shallow water of fens, bogs, springs, wet meadows and shores. Circumboreal, in Am., s to NJ, OH, IL, MO, NE, MO, ID and CA.

n=24	mean	$S\bar{x}$	range
pH	7.89	0.48	7.00-9.49
conductivity	542.59	93.15	103.00-2182.00
alkalinity	621.31	411.41	60.00-1049.30

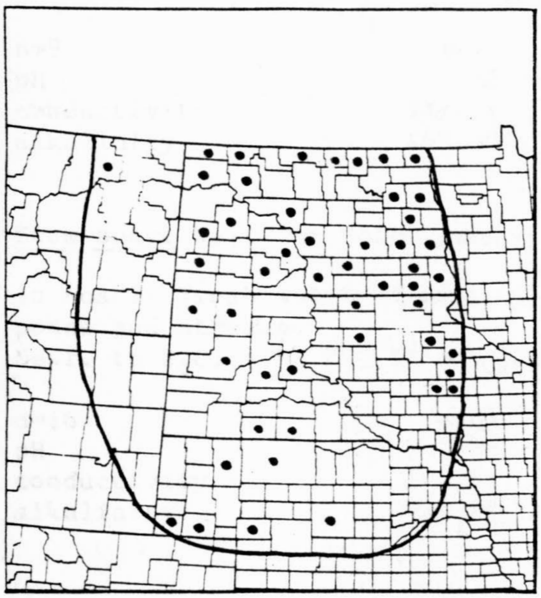
<u>Polygonum</u> <u>coccineum</u> Muhl.



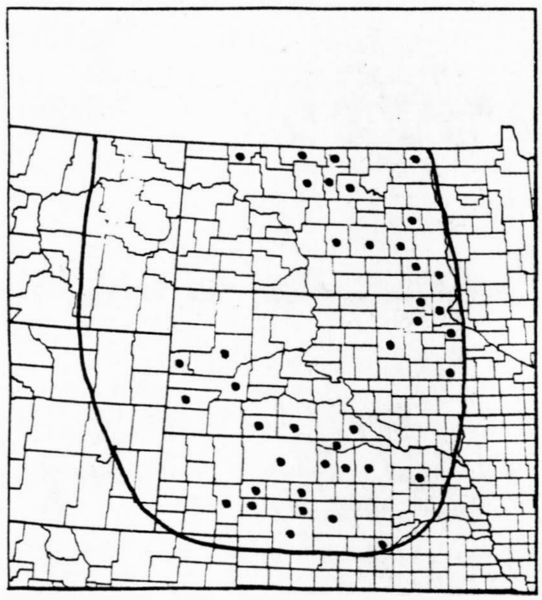
<u>Nasturtium</u> <u>officinale</u> R. Br.



<u>Rorippa</u> <u>palustris</u> (L.) Besser



<u>Lysimachia</u> <u>thyrsiflora</u> L.



Haloragaceae, the Water Milfoil Family

Myriophyllum exalbescens Fern. -- Common water milfoil

Fresh to moderately brackish water of lakes, ponds, marshes and slow-moving streams.
Circumboreal, s in Am. to MD, OH, IN, TX, NM and CA.

n=43	mean	$S\bar{x}$	range
pH	8.38	0.11	7.39-9.69
conductivity	1337.39	162.35	179.00-3787.00
alkalinity	229.39	23.31	61.30-968.00

Myriophyllum verticillatum L. -- Needleleaf water milfoil

Fresh water of lakes, ponds, marshes and slow-moving streams.
Circumboreal, in Am., s to MA, NY, IN, ne TX, NE, UT and B.C.

n=3	mean	$S\bar{x}$	range
pH	7.49	1.75	7.20-8.60
conductivity	609.33	127.43	358.00-770.00
alkalinity	302.66	82.94	179.00-460.00

Apiaceae, the Parsley Family

Berula erecta (Huds.) Cov. -- Water parsnip

Springs, spring-fed streams, seepage marshes and fens.
NY and Ont. to B.C., s to FL, Mex., C.Am. and Baja CA.

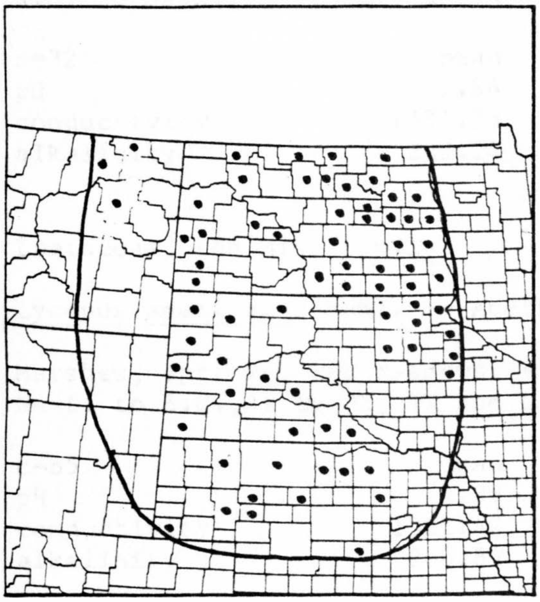
n=9	mean	$S\bar{x}$	range
pH	7.55	0.93	7.10-8.79
conductivity	927.18	343.47	103.00-2937.00
alkalinity	169.30	34.83	50.00-366.00

Sium suave Walt. -- Water parsnip

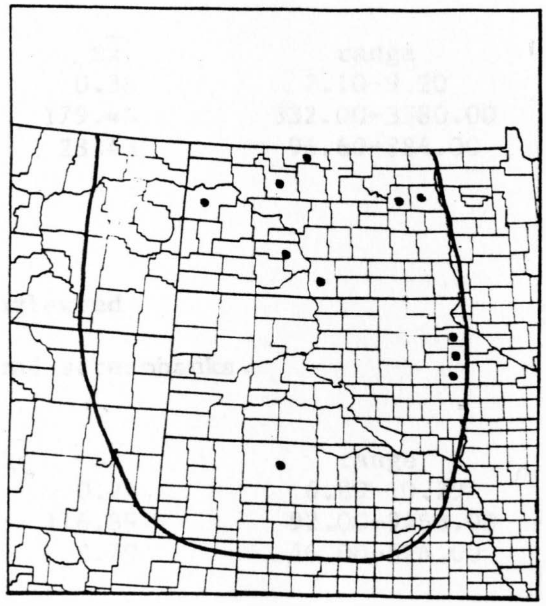
In mostly fresh water of marshes, springs, swamps and margins of lakes, ponds and streams.
Newf. to B.C.,s to FL, TX and CA.

n=16	mean	$S\bar{x}$	range
pH	7.59	0.61	7.10-9.00
conductivity	671.99	119.69	92.00-1862.78
alkalinity	224.09	27.35	85.00-526.00

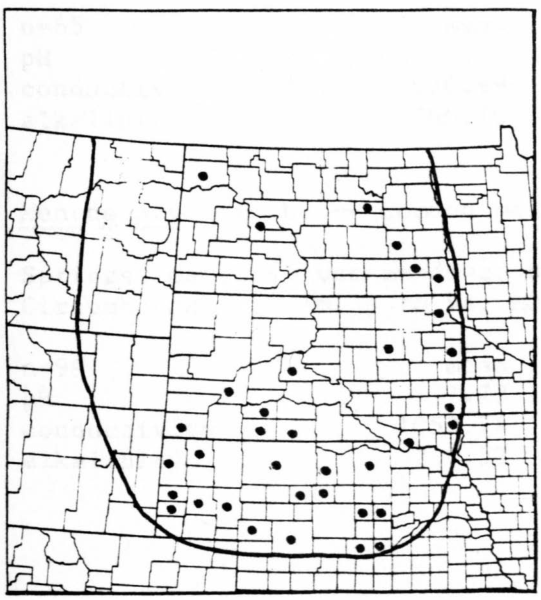
Myriophyllum exalbescens Fern.



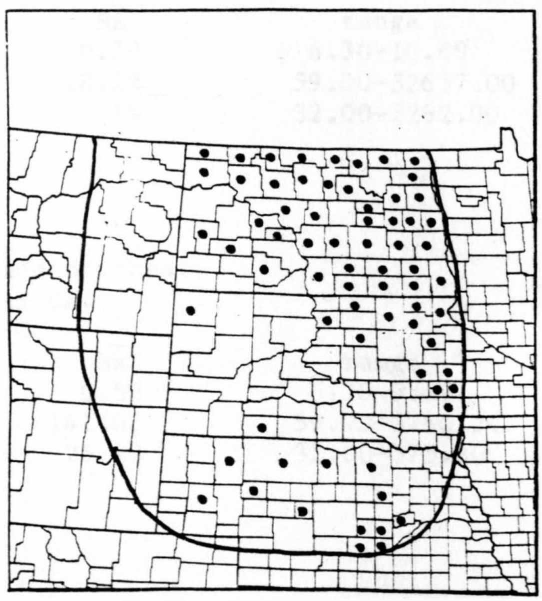
Myriophyllum verticillatum L.



Berula erecta (Huds.) Cov.



Sium suave Walt.



Asclepiadaceae, the Milkweed Family

Asclepias incarnata L. -- Swamp milkweed

Marshes, springs, fens, swamps, lake shores and stream margins.
N.S. to Sask., s to FL, TX and NM.

n=32	mean	$S\bar{x}$	range
pH	7.84	0.38	7.10-9.20
conductivity	1331.75	179.45	332.00-3380.00
alkalinity	229.24	28.43	96.60-884.00

Lamiaceae, the Mint Family

Lycopus americanus Muhl. -- American bugleweed

Marshes, springs, wet meadows, shores and streambanks.
Newf. to B.C., s to FL, TX and CA.

n=85	mean	$S\bar{x}$	range
pH	7.85	0.24	6.89-10.79
conductivity	1021.42	116.89	92.00-9463.00
alkalinity	200.84	8.79	46.00-526.00

Lycopus asper Greene -- Rough bugleweed

Marshes, springs, wet meadows, shores and streambanks.
Ont. and MI to B.C., s to IA, KS, NM and CA.

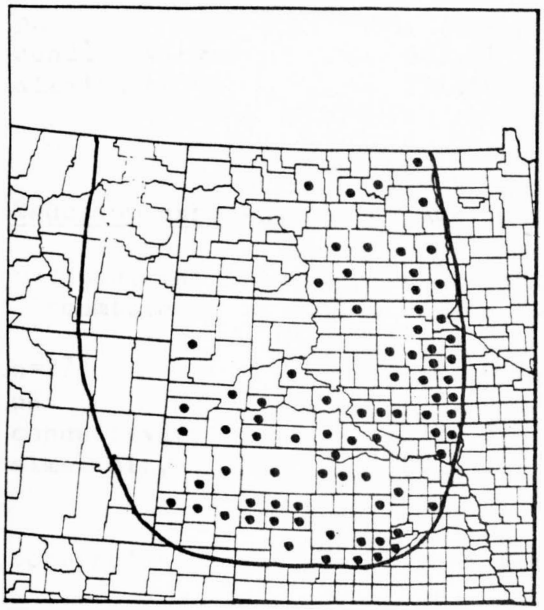
n=65	mean	$S\bar{x}$	range
pH	7.69	0.79	6.30-10.69
conductivity	1970.99	528.29	59.00-32637.00
alkalinity	305.78	40.19	32.00-2282.00

Mentha arvensis L. -- Common mint

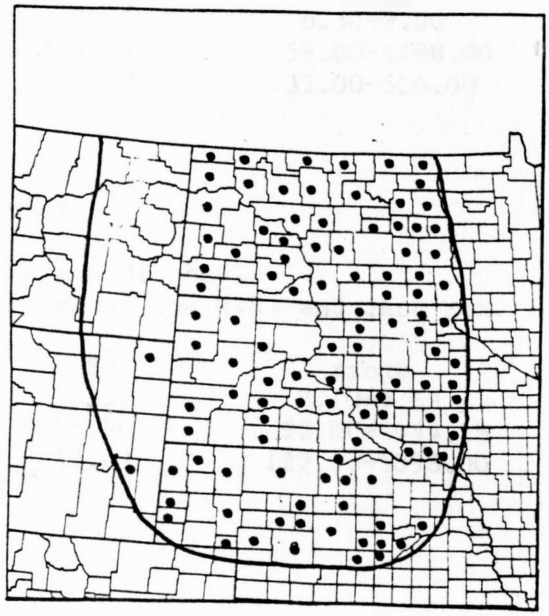
Springs, marshes, wet meadows, swamps and ditches.
Circumboreal, in Am. s to VA, MO, NM and CA.

n=99	mean	$S\bar{x}$	range
pH	7.73	0.53	6.30-9.49
conductivity	1052.74	141.06	59.00-3266.24
alkalinity	238.52	25.23	32.00-575.30

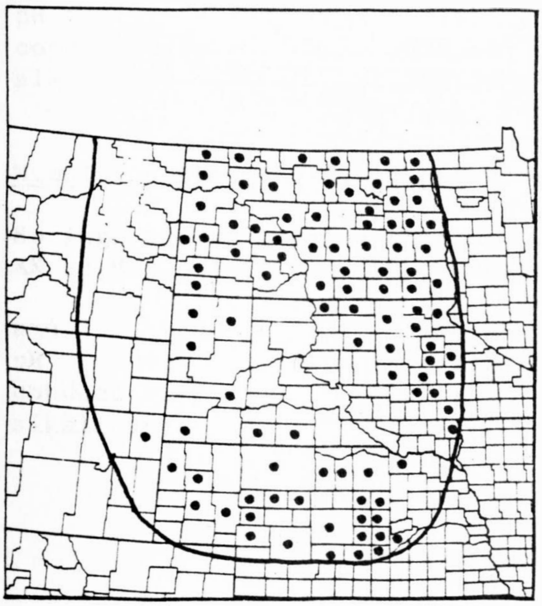
Asclepias incarnata L.



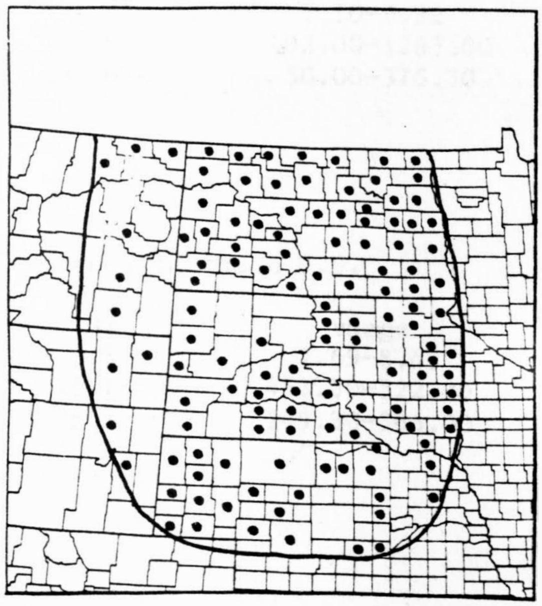
Lycopus americanus Muhl.



Lycopus asper Greene



Mentha arvensis L.



Scutellaria galericulata L. -- Marsh skullcap

Springs, marshes, ditches, wet meadows, shores and streambanks.
Circumboreal, in Am. s to DE, OH, IL, MO, n TX, AZ and CA.

n=13	mean	$S\bar{x}$	range
pH	7.27	1.76	6.30-9.00
conductivity	603.41	104.55	59.00-1198.00
alkalinity	231.40	39.69	32.00-526.00

Teucrium canadense L. -- American germander

Marshes, wet meadows, shores, streambanks and ditches.
Circumboreal, in Am., across s Can., throughout the U.S. and into Mex.

n=27	mean	$S\bar{x}$	range
pH	7.90	0.36	7.10-9.69
conductivity	1272.75	206.96	92.00-4644.18
alkalinity	291.45	40.69	122.60-1098.00

Scrophulariaceae, the Figwort Family

Mimulus glabratus H.B.K. -- Roundleaf monkey-flower

Ponds, cold springs, seepage areas and banks of spring-fed streams.
MI to Man. and MT, s to TX, AZ, NV and into Mex. and S. Am.

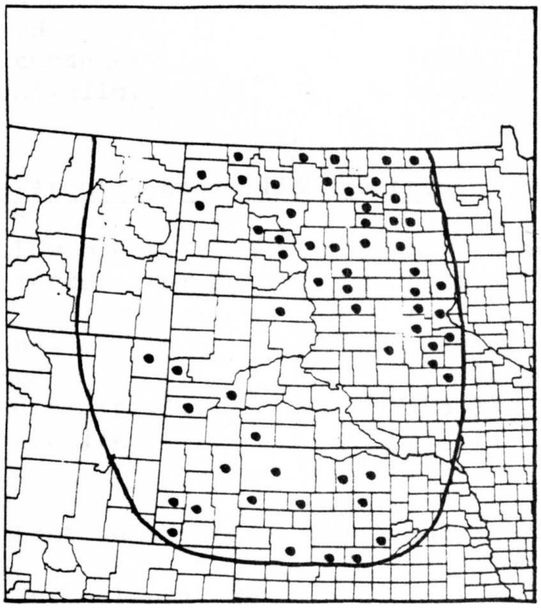
n=5	mean	$S\bar{x}$	range
pH	7.59	1.42	7.10-9.22
conductivity	358.46	160.03	103.00-1283.00
alkalinity	162.50	103.09	50.00-575.30

Mimulus guttatus D.C. -- Monkey-flower

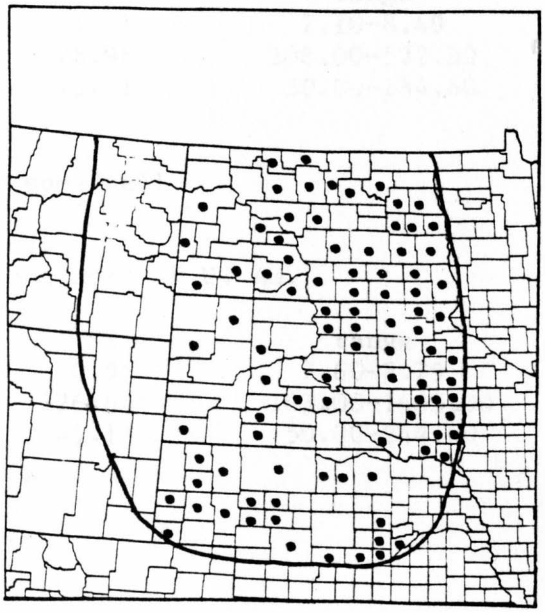
Springs and spring-fed streams.
AK to Mex., intro. as an ornamental and escaped in the e U.S.

n=4	mean	$S\bar{x}$	range
pH	7.91	0.37	7.69-8.49
conductivity	491.15	15.11	453.30-522.30
alkalinity	289.97	26.39	249.30-366.00

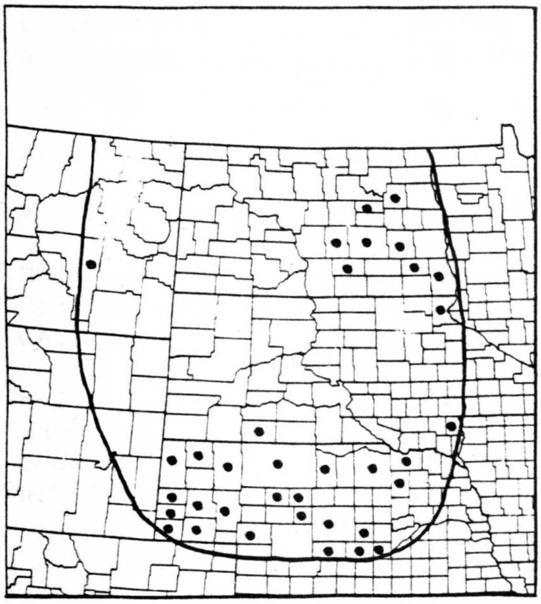
Scutellaria galericulata L.



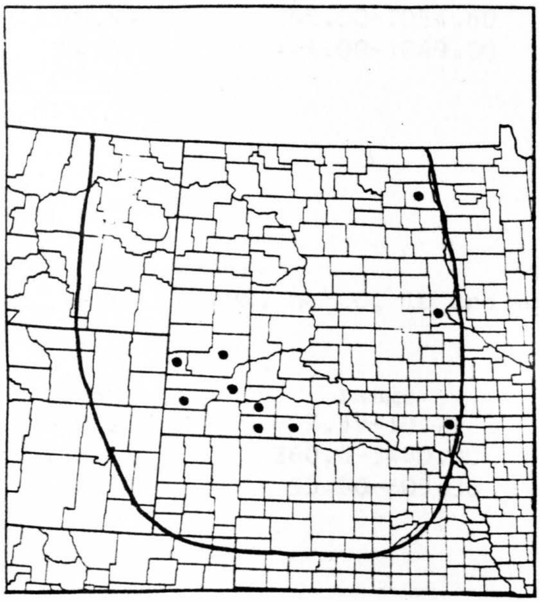
Teucrium canadense L.



Mimulus glabratus H. B. K.



Mimulus guttatus DC.



Veronica americana Schwein. -- Brooklime

Springs and fresh streams.
Newf. to AK, s to NC, TX, CA and into Mex.

n=6	mean	$S\bar{x}$	range
pH	7.59	1.11	7.10-8.49
conductivity	360.53	75.98	108.00-522.30
alkalinity	183.92	43.11	50.00-284.60

Veronica anagallis-aquatica L. -- Water speedwell

Low areas, floodplains and stream margins.
Intro. from Europe, naturalized throughout most of N. Am.

n=4	mean	$S\bar{x}$	range
pH	8.04	0.55	7.60-8.79
conductivity	495.33	326.64	103.00-1465.00
alkalinity	125.13	45.18	50.00-244.60

Lentibulariaceae, the Bladderwort Family

Utricularia vulgaris L. -- Bladderwort

Standing water of marshes, ditches, lakes and ponds.
Circumboreal, in Am. s to FL, TX, AZ and CA.

n=41	mean	$S\bar{x}$	range
pH	7.61	0.52	6.89-10.69
conductivity	753.88	78.99	98.00-2084.60
alkalinity	238.40	24.57	46.00-1049.30

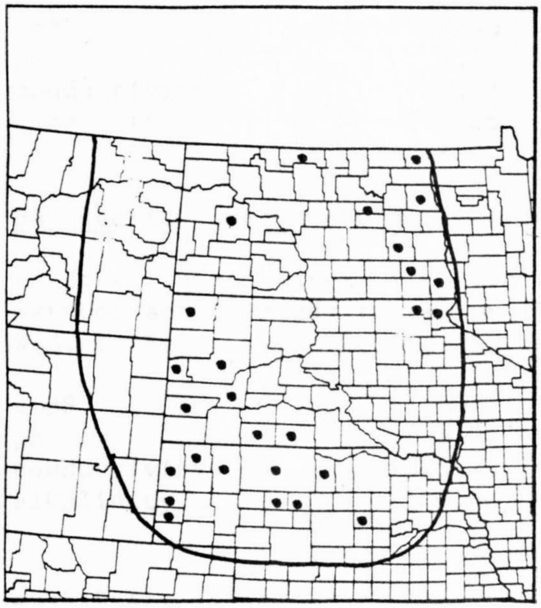
Alismataceae, the Water Plantain Family

Alisma gramineum Gmel. -- Narrowleaf water plantain

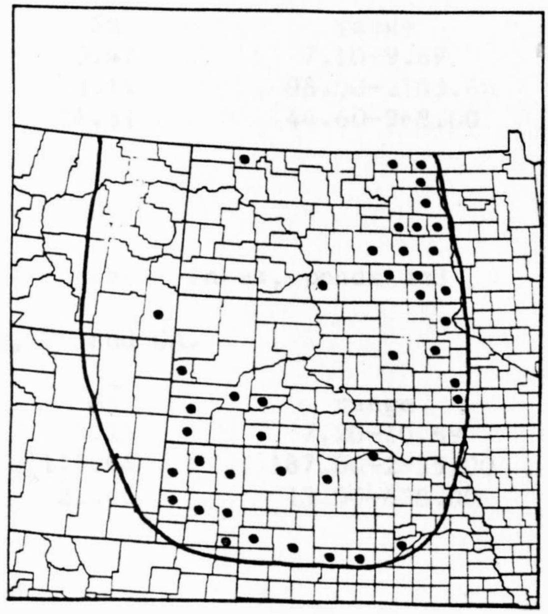
Muddy shores, streambanks or in shallow brackish water.
Circumboreal, in Ma. from Que. to sw B.C., s to NY, MN, ne CO, ID and n GA.

n=20	mean	$S\bar{x}$	range
pH	8.19	0.23	7.39-10.79
conductivity	1389.62	248.61	260.0-3440.00
alkalinity	216.50	34.51	93.60-609.30

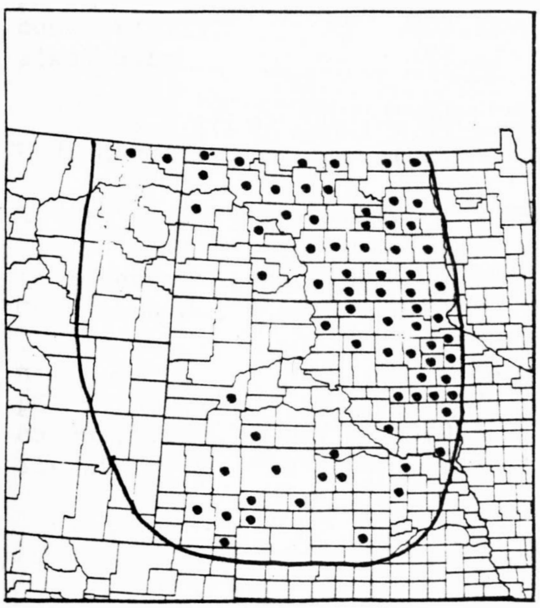
Veronica americana Schwein.



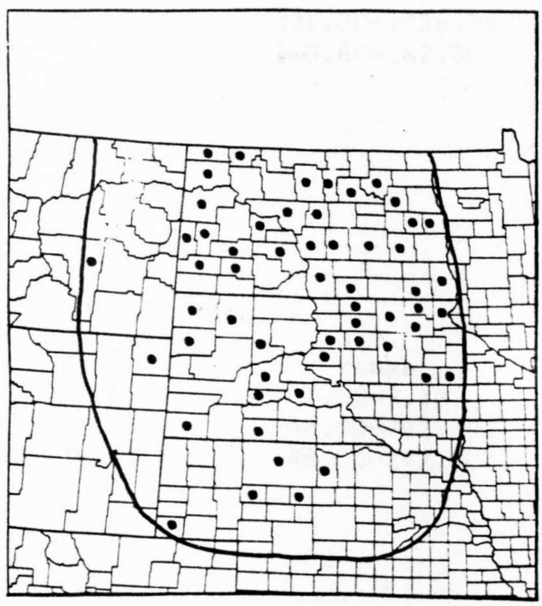
Veronica anagallis-aquatica L.



Utricularia vulgaris L.



Alisma gramineum Gmel.



Alisma plantago-aquatica L. -- Water plantain

Muddy shores, streambanks and in shallow brackish water.
N.S. to B.C., s to NY, n MI, WI, MO, KS, CO, AZ and CA; also Eurasia, Africa and Australia.

n=45	mean	$S\bar{x}$	range
pH	7.75	0.42	7.10-9.69
conductivity	704.67	70.14	98.00-2103.60
alkalinity	223.06	24.31	44.60-968.00

Sagittaria cuneata Sheld. -- Arrowhead

In fresh to moderately brackish water of streams, lakes, ponds and marshes and on muddy shores or flats.
N.S. to B.C., s to NY, IN, IL, n TX, NM, UT and CA.

n=38	mean	$S\bar{x}$	range
pH	8.04	0.25	7.20-10.69
conductivity	1023.23	115.64	187.00-2825.00
alkalinity	183.58	22.43	13.00-628.00

Sagittaria latifolia Willd. -- Arrowhead

In shallow water, marshes, shores of lakes and ponds or on mud flats.
N.S. and Que. to B.C., s to n S.Am.

n=6	mean	$S\bar{x}$	range
pH	7.79	0.66	7.39-10.69
conductivity	503.22	108.43	331.00-1026.34
alkalinity	197.32	20.17	140.60-262.00

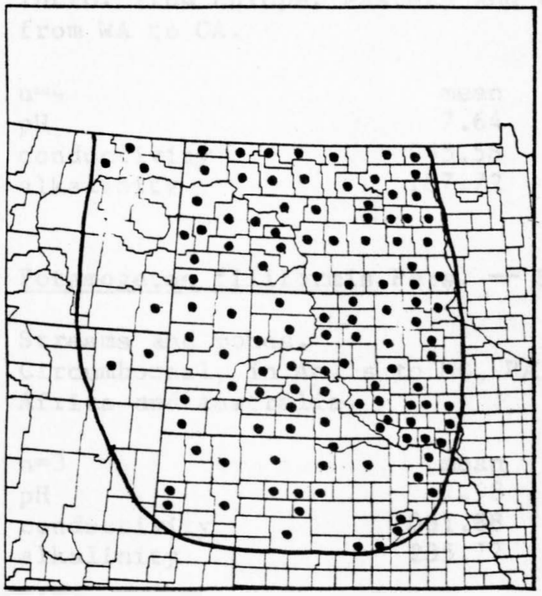
Hydrocharitaceae, the Frog's-bit Family

Elodea canadensis Michx. -- Waterweed

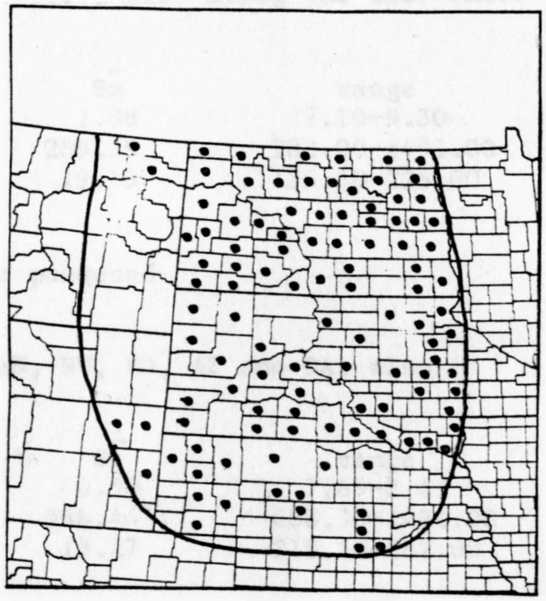
In reservoirs and sluggish water of streams.
Que. to B.C., s to NC, AL, AR, OK, CO, UT, NV and CA.

n=10	mean	$S\bar{x}$	range
pH	8.24	0.24	7.60-9.30
conductivity	390.87	81.48	98.00-792.49
alkalinity	144.23	24.91	46.00-272.00

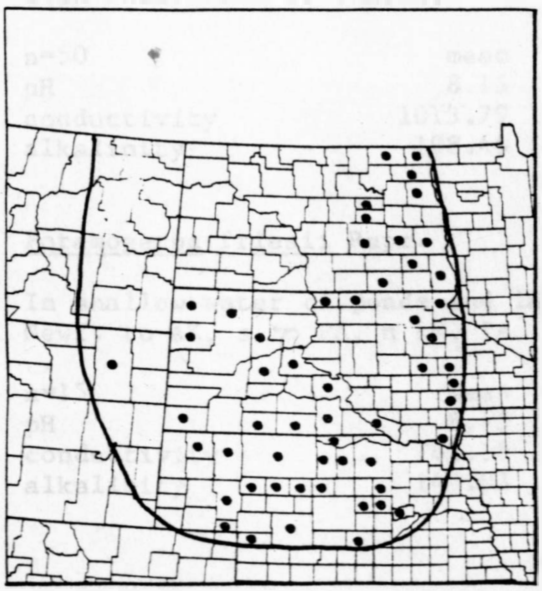
Alisma plantago-aquatica



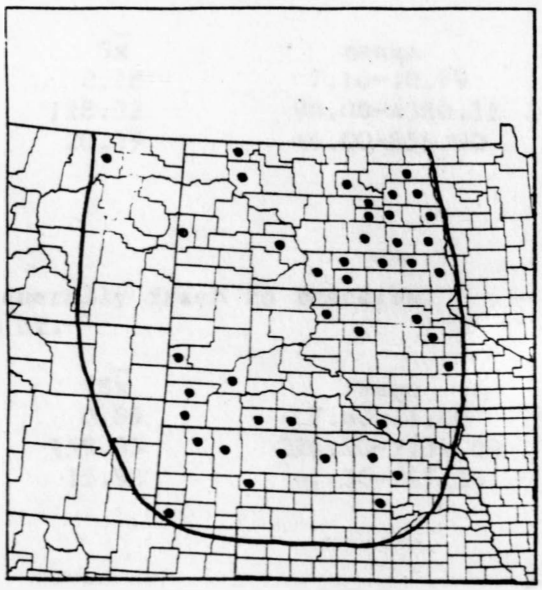
Sagittaria cuneata Sheld.



Sagittaria latifolia Willd.



Elodea canadensis Michx.



Potamogetonaceae, the Pondweed Family

Potamogeton crispus L. -- Curly pondweed

Lakes, ponds and slow streams.
Intro. from Europe; eastern and central U.S., also along the West coast from WA to CA.

n=4	mean	$S\bar{x}$	range
pH	7.64	1.88	7.10-9.30
conductivity	955.58	289.39	283.00-1491.00
alkalinity	187.72	19.13	135.30-226.00

Potamogeton filiformis Pers. -- Slender pondweed

Streams and ponds.
Circumboreal, in Am. s to ME, PA, MI, MN, NW, CO, AZ and CA; also Africa and Australia.

n=3	mean	$S\bar{x}$	range
pH	7.98	0.50	7.69-8.49
conductivity	1061.88	238.44	668.30-1491.00
alkalinity	235.77	13.27	219.30-262.00

Potamogeton foliosus Raf. -- Leafy pondweed

Shallow water of lakes, ponds, rivers and streams.
Newf. to B.C., s throughout most of the U.S. and into Mex. and C. Am.; also Hawaii and W. Indies.

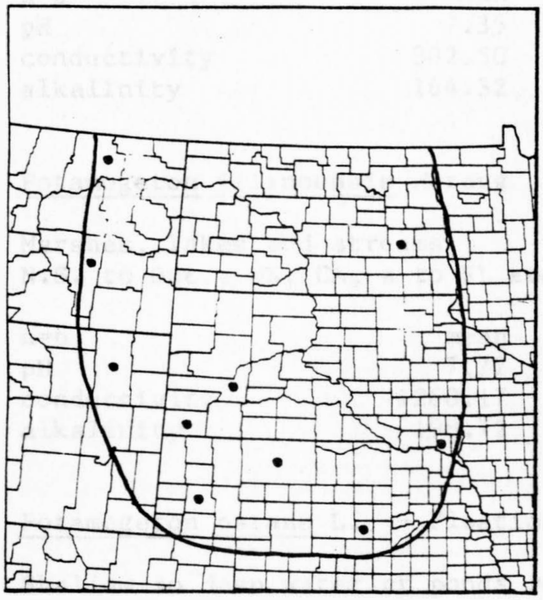
n=50	mean	$S\bar{x}$	range
pH	8.15	0.18	7.10-10.79
conductivity	1013.79	128.02	98.00-4380.31
alkalinity	198.46	20.29	46.00-856.00

Potamogeton friesii Rupr.

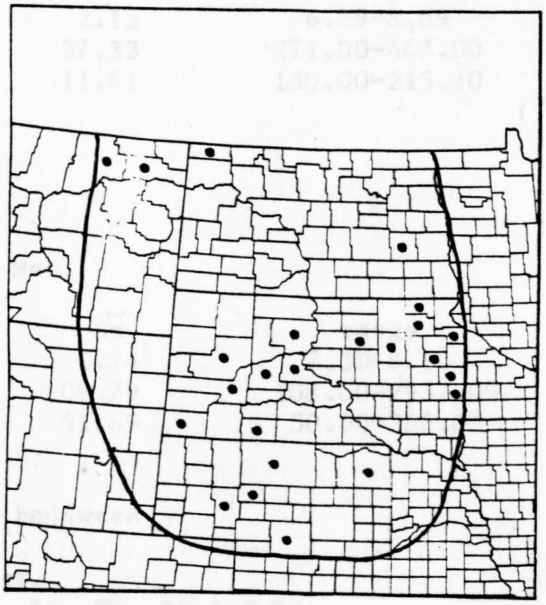
In shallow water of ponds and lakes, generally fresh to brackish.
Newf. to AK, s to PA, n IN, IA, NE and UT.

n=15	mean	$S\bar{x}$	range
pH	8.43	0.09	7.60-11.00
conductivity	763.18	159.83	226.00-2139.00
alkalinity	140.03	15.98	61.30-267.30

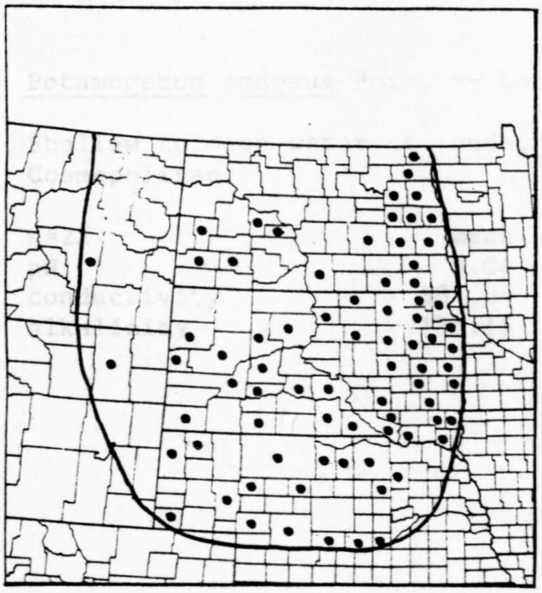
Potamogeton crispus L.



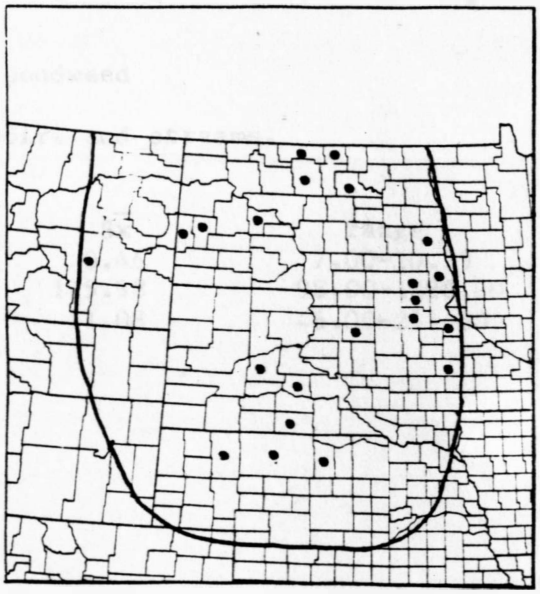
Potamogeton filiformis Pers.



Potamogeton foliosus Raf.



Potamogeton friesii Rupr.



Potamogeton gramineus L. -- Variable pondweed

Shallow standing water of ponds, lakes and marshes.
Circumboreal, in Am. s to NY, IA, NE and CA.

n=6	mean	$S\bar{x}$	range
pH	7.35	2.15	6.89-8.89
conductivity	382.50	37.33	271.00-467.00
alkalinity	164.32	11.41	130.00-213.30

Potamogeton illinoensis Morong

Marshes, lakes and streams.
N.S. to Ont., MN, CA, s to FL and into Mex.

n=6	mean	$S\bar{x}$	range
pH	7.77	0.74	7.30-8.60
conductivity	1260.17	509.79	108.00-2937.00
alkalinity	198.72	41.69	50.00-366.00

Potamogeton natans L. -- Floating leaf pondweed

Shallow to deep water of ponds and lakes.
Circumboreal, in Am. s to PA, IN, IA, n KS, NM, AZ and CA.

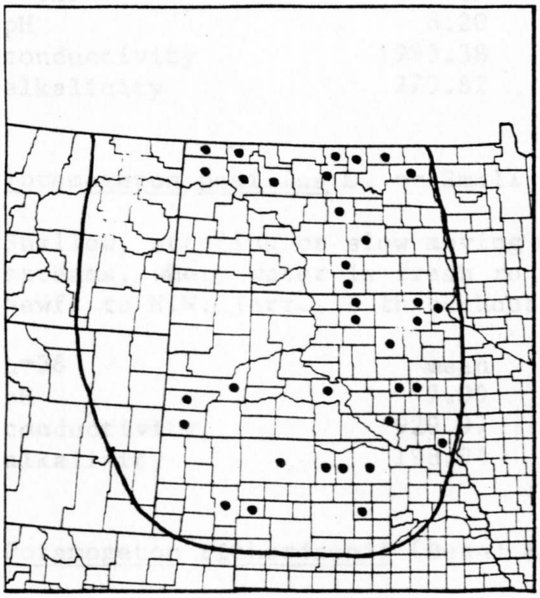
n=4	mean	$S\bar{x}$	range
pH	8.13	0.59	7.60-10.69
conductivity	362.11	65.54	227.00-541.42
alkalinity	161.30	23.75	112.00-223.30

Potamogeton nodosus Poir. -- Longleaf pondweed

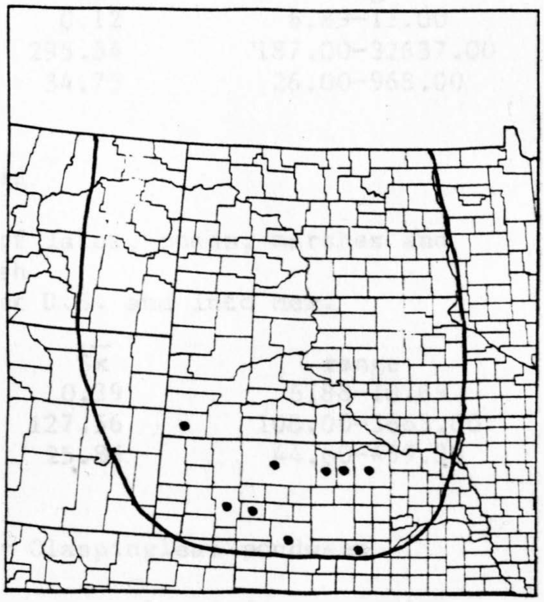
Shallow to deep water of ponds, reservoirs and streams.
Cosmopolitan.

n=22	mean	$S\bar{x}$	range
pH	8.04	0.46	7.00-10.79
conductivity	681.04	115.98	98.00-1888.00
alkalinity	132.15	11.08	46.00-211.30

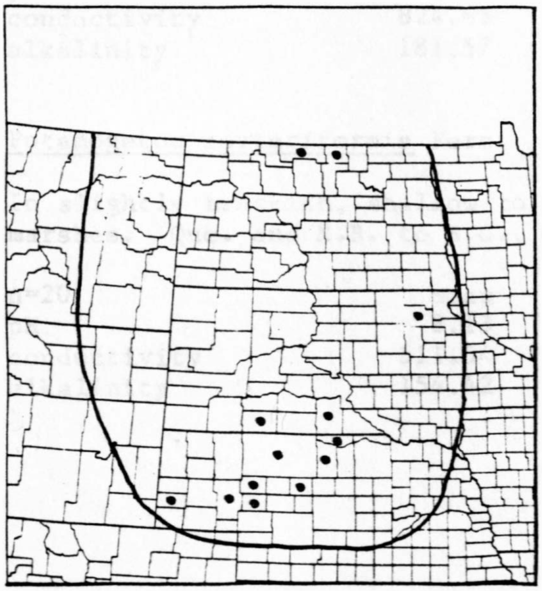
Potamogeton gramineus L.



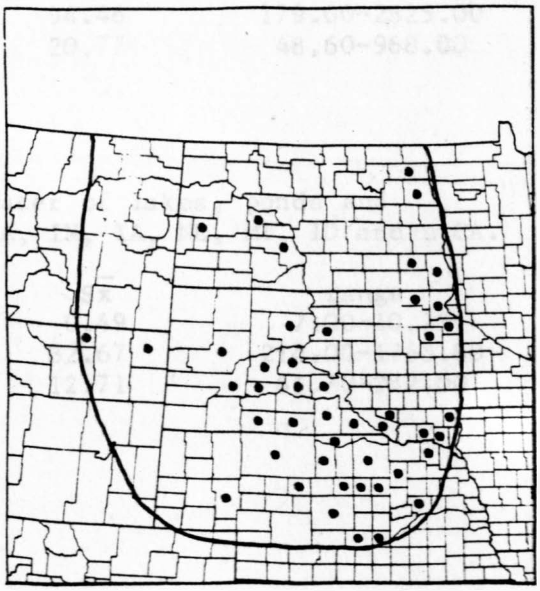
Potamogeton illinoensis Morong.



Potamogeton natans L.



Potamogeton nodosus Poir.



Potamogeton pectinatus L. -- Sago pondweed

Shallow to deep water of lakes, ponds, marshes, rivers and streams. Nearly cosmopolitan.

n=137	mean	$S\bar{x}$	range
pH	8.20	0.12	6.89-11.00
conductivity	1993.38	295.54	187.00-32637.00
alkalinity	273.82	34.75	26.00-968.00

Potamogeton pusillus L. -- Small pondweed

Shallow, standing or slow moving water of lakes, ponds, marshes and streams, where water is fresh to brackish.
Newf. to N.W. Terr., s throughout most of U.S. and into Mex.

n=38	mean	$S\bar{x}$	range
pH	7.99	0.39	6.88-10.69
conductivity	929.97	127.56	108.00-3663.00
alkalinity	198.94	25.85	44.60-459.30

Potamogeton richardsonii (Benn) Rydb. -- Claspingleaf pondweed

Shallow to deep water of ponds, marshes, reservoirs and slow moving streams, where water is fresh to brackish.
Labr. to AK, s to PA, IN, IA, NE, CO, UT and CA.

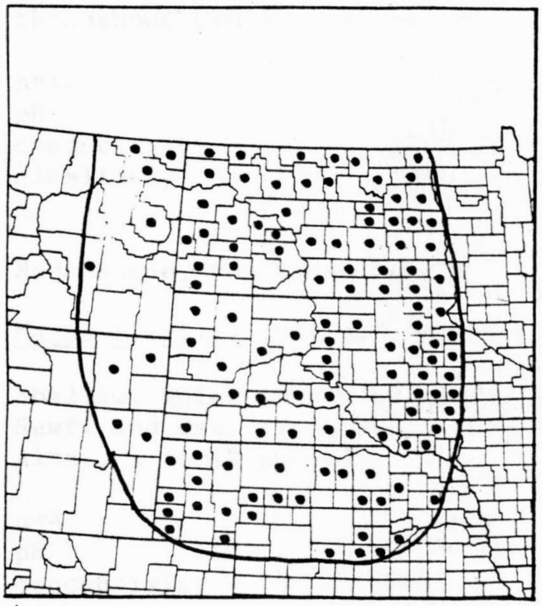
n=45	mean	$S\bar{x}$	range
pH	8.52	0.07	7.60-10.79
conductivity	824.65	94.46	179.00-2825.00
alkalinity	181.57	20.77	48.60-968.00

Potamogeton zosteriformis Fern.

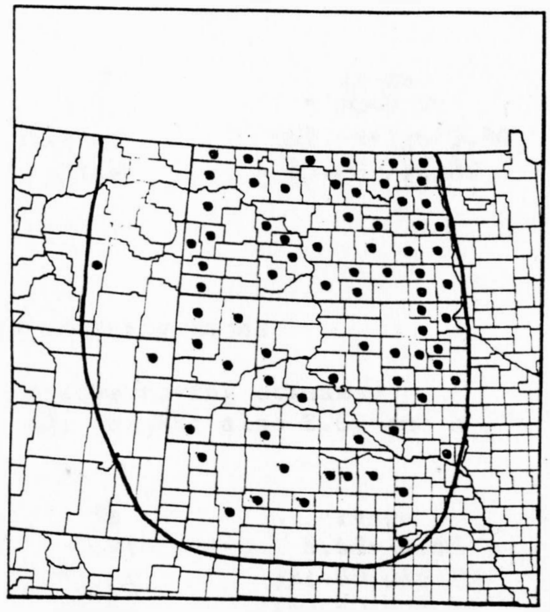
In slightly brackish, shallow to deep water of lakes, ponds and marshes. Que. and N.B. to B.C., s to VA, IN, IA, NE, MT, ID and n CA.

n=20	mean	$S\bar{x}$	range
pH	8.13	0.49	7.00-10.79
conductivity	511.54	82.67	214.00-1765.00
alkalinity	154.42	12.71	61.30-272.00

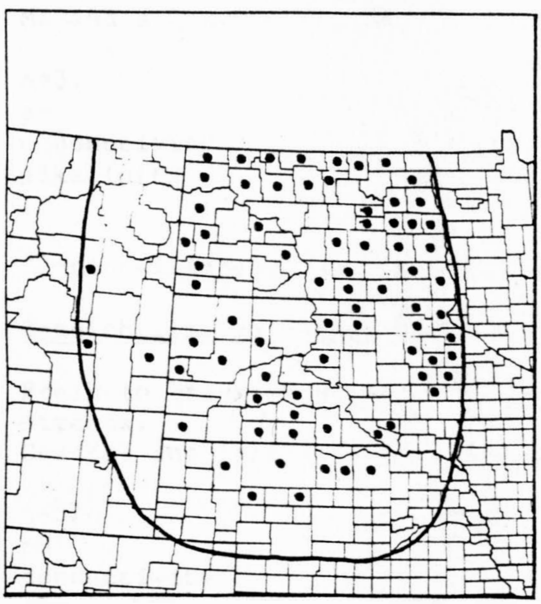
Potamogeton pectinatus L.



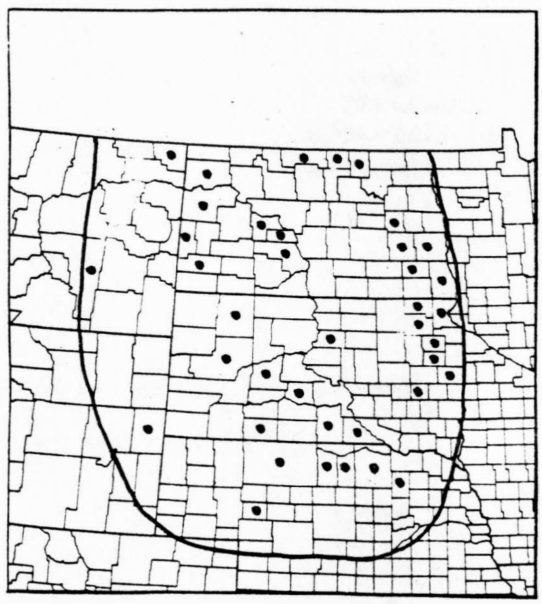
Potamogeton pusillus L.



Potamogeton richardsonii (Benn.) Rydb.



Potamogeton zosteriformis Fern.



Ruppiaceae, the Ditch-grass Family

Ruppia maritima L. -- Widgeon-grass

Brackish to saline waters of lakes, ponds and marshes.
Coastal marshes from N. Am. to S. Am. and in Europe, also inland throughout Canada and the U.S.

n=17	mean	$S_{\bar{x}}$	range
pH	8.79	0.03	8.30-9.79
conductivity	6853.13	2035.31	692.93-32673.00
alkalinity	1742.66	1418.32	80.00-752.00

Najadaceae, the Naiad Family

Najas flexilis (Willd.) Rostk. & Schmidt -- Shiny najas

Shallow, quiet waters of ponds, lakes and slow-moving streams.
Newf. and Que. to se Man., s to MD, IN, IA, and NE: also B.C. and n Alta., s to ID and CA.

n=4	mean	$S_{\bar{x}}$	range
pH	8.88	0.05	8.69-10.69
conductivity	461.45	81.82	331.00-685.79
alkalinity	170.12	20.58	140.60-228.60

Najas guadalupensis (Spreng.) Magnus -- Southern naiad

Shallow water of lakes, ponds and marshes.
MA and s Que. to MN, SD, WY and OR, s to Mex., C. and S. Am.

n=31	mean	$S_{\bar{x}}$	range
pH	8.39	0.11	7.69-11.00
conductivity	785.10	102.61	98.00-2103.60
alkalinity	160.73	18.56	46.00-603.30

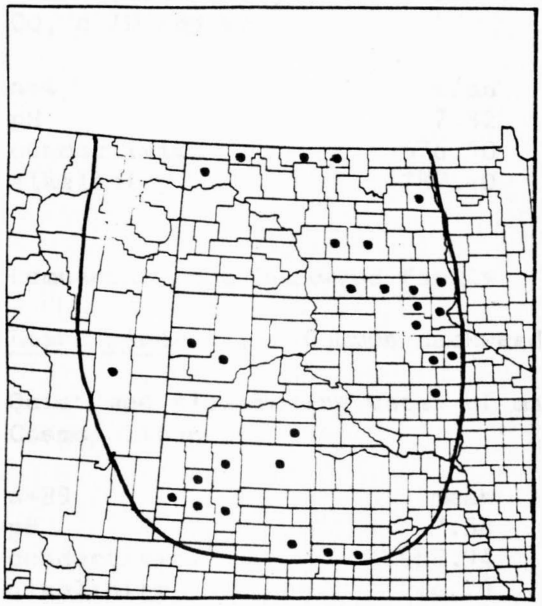
Zannichelliaceae, the Horned Pondweed Family

Zannichellia palustris L. -- Horned pondweed

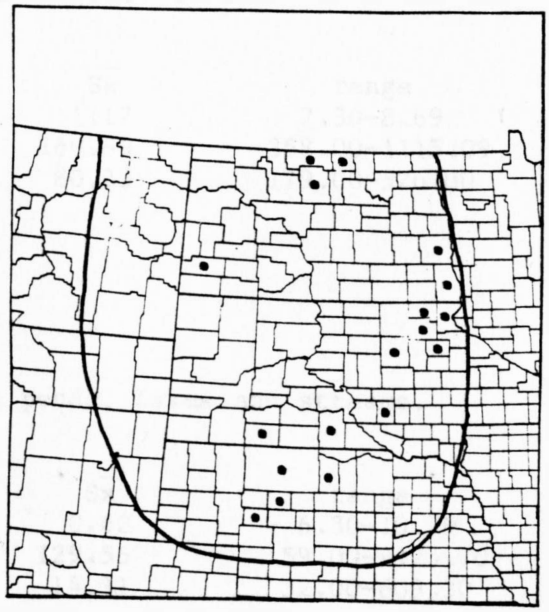
Fresh to brackish water of lakes, reservoirs, ponds, marshes and streams.
Coastal and inland N. Am.; also S. Am., Eurasia and Africa.

n=37	mean	$S_{\bar{x}}$	range
pH	8.01	0.29	7.10-11.00
conductivity	1782.52	347.11	108.00-12000.00
alkalinity	226.09	22.87	48.60-486.60

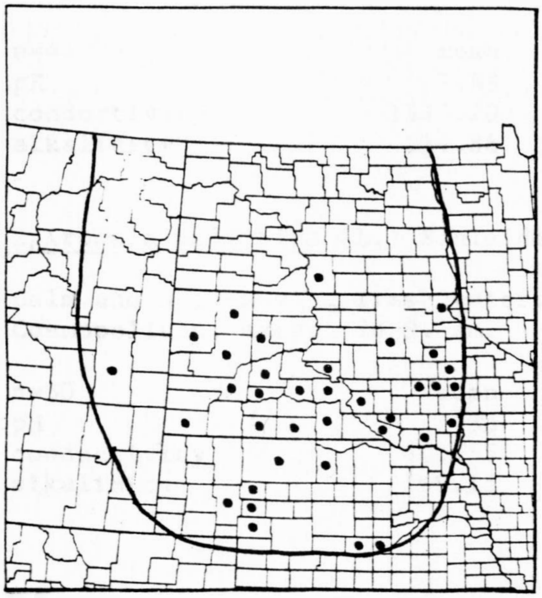
Ruppia maritima L.



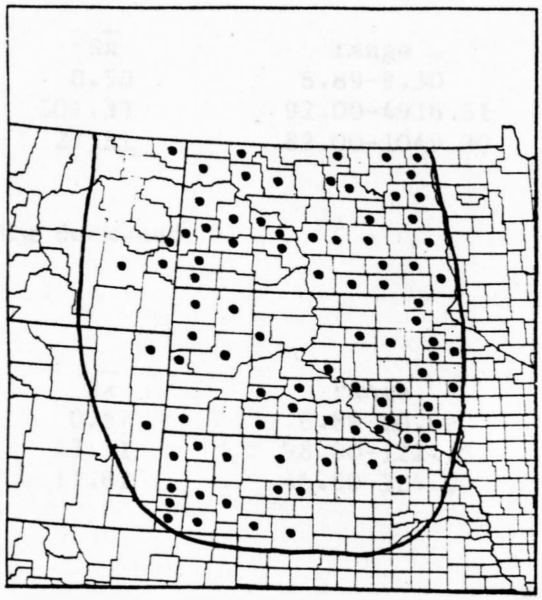
Najas flexilis (Willd.) R. & S.



Najas guadalupensis (Spreng.) Magnus



Zannichellia palustris L.



Araceae, the Arum Family

Acorus calamus L. -- Sweet flag

Bogs, swamps, marshes and slow-moving streams.
Intro. from Europe, in N. Am. from N.S. and Que. to Alta. s to FL, TX, CO, n ID and WA.

n=4	mean	$S_{\bar{x}}$	range
pH	7.82	1.17	7.30-8.69
conductivity	676.50	160.89	358.00-1115.09
alkalinity	287.40	80.23	179.00-526.00

Lemnaceae, the Duckweed Family

Lemna minor L. -- Common duckweed

Quiet and slow-moving water of marshes, ponds, lakes and streams.
Cosmopolitan.

n=89	mean	$S_{\bar{x}}$	range
pH	7.58	0.62	6.30-10.79
conductivity	988.94	129.56	59.00-9125.70
alkalinity	214.19	14.31	32.00-609.30

Lemna trisulca L. -- Star duckweed

Lakes, ponds and marshes.
Temperate zones of the N. Hemisphere.

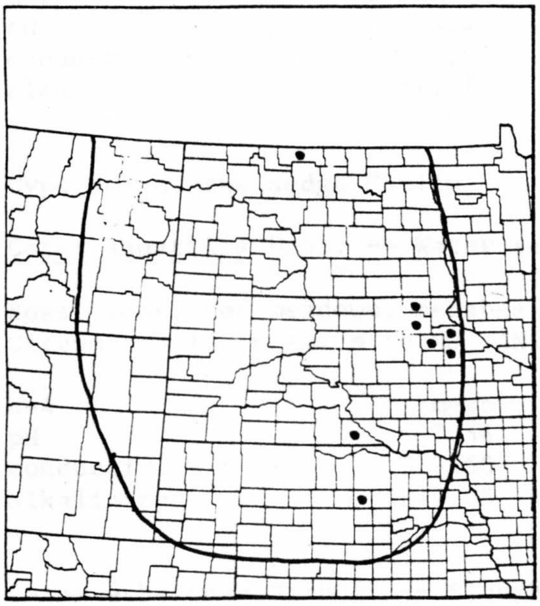
n=44	mean	$S_{\bar{x}}$	range
pH	7.53	0.50	6.89-9.30
conductivity	1387.70	301.33	92.00-4916.51
alkalinity	254.86	27.51	82.00-1049.30

Spirodela polyrhiza (L.) Schleiden -- Big duckweed

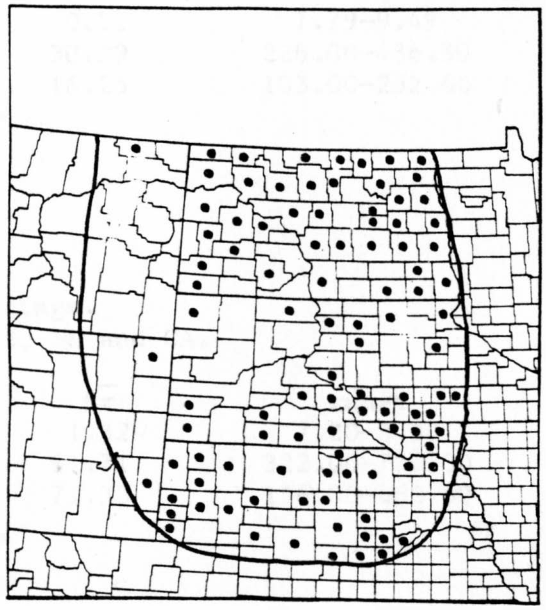
Calm and slow-moving fresh water.
Cosmopolitan, except in S. Am.

n=30	mean	$S_{\bar{x}}$	range
pH	7.83	0.57	6.89-10.69
conductivity	400.55	43.21	98.00-1224.52
alkalinity	169.15	11.82	46.00-324.00

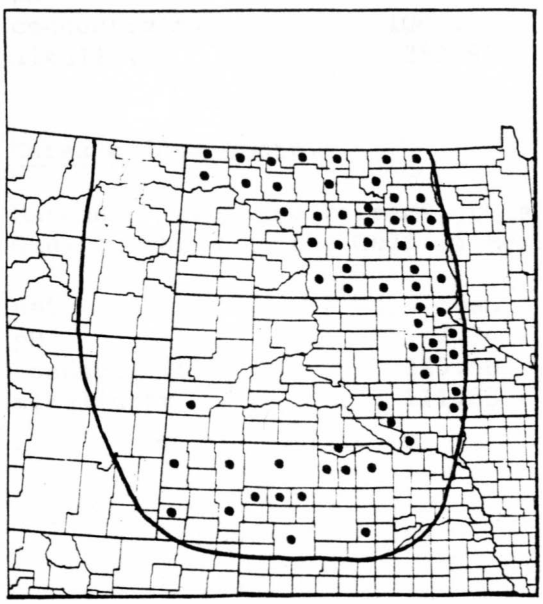
Acorus calamus L.



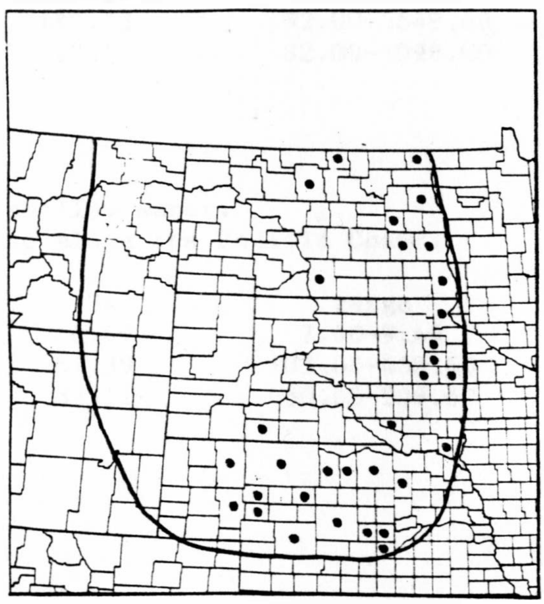
Lemna minor L.



Lemna trisulca L.



Spirodela polyrhiza (L.) Schleiden



Wolffia columbiana Karst. -- Water-meal

In fresh, quiet waters of ponds and marshes.
MA to e ND, s to n S. Am.

n=7	mean	$S\bar{x}$	range
pH	8.43	0.21	7.79-9.49
conductivity	363.55	30.29	226.00-486.30
alkalinity	171.78	16.25	103.00-232.60

Cyperaceae, the Sedge Family

Carex aquatilis Wahl. -- Water sedge

Bogs, fens, wet meadows, marshes and springs.
Circumboreal, in Am. s to NJ, IN, IA, KS, NM and CA.

n=4	mean	$S\bar{x}$	range
pH	7.56	1.32	7.20-8.30
conductivity	539.50	91.71	322.00-770.00
alkalinity	249.65	71.33	156.00-460.00

Carex atherodes Spreng. -- Slough sedge

Wet meadows and shallow water of marshes, streams and ponds.
Circumboreal, in Am. s to NY, MO, NE, CO, UT and OR.

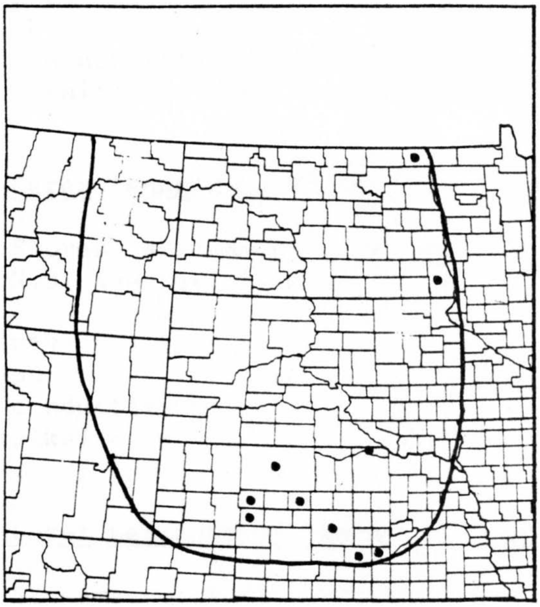
n=55	mean	$S\bar{x}$	range
pH	7.71	0.39	6.89-10.69
conductivity	1001.30	137.73	92.00-5649.60
alkalinity	252.95	22.17	82.00-1098.00

Carex comosa Boott.

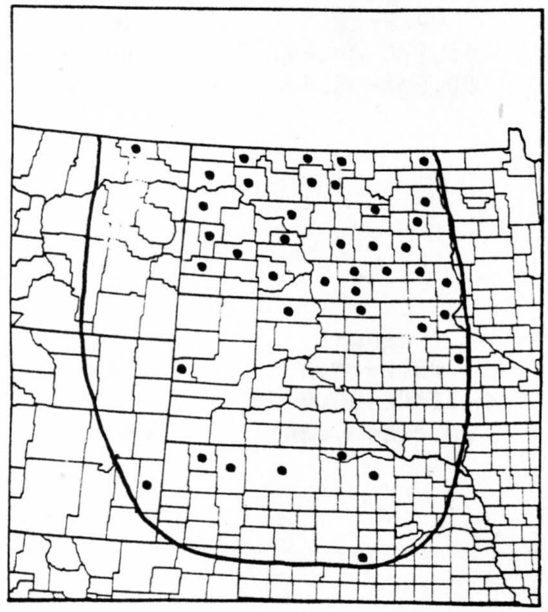
Marshes, lakes and streams, usually in shallow water.
Que. to MN, s to the Gulf of Mexico; also along the Pacific Coast.

n=5	mean	$S\bar{x}$	range
pH	7.94	0.49	7.60-9.49
conductivity	220.58	61.39	103.00-408.60
alkalinity	111.88	32.11	50.00-208.60

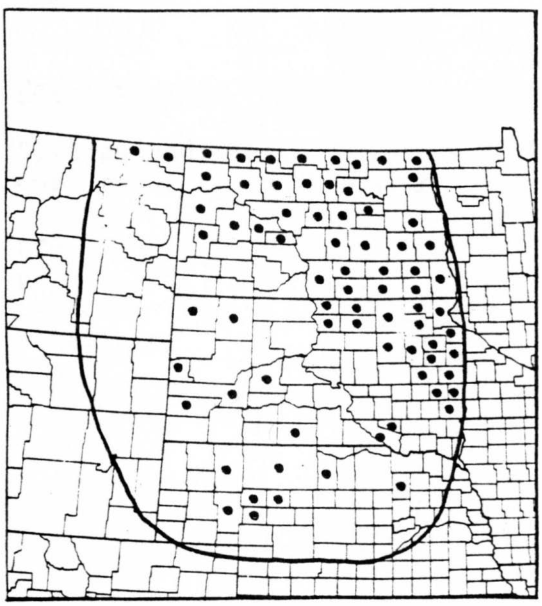
Wolffia columbiana Karst.



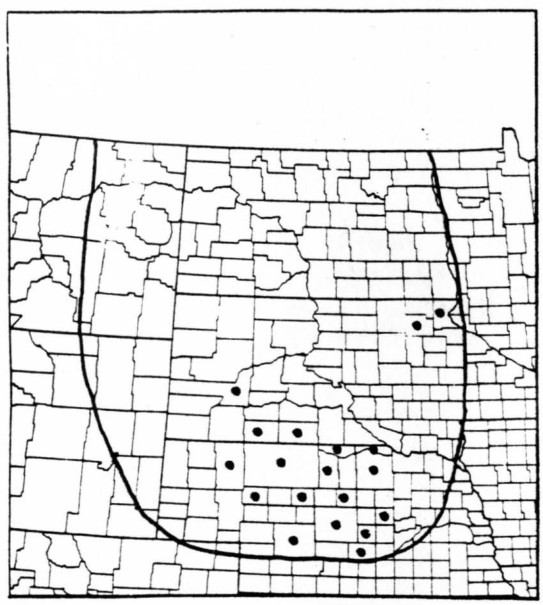
Carex aquatilis Wahl.



Carex atherodes Spreng.



Carex comosa Boott.



Carex lacustris Willd.

Springs and shallow water of swamps and marshes.
Que. to Sask., s to FL and TX.

n=10	mean	$S\bar{x}$	range
pH	7.95	0.60	7.20-9.49
conductivity	379.51	73.54	103.00-783.60
alkalinity	196.53	40.34	60.60-460.00

Carex lanuginosa Michx. -- Woolly sedge

Shores, streambanks, wet meadows, marshes and springs.
N.B. and Que. to B.C., s to VA, TN, AR, TX and CA.

n=66	mean	$S\bar{x}$	range
pH	7.72	0.38	6.89-9.69
conductivity	1244.53	490.14	98.00-32637.00
alkalinity	235.43	18.96	46.00-856.00

Carex nebraskensis Dewey -- Nebraska sedge

Streams, springs, wet meadows and marshes.
ND to B. SC., s to KS, NM and CA.

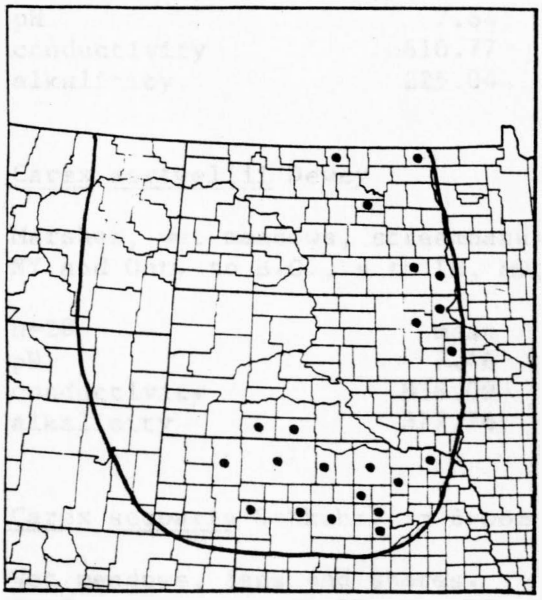
n=22	mean	$S\bar{x}$	range
pH	8.28	0.15	7.60-9.69
conductivity	1024.00	398.59	98.00-8644.00
alkalinity	440.54	171.94	46.00-3753.30

Carex prarisa Dewey

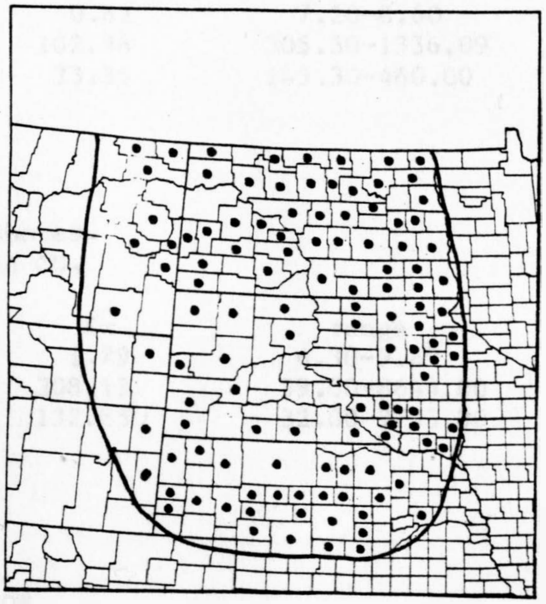
Springs and fens.
Que. to Sask., s to NJ, OH, IA and NE.

n=4	mean	$S\bar{x}$	range
pH	7.98	0.44	7.69-8.69
conductivity	517.15	263.42	161.30-1283.00
alkalinity	244.60	116.93	73.60-575.30

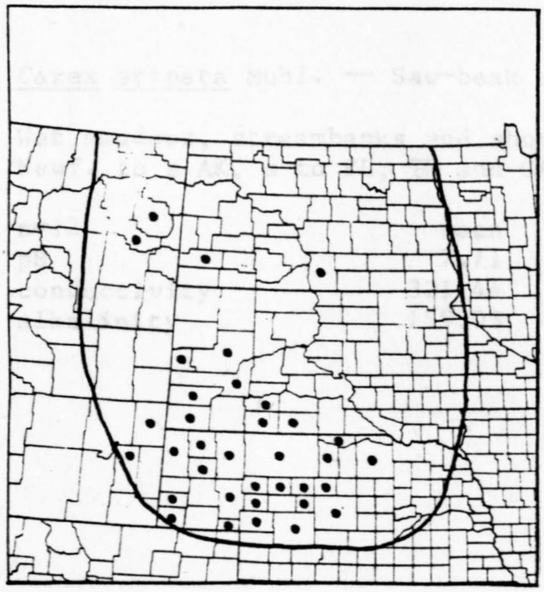
Carex lacustris Willd.



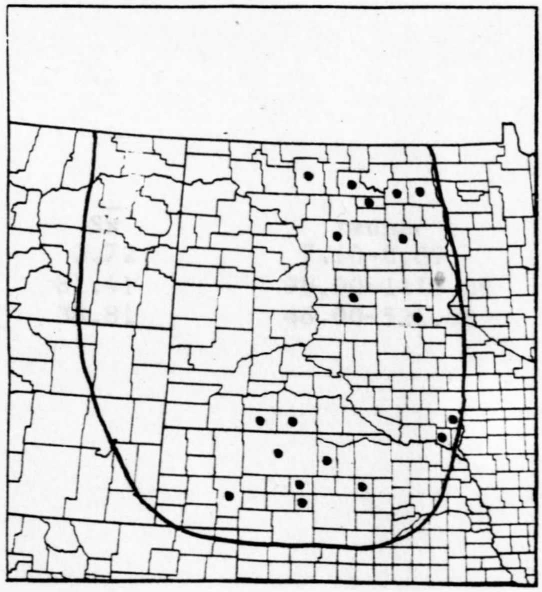
Carex lanuginosa Michx.



Carex nebraskensis Dewey



Carex prarisa Dewey



Carex rostrata Stokes

Marshes, wet meadows, bogs, springs and shores.
Circumboreal, in Am. s to DE, MD, IN, IA, NE, NM and CA.

n=9	mean	$S\bar{x}$	range
pH	7.64	0.82	7.20-8.60
conductivity	610.77	102.38	305.30-1336.09
alkalinity	225.04	33.36	145.30-460.00

Carex sartwellii Dewey

Marshes, wet meadows, streambanks and shores.
NY and Ont. to B.C., s to IN, MO, NE and CO.

n=28	mean	$S\bar{x}$	range
pH	7.46	1.79	6.30-9.69
conductivity	838.09	308.13	59.00-8644.00
alkalinity	377.76	132.85	32.00-3753.30

Carex scoparia Schkuhr. -- Broom sedge

Wet meadows, fens and shores.
Newf. to B.C., s to FL, AR, KS, NM and OR.

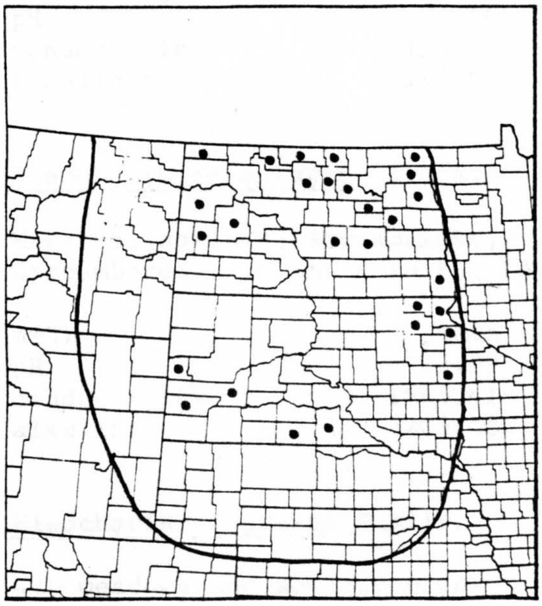
n=8	mean	$S\bar{x}$	range
pH	7.85	0.95	7.10-8.89
conductivity	371.36	146.00	98.00-1221.00
alkalinity	171.97	67.34	46.00-560.00

Carex stipata Muhl. -- Saw-beak sedge

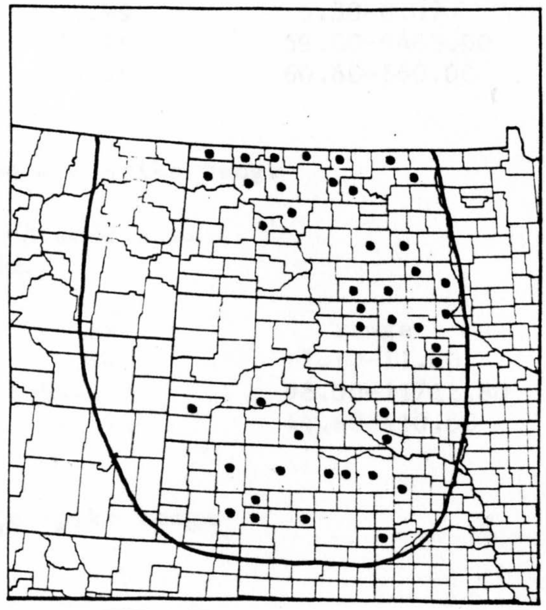
Wet meadows, streambanks and shores.
Newf. to s AK, s to FL, TX and CA.

n=12	mean	$S\bar{x}$	range
pH	7.71	0.72	7.10-8.89
conductivity	321.44	81.41	98.00-1115.09
alkalinity	155.03	38.81	46.00-526.00

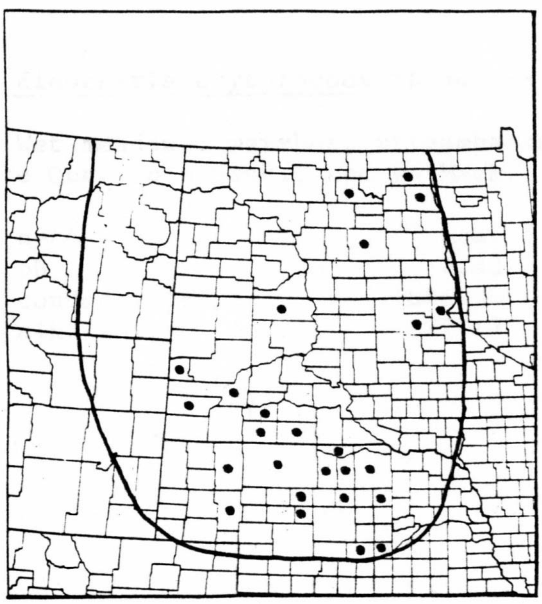
Carex rostrata Stokes



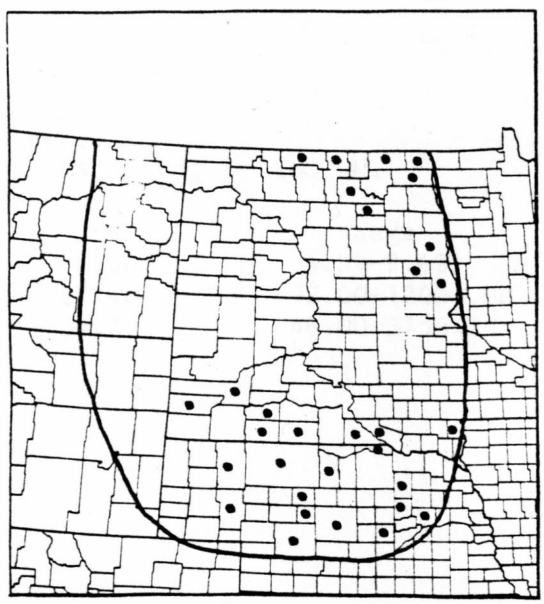
Carex sartwellii Dewey



Carex scoparia Schkuhr.



Carex stipata Muhl.



Carex stricta Lam.

Marshes, wet meadows, fens, springs, streambanks and shores.
Newf. to Man., s to FL, TX and CO.

n=25	mean	$S_{\bar{x}}$	range
pH	7.44	1.99	6.30-8.89
conductivity	938.13	371.76	59.00-9463.00
alkalinity	203.92	24.78	60.60-560.00

Eleocharis acicularis (L.) R. & S. -- Needle spike sedge

Marshes, springs, streambanks, shores and mudflats.
Circumboreal, in Am. s to FL, LA and Mex.

n=21	mean	$S_{\bar{x}}$	range
pH	7.99	0.43	7.10-11.00
conductivity	1545.41	544.22	98.00-11712.80
alkalinity	205.58	42.92	44.60-410.60

Eleocharis compressa Sulliv. -- Flatstem spike sedge

Wet meadows and seepage areas.
Que. to NY to Sask., s to VA, GA, AL, MO, TX and CO.

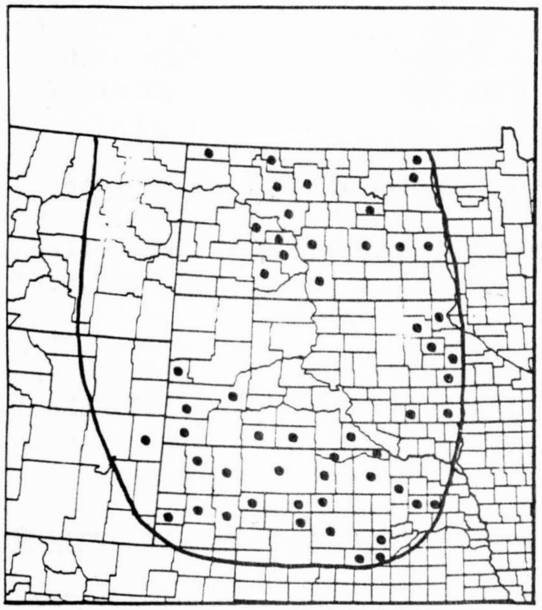
n=5	mean	$S_{\bar{x}}$	range
pH	8.13	0.26	7.79-8.79
conductivity	441.73	124.06	103.00-1221.00
alkalinity	285.04	84.25	60.60-560.00

Eleocharis erythropoda Steud. -- Spikerush

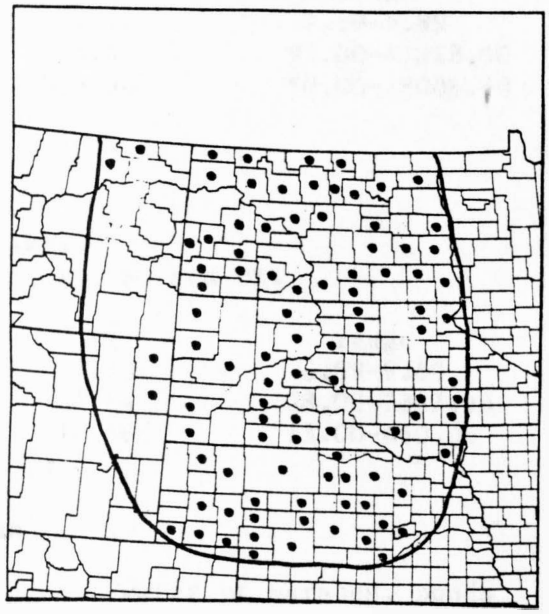
Wet meadows, marshes, streambanks and shores.
e Que. to n Sask., and sw Mack., s to VA, TN, n TX, CO and NM.

n=64	mean	$S_{\bar{x}}$	range
pH	7.83	0.30	6.89-9.69
conductivity	1686.90	280.46	92.00-12000.00
alkalinity	272.68	57.79	46.00-3753.30

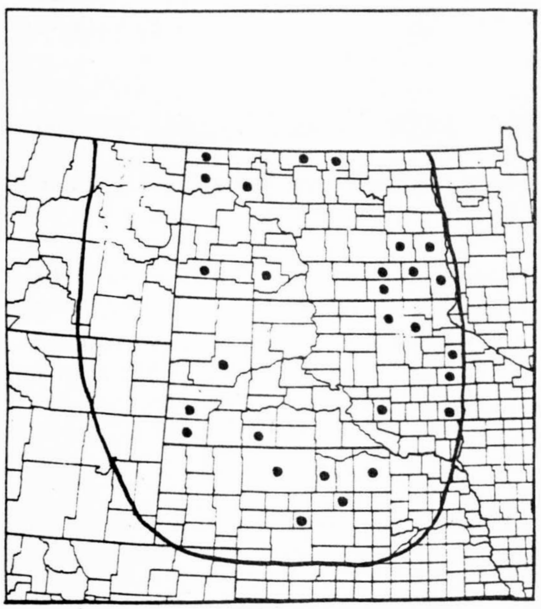
Carex stricta Lam.



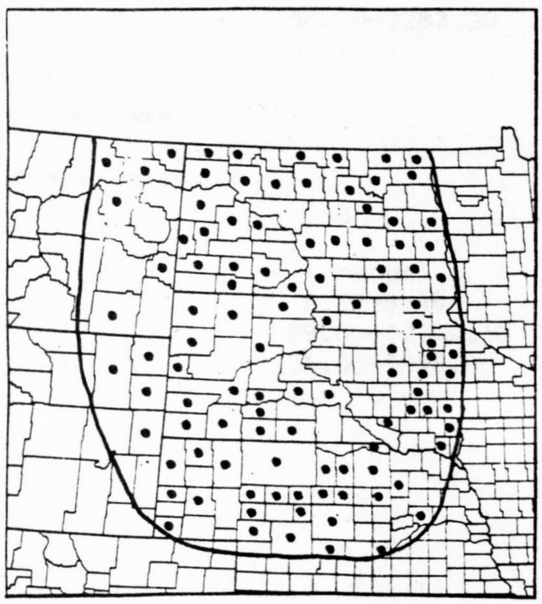
Eleocharis acicularis (L.) R. & S.



Eleocharis compressa Sulliv.



Eleocharis erythropoda Steud.



Eleocharis macrostachya Britt. -- Spikerush

Wet meadows, shallow marshes, streambanks and shores.
IL to AK, s to MO, TX, CA and into Mex.

n=51	mean	$S\bar{x}$	range
pH	8.30	0.12	7.39-9.89
conductivity	1848.32	806.44	92.00-41028.00
alkalinity	658.28	355.36	50.00-18006.60

Eleocharis smallii Britt. -- Spikerush

Shallow water of marshes, streams and lakes.
Labr. and Newf. to Man., s to DE, VA, TN, AL, MO and OK.

n=29	mean	$S\bar{x}$	range
pH	7.70	0.62	6.89-9.60
conductivity	738.15	104.64	108.00-2347.30
alkalinity	165.51	16.86	13.00-460.00

Scirpus acutus Muhl. -- Hardstem bulrush

Emergent in shallow to deep, usually brackish water of marshes, ponds and lakes.
N.S. to B.C., s to NC, TX and CA.

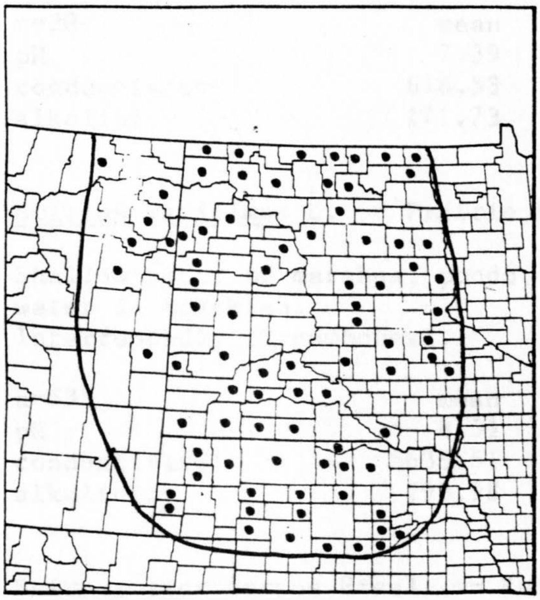
n=137	mean	$S\bar{x}$	range
pH	7.99	0.15	7.00-10.69
conductivity	2590.04	536.23	103.00-37002.00
alkalinity	308.63	23.78	50.00-2282.00

Scirpus fluviatilis (Torr.) Gray -- River bulrush

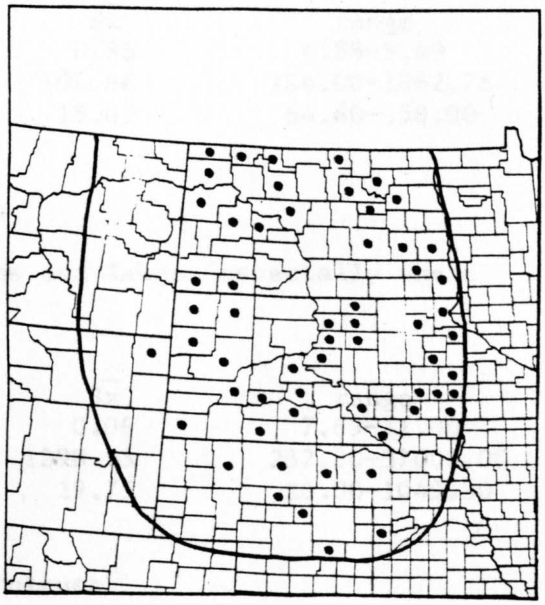
Shallow water of marshes, ponds, streams and lakes.
Que. to WA, s to VA, MO, KS and CA.

n=102	mean	$S\bar{x}$	range
pH	7.71	0.53	6.30-9.49
conductivity	1278.55	159.34	59.00-12364.30
alkalinity	252.29	17.98	94.00-1098.00

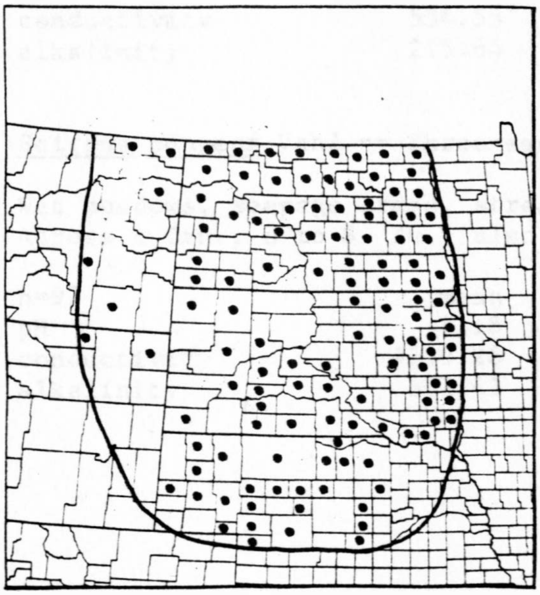
Eleocharis macrostachya Britt.



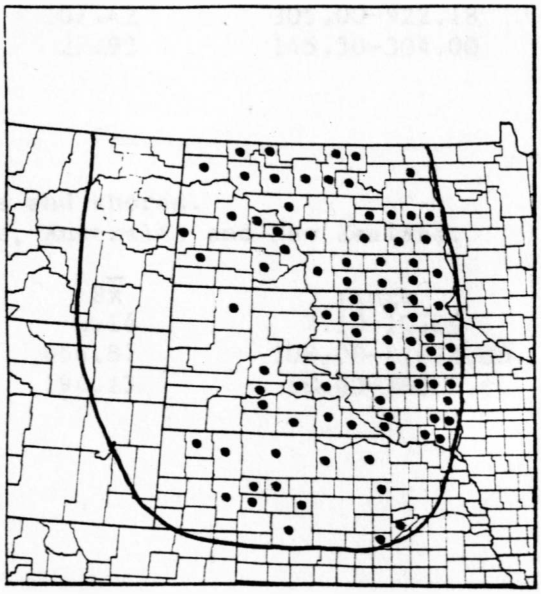
Eleocharis smallii Britt.



Scirpus acutus Muhl.



Scirpus fluviatilis (Torr.) Gray



Scirpus heterochaetus Chase -- Slender bulrush

Emergent in shallow to deep, usually fresh water of marshes, ponds and lakes.
Que. and MA to ND, s to VA, MO, n TX and into WA and CA.

n=20	mean	$S\bar{x}$	range
pH	7.39	0.96	6.88-9.49
conductivity	618.53	107.88	186.00-1862.78
alkalinity	171.73	15.65	64.60-358.00

Scirpus maritimus L. -- Prairie bulrush

Shallow water of marshes, ponds, streams and lakes, especially where water is brackish.
Interruptedly circumboreal.

n=53	mean	$S\bar{x}$	range
pH	8.51	0.06	7.69-11.00
conductivity	5636.61	1298.13	232.30-37002.00
alkalinity	293.98	29.75	26.00-1049.30

Scirpus microcarpus Presl. -- Redstem bulrush

In fresh water of marshes, wet meadows, springs and streambanks.
Newf. to B.C., s to WV, n IL, IA, NE, NM and CA.

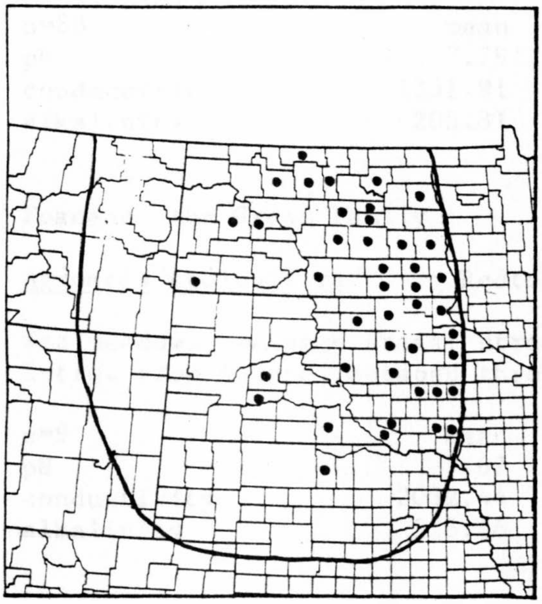
n=5	mean	$S\bar{x}$	range
pH	7.94	0.35	7.69-8.49
conductivity	534.55	107.42	305.00-922.18
alkalinity	215.64	27.93	145.30-304.00

Scirpus pungens Vahl -- Three-square

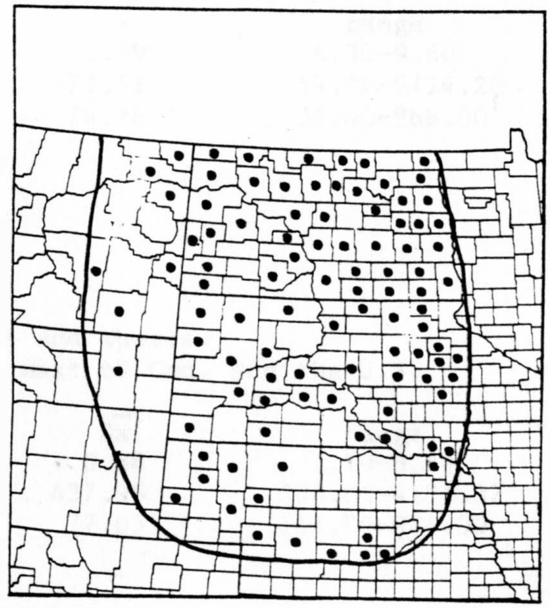
Wet meadows, seepage areas, streambanks and shores.
Across s Can., s to S. Am.; also Europe, Australia and New Zealand.

n=97	mean	$S\bar{x}$	range
pH	8.18	0.14	7.10-10.69
conductivity	4539.28	856.87	108.00-41028.00
alkalinity	631.43	194.13	50.00-18006.60

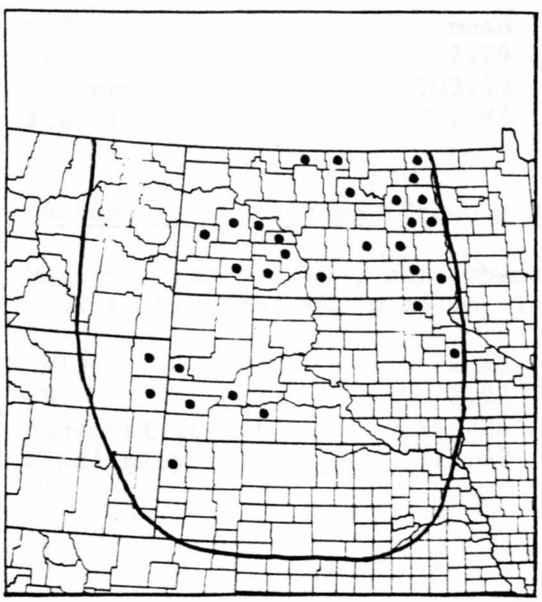
Scirpus heterochaetus Chase



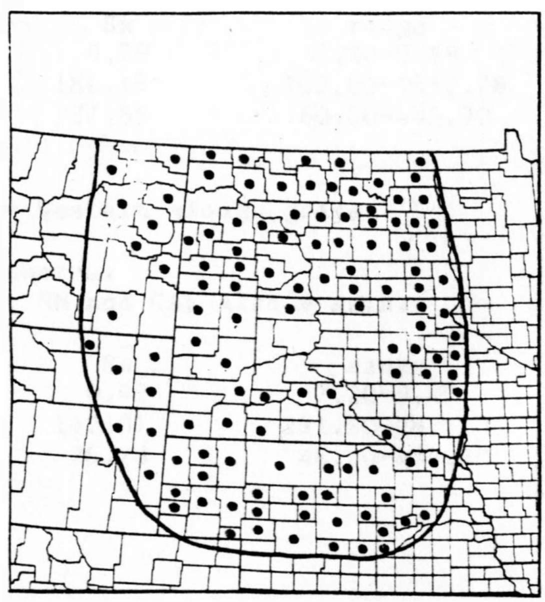
Scirpus maritimus L.



Scirpus microcarpus Presl.



Scirpus pungens Vahl



Scirpus validus Vahl -- Softstem bulrush

Emergent in shallow to deep, usually fresh water of marshes, ponds and lakes.
Newf. to s AK, s to S. Am.

n=88	mean	$S_{\bar{x}}$	range
pH	7.79	0.59	6.30-9.60
conductivity	1351.91	179.51	59.00-6724.20
alkalinity	205.81	14.78	32.00-968.00

Poaceae, the Grass Family

Agrostis stolonifera L. -- Redtop

Wet meadows, seepage areas, streambanks and shores.
Intro. from Europe, escaped throughout most of Can. and the U.S.

n=9	mean	$S_{\bar{x}}$	range
pH	7.67	0.88	7.10-8.89
conductivity	2032.44	437.95	398.00-4184.87
alkalinity	316.16	77.05	161.00-884.00

Alopecurus aequalis Sobol. -- Short-awn foxtail

Wet meadows and shallow water of marshes, springs, streambanks and shores.
Circumboreal, in Am. s to NJ, PA, OH, IL, MO, KS, NM and CA.

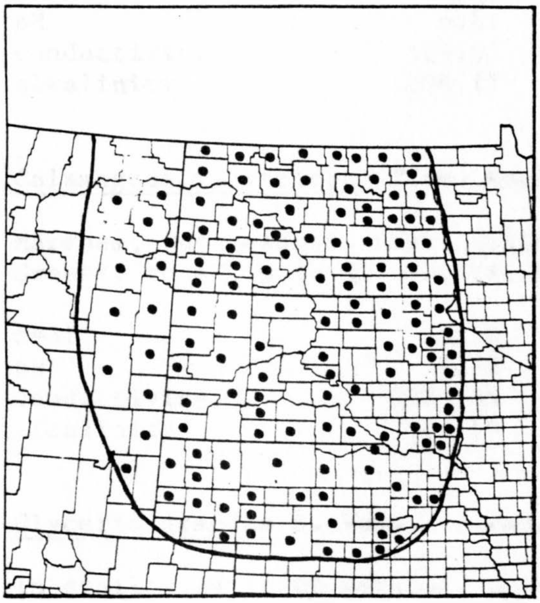
n=9	mean	$S_{\bar{x}}$	range
pH	7.79	0.79	7.20-9.49
conductivity	903.39	186.14	103.00-1862.78
alkalinity	222.85	37.85	60.00-445.30

Beckmannia syzigachne (Steud.) Fern. -- Western slough grass

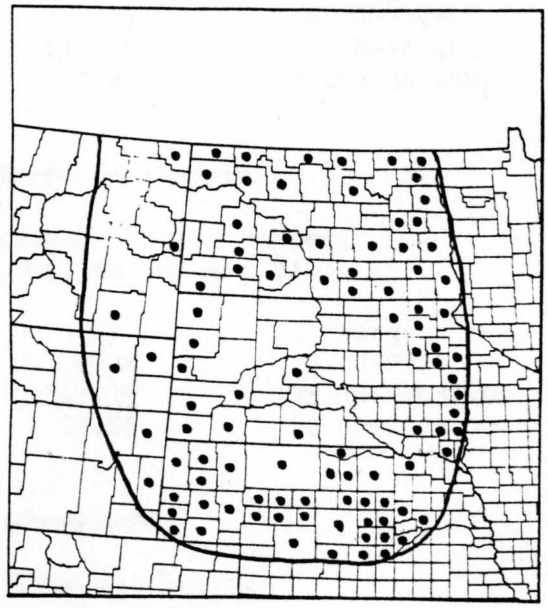
Marshes, wet meadows, streambanks and shores.
w NY to Man. and AK, s to OH, IA, n KS, NM and CA; also e Asia.

n=19	mean	$S_{\bar{x}}$	range
pH	7.98	0.42	7.20-9.49
conductivity	995.86	162.07	291.60-2825.00
alkalinity	217.99	26.18	48.00-459.30

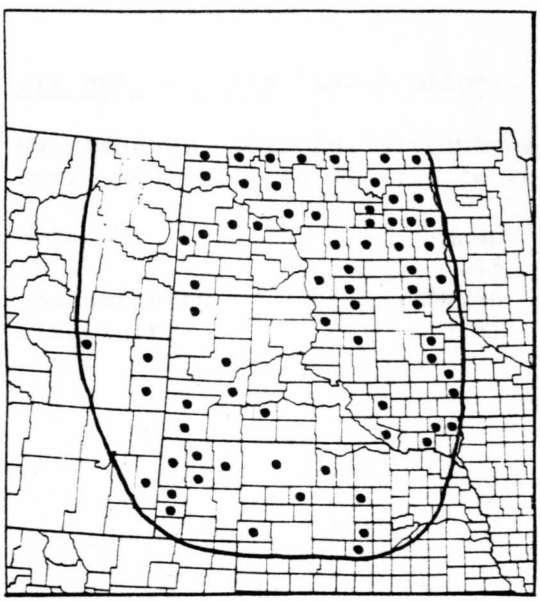
Scirpus validus Vahl



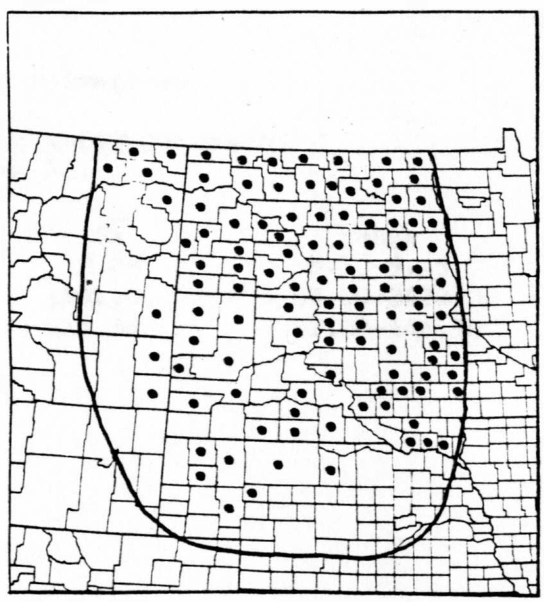
Agrostis stolonifera L.



Alopecurus aequalis Sobol.



Beckmannia syzigachne (Steud.) Fern.



<u>Calamagrostis</u> <u>canadensis</u> (Michx.) Beauv. -- Bluejoint reedgrass

Bogs, wet meadows, springs, streambanks and shores.
Greenl. to AK, s to NJ, WV, NC, KS, NM and CA.

n=4	mean	$S\bar{x}$	range
pH	6.81	1.51	6.30-7.69
conductivity	529.50	110.58	59.00-740.01
alkalinity	208.57	78.84	32.00-361.30

<u>Calamagrostis</u> <u>stricta</u> (Timm) Koel. -- Northern reedgrass

Marshes, wet meadows, bogs, springs, streambanks and shores.
Greenl. to AK, s to NY, PA, VA, OH, MO, KS, NM, AZ and CA.

n=31	mean	$S\bar{x}$	range
pH	7.78	0.38	7.10-9.79
conductivity	3381.49	1212.20	108.00-32637.00
alkalinity	306.45	43.58	50.00-1098.00

<u>Glyceria</u> <u>grandis</u> S. Wats. -- American mannagrass

In shallow water of marshes, ponds, streams and lakes.
Que. and N.S. to AK, s to VA, TN, LA, NE, NM, AZ and WA.

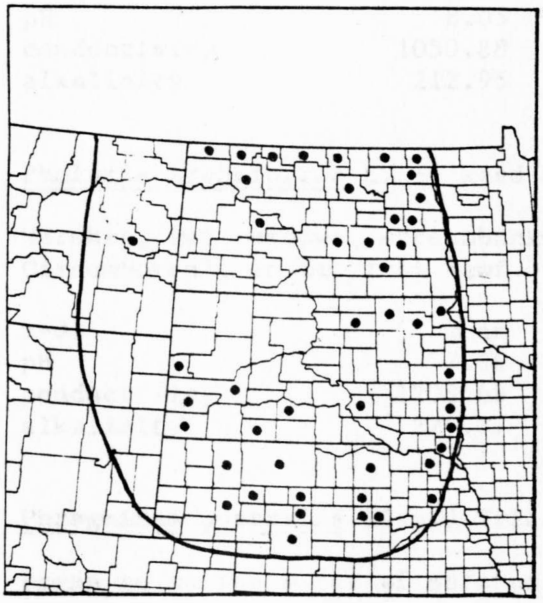
n=24	mean	$S\bar{x}$	range
pH	7.36	2.04	6.30-9.49
conductivity	839.92	143.00	59.00-3420.00
alkalinity	249.25	25.83	32.00-526.00

<u>Glyceria</u> <u>striata</u> (Lam.) Hitchc. -- Fowl mannagrass

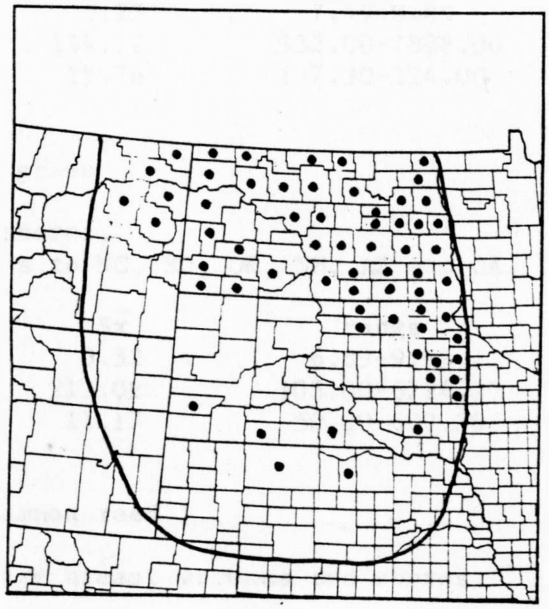
Wet meadows, springs, streambanks, where water is fresh.
Newf. and Labr. to B.C., s to FL, TX and CA.

n=24	mean	$S\bar{x}$	range
pH	7.45	2.05	6.30-9.49
conductivity	789.46	160.10	59.00-3420.00
alkalinity	243.85	122.54	32.00-445.30

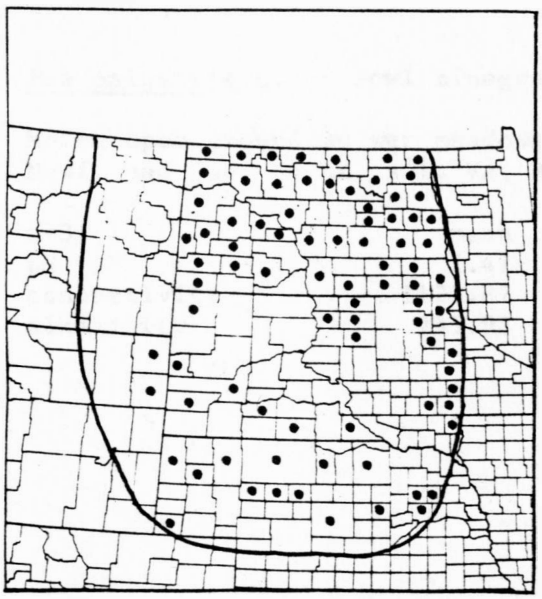
Calamagrostis canadensis (Michx.) Beuv.



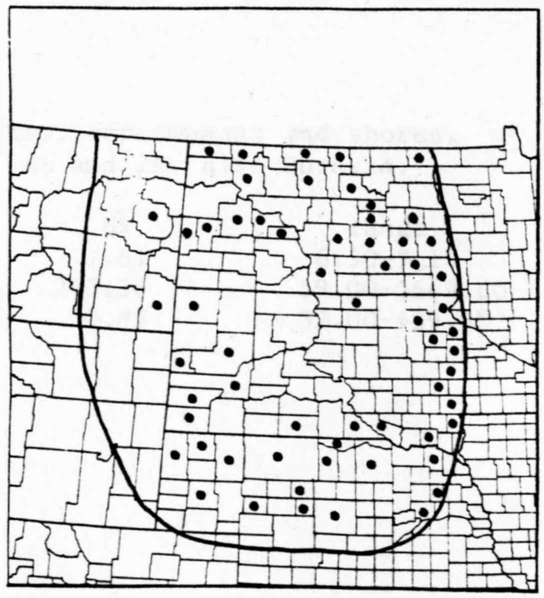
Calamagrostis stricta (Timm) Koel.



Glyceria grandis S. Wats.



Glyceria striata (Lam.) Hitchc.



Leersia oryzoides (L.) Sw. -- Rice cutgrass

Streambanks and shores.
Que. and N.S. to B.C., s to FL, TX and CA.

n=14	mean	$S\bar{x}$	range
pH	8.05	0.23	7.49-8.89
conductivity	1050.88	134.72	332.00-1888.00
alkalinity	212.95	15.76	137.30-324.00

Phalaris arundinacea L. -- Reed canary grass

Marshes, wet meadows, streambanks and shores.
Circumboreal, in Am. from Newf. to AK, s to NC, MO, OK, NM, AZ and CA.

n=81	mean	$S\bar{x}$	range
pH	7.66	0.32	6.89-9.69
conductivity	1208.69	213.02	103.00-6724.20
alkalinity	224.87	11.17	50.00-609.30

Phragmites australis (Cav.) Trin. -- Common reed

Fresh to saline water of marshes, seepage areas, streams and shores.
Nearly cosmopolitan.

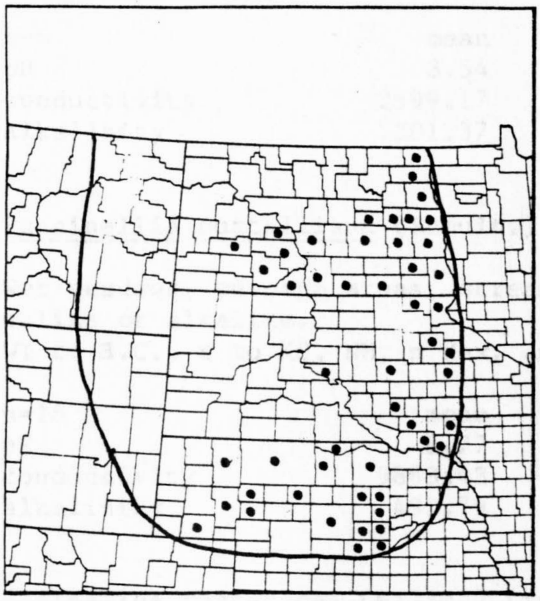
n=65	mean	$S\bar{x}$	range
pH	8.00	0.19	7.00-9.89
conductivity	3240.74	658.03	92.00-32637.00
alkalinity	307.40	28.61	50.00-1196.60

Poa palustris L. -- Fowl bluegrass

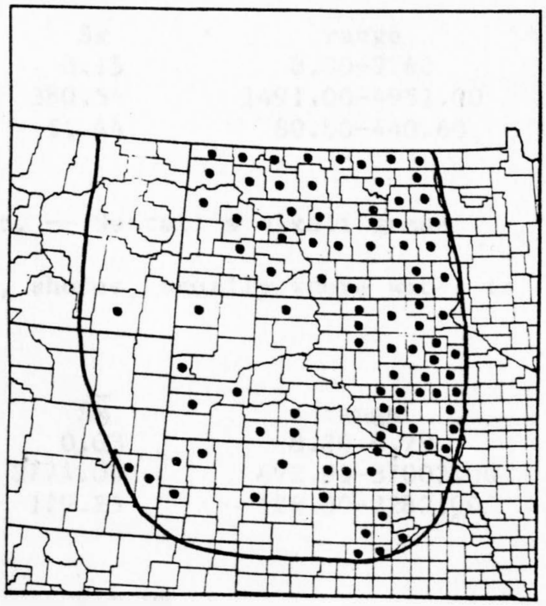
Moist open ground or wet meadows, marshes, streambanks and shores.
Newf. and Que. to AK, s to VA, MO, NE, NM and CA; also Eurasia.

n=31	mean	$S\bar{x}$	range
pH	7.47	1.61	6.30-9.10
conductivity	1123.82	243.36	59.00-5649.60
alkalinity	235.95	20.82	32.00-459.30

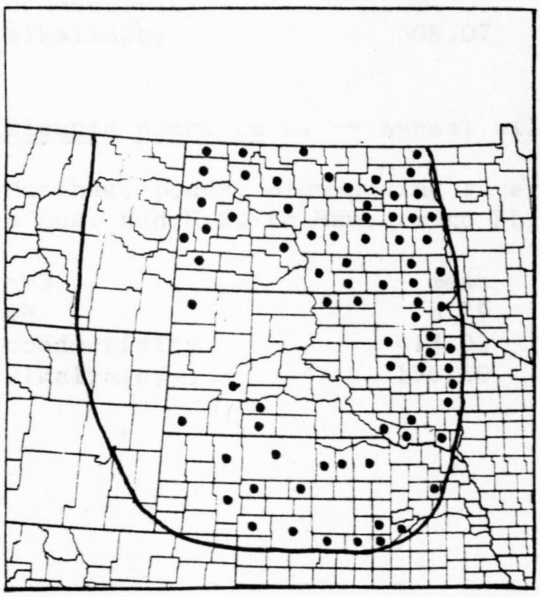
Leersia oryzoides (L.) Sw.



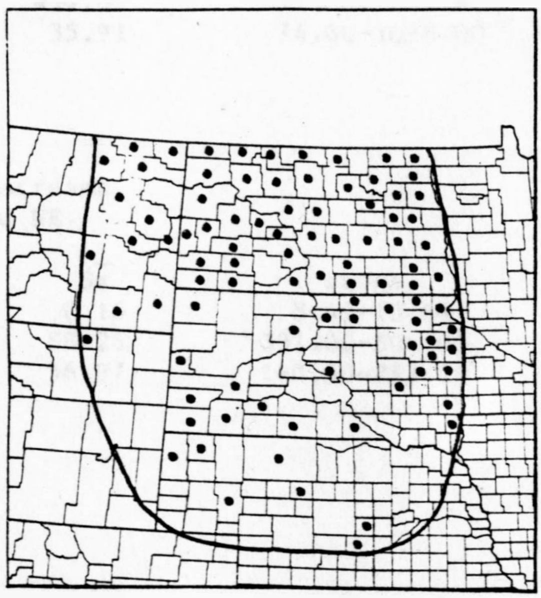
Phalaris arundinacea L.



Phragmites australis (Cav.) Trin.



Poa palustris L.



Polypogon monspeliensis (L.) Desf. -- Rabbitfoot

Springs, streambanks and shores.
Intro. from Europe, from N.B. to AK, s to GA, OK, TX and CA; also C. and S. Am.

n=6	mean	$S\bar{x}$	range
pH	8.54	0.15	8.00-9.60
conductivity	2699.17	380.54	1491.00-4951.00
alkalinity	201.37	51.44	80.00-440.60

Puccinellia nuttalliana (Schult.) Hitchc. -- Nuttall's alkali grass

Wet meadows, seepage areas, streambanks, shores, usually where water is saline or alkaline.
WI to B.C., s to KS, NM, n Mex. and CA.

n=16	mean	$S\bar{x}$	range
pH	8.77	0.03	8.30-9.79
conductivity	9868.43	2774.04	692.93-37002.00
alkalinity	493.79	129.25	126.00-2282.00

Scolochloa festucacea (Willd.) Link -- Sprangletop

Fresh to brackish shallow water of marshes, ponds and lakes.

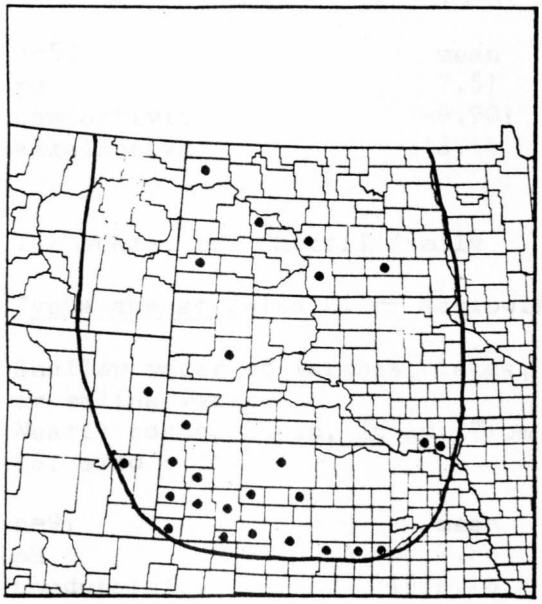
n=35	mean	$S\bar{x}$	range
pH	7.66	0.42	7.00-9.60
conductivity	1884.39	434.62	92.00-5649.60
alkalinity	308.07	35.91	74.60-1098.00

Zizania aquatica L. -- Annual wildrice

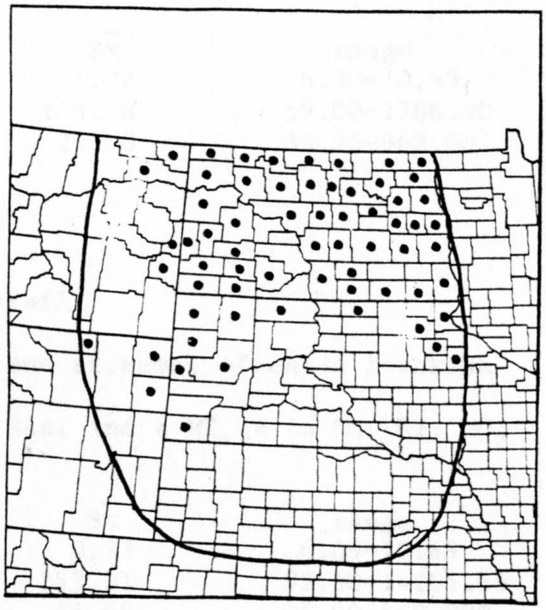
Marshes, ponds, slow-moving rivers and streams.
e Que. and N.S. to Man., s to FL, LA and NE.

n=3	mean	$S\bar{x}$	range
pH	8.79	0.16	8.49-10.69
conductivity	418.00	88.26	331.00-506.00
alkalinity	196.80	56.37	140.60-253.00

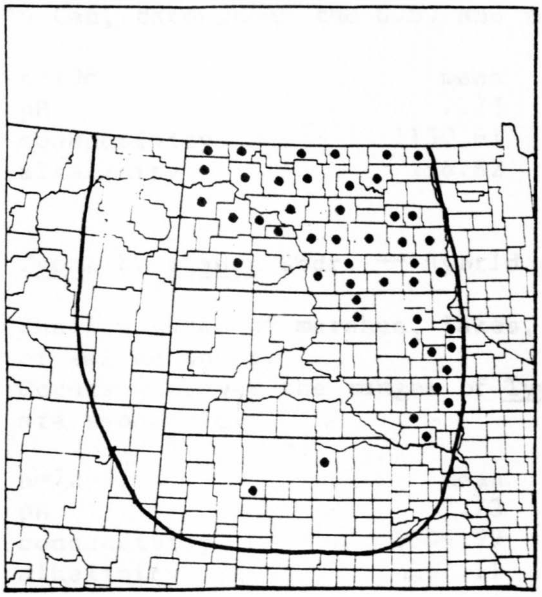
Polypogon monspeliensis (L.) Desf.



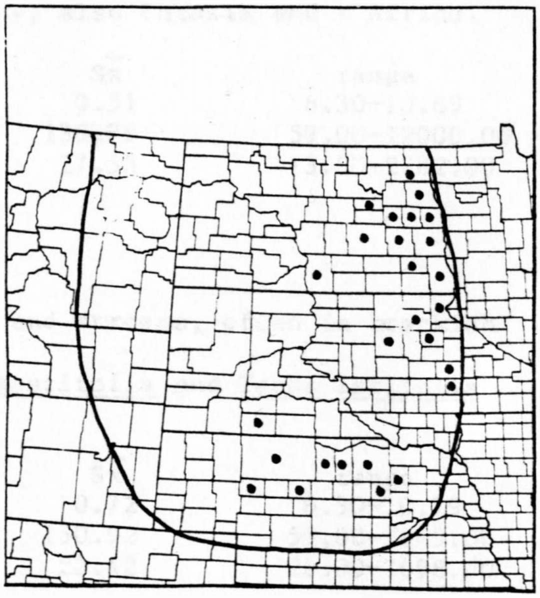
Puccinellia nuttalliana (Schult.) Hitchc.



Scolochloa festucacea (Willd.) Link



Zizania aquatica L.



Sparganiaceae, the Burreed Family

Sparganium eurycarpum Engelm. -- Giant Burreed

Shallow water of marshes, streams, ponds and lakes.
Newf. to B.C., s to NJ, OH, IN, MO, OK, AZ and CA.

n=52	mean	$S_{\bar{x}}$	range
pH	7.51	1.02	6.30-10.69
conductivity	769.901	106.78	59.00-1706.00
alkalinity	218.46	21.50	32.00-968.00

Typhaceae, the Cattail Family

Typha angustifolia L. -- Narrowleaf cattail

Shallow water of marshes, lakes, ponds and streams, often in brackish or saline water.
Nearly cosmopolitan, in Am. from ME to Man. and s MT, s to SC, KY, MO, KS; also c CA.

n=91	mean	$S_{\bar{x}}$	range
pH	7.84	0.23	6.89-10.69
conductivity	1956.18	253.01	92.00-14205.65
alkalinity	252.91	16.69	26.00-968.000

Typha latifolia L. -- Common cattail

Shallow water of marshes, lakes, ponds and streams.
s Can, throughout the U.S. and into Mex., also Eurasia and n Africa.

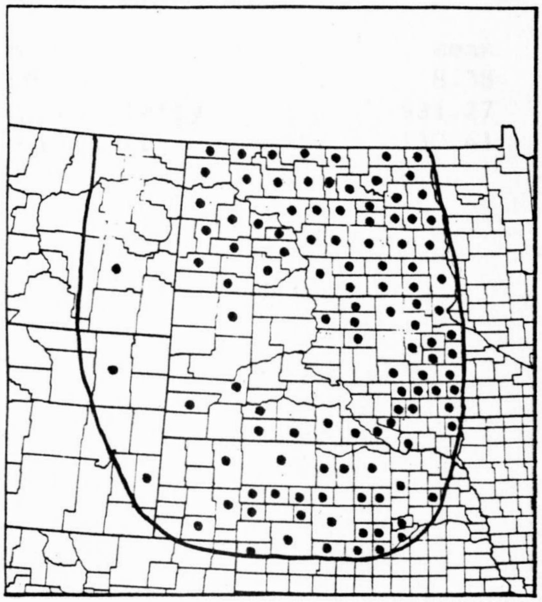
n=106	mean	$S_{\bar{x}}$	range
pH	7.73	0.51	6.30-10.69
conductivity	1150.61	136.79	59.00-12000.00
alkalinity	256.82	27.33	13.00-2282.00

Typha X. glauca Godr. -- Hybrid cattail

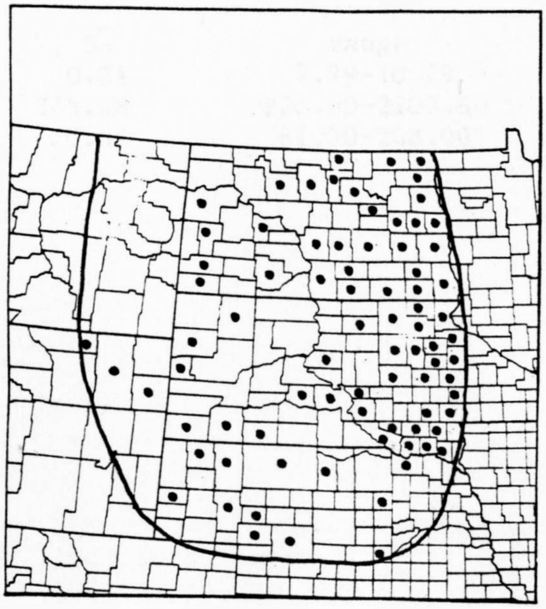
Shallow water of marshes, lakes, ponds and streams, often in brackish or saline water.
Occurs wherever the ranges of *Typha angustifolia* and *Typha latifolia* are sympatric.

n=72	mean	$S_{\bar{x}}$	range
pH	7.73	0.72	6.30-10.79
conductivity	1609.99	150.92	59.00-5649.00
alkalinity	257.11	22.42	26.00-1098.00

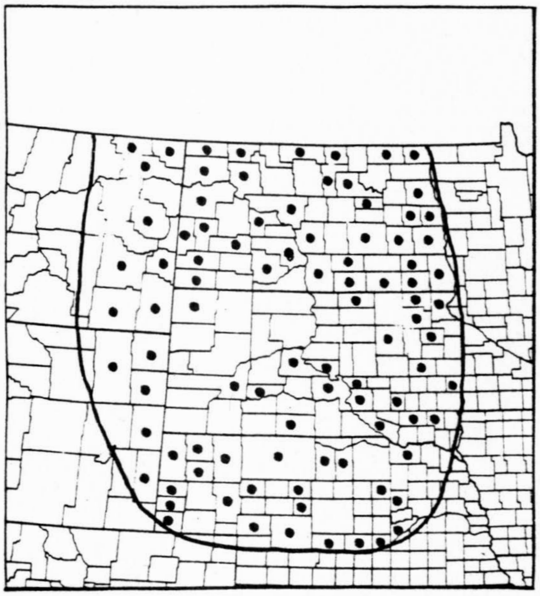
Sparganium eurycarpum Engelm.



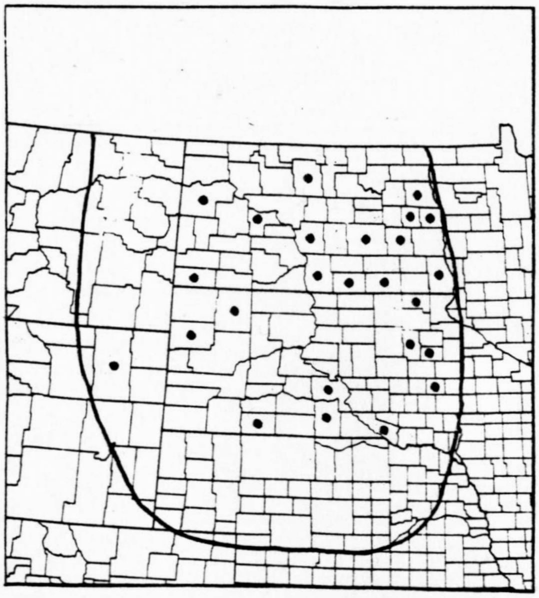
Typha angustifolia L.



Typha latifolia L.



Typha X. glauca Godr.



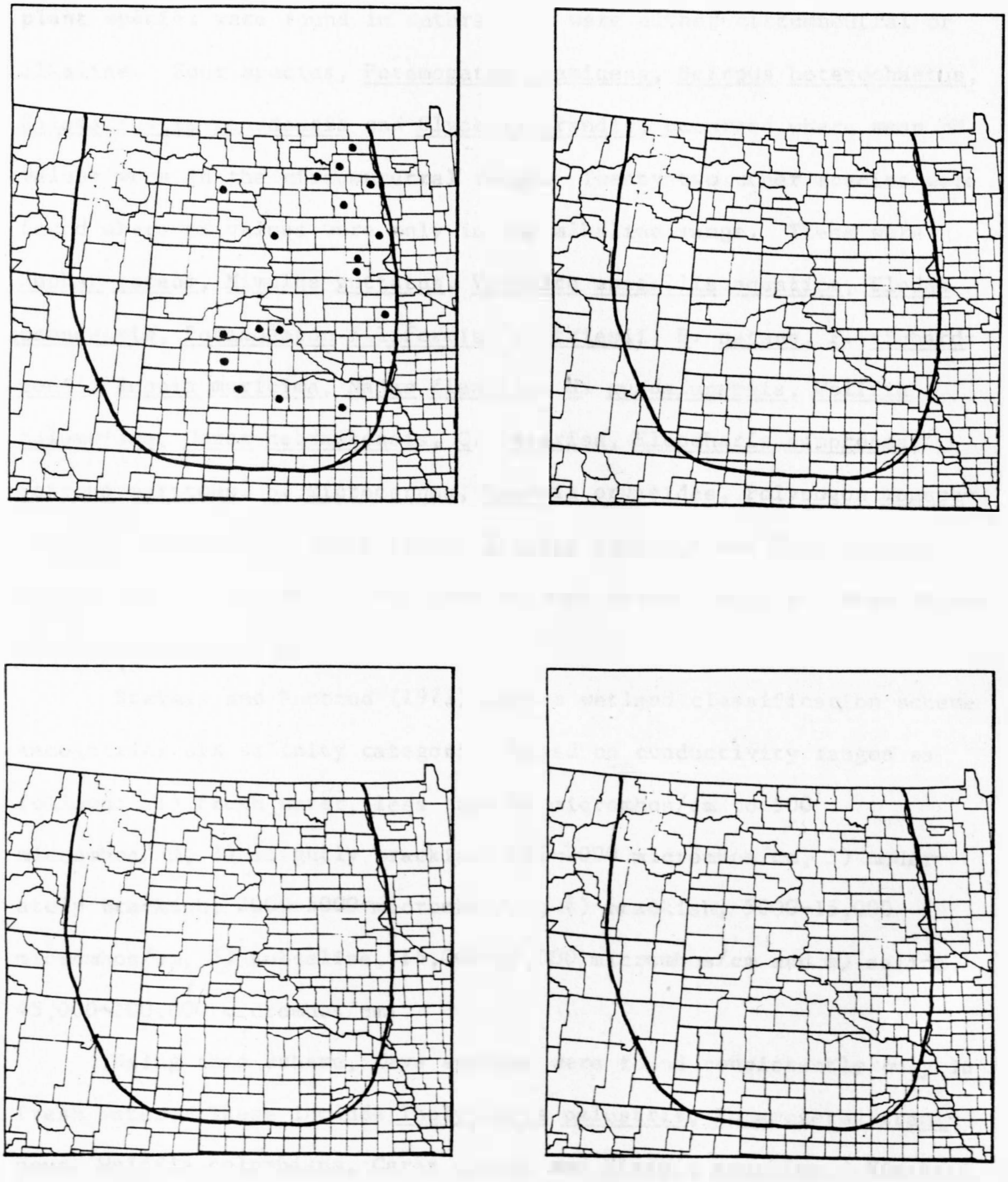
Pontederiaceae, the Pickerelweed Family

<u>Heteranthera dubia</u> (Jacq.) MacM. -- Water stargrass

Streams and impoundments.
Que. to ND and WA, s to FL, TX, CA and into Mex.

n=7	mean	$S_{\bar{x}}$	range
pH	8.38	0.21	7.79-10.79
conductivity	981.27	275.48	226.00-2103.60
alkalinity	130.41	20.52	61.30-208.00

Heteranthera dubia (Jacq.) MacM



According to the pH modifier scheme of Cowardin, et al. (1979) in which acid waters have a pH of less than 5.5, circumneutral waters a pH of 5.5 - 7.4 and alkaline waters a pH of greater than 7.4, all 97 plant species were found in waters that were either circumneutral or alkaline. Four species, Potamogeton gramineus, Scirpus heterochaetus, Calamagrostis canadensis and Glyceria grandis, occurred where mean pH values were in the circumneutral range. Twenty-two other species were found where pH values were only in the alkaline range. These were Nuphar luteum, Mimulus guttatus, Veronica anagallis-aquatica, Elodea canadensis, Potamogeton filiformis, P. friesii, P. natans, P. richardsonii, Ruppia maritima, Najas flexilis, N. guadalupensis, Wolffia columbiana, Carex nebraskensis, C. prarisa, Eleocharis compressa, Scirpus maritmus, S. microcarpus, Leersia oryzoides, Polypogon monspeliensis, Puccinellia nuttalliana, Zizania aquatica and Heteranthera dubia. All other species occurred in both ranges, with all mean values in the alkaline range.

Stewart and Kantrud (1972) used a wetland classification scheme recognizing six salinity categories based on conductivity ranges as follows: 1) fresh water, less than 40 micromhos/cm to 500 micromhos/cm, 2) slightly brackish, 500-2000 micromhos/cm, 3) moderately brackish, 2000-5000 micromhos/cm, 4) brackish, 5000-15,000 micromhos/cm, 5) subsaline, 15,000-45,000 micromhos/cm and 6) saline, 45,000-100,000 micromhos/cm.

Using this scheme, five species were found consistently only in fresh water. These include Thelypteris palustris, Potamogeton gramineus, Wolffia columbiana, Carex comosa and Zizania aquatica. Nineteen other species occurred in waters with mean conductivity values in the fresh water range. These are Myriophyllum verticillatum, Sium suave, Mimulus guttatus, Veronica americana, Sagittaria latifolia, Potamogeton natans, P. zosteriformis, Najas flexilis, Acorus calamus, Spirodela polyrhiza, Carex aquatilis, C. lacustris, C. prarisa, C. scoparia, C. stipata, Eleocharis compressa, Scirpus heterochaetus, S. microcarpus and Calamagrostis canadensis.

Eleven species were found to tolerate subsaline conditions. These are Lycopus asper, Potamogeton pectinatus, Ruppia maritima, Carex lanuginosa, Eleocharis macrostachya, Scirpus acutus, S. maritimus, S. pungens, Carex stricta, Phragmites australis and Puccinellia nuttalliana. All, with the exception of Ruppia maritima and Puccinellia nuttalliana, were also found in fresh water ranges.

Most waters of the northern Great Plains have high buffering capacities and the alkalinity readings are quite high. Lind (1974) stated that expected alkalinity readings fall within 45-200 mg/l $CaCO_3$. Due to the nature of substrates in the Plains region, alkalinity readings may be much higher. In this study, alkalinity was found to be as high as 18,006.6 mg/l $CaCO_3$. Values up to 34 mg/l $CaCO_3$ are considered low for alkalinity. Medium values range from 35-82 mg/l $CaCO_3$ and the high range includes values greater than 83 mg/l $CaCO_3$ (Ellis 1955).

Using this scheme, most of the aquatic plants were found in waters of medium to high alkalinity. These are Marsilea vestita, Nuphar luteum, Myriophyllum verticillatum, Sium suave, Asclepias incarnata, Teucrium canadense, Mimulus guttatus, Alisma gramineum, Sagittaria latifolia, Potamogeton crispus, P. filiformis, P. gramineus, P. natans, Najas flexilis, Acorus calamus, Wolffia columbiana, Carex aquatilis, C. rostrata, Scirpus fluviatilis, Leersia oryzoides, Puccinellia nuttalliana and Zizania aquatica.

Sixteen other species were found in waters that varied greatly, with alkalinities as low as 13 mg/l $CaCO_3$ to as high as 18.006.6 mg/l $CaCO_3$. These species are Polygonum coccineum, Lycopus asper, Sagittaria cuneata, Potamogeton pectinatus, Lemna minor, Carex nebraskensis, C. sartwellii, Eleocharis macrostachya, Eleocharis smallii, Scirpus maritimus, S. pungens, S. validus, Sparganium eurycarpum, Typha angustifolia, Typha latifolia and Typha X glauca.

DISCUSSION

Since this is a baseline study and there are limited sample numbers for some of the reported species, actual correlations between water chemistry and aquatic plant occurrence cannot be performed. Certain trends, however, can be seen in the data and these trends tend to follow the findings of Stewart and Kantrud (1972). Some of the plant species which they identify as water quality indicators appear to be reaffirmed by this study. Known tolerance ranges for pH, alkalinity and, most notably, for conductivity, have been extended for several species as a result of this study.

Of the three water chemistry parameters measured, conductivity of surface water appears to have the greatest influence on the presence or absence of certain aquatic plants. Those species found consistently in fresh water, or those that occur in waters with mean conductivity values in the fresh water range, tend to be restricted to waters with low conductivity. *Myriophyllum verticillatum*, *Sium suave*, *Veronica americana*, *Najas flexilis*, *Spirodela polyrhiza*, *Scirpus heterochaetus* and *S. microcarpus*, all recognized by Stewart and Kantrud (1972) as fresh water indicators, occurred in waters with mean conductivity values in the fresh water range. These species were rarely found in waters that were more than slightly brackish. *Mimulus guttatus*, *Sagittaria latifolia*, *Potamogeton natans*, *P. zosteriformis*, *Acorus calamus*, *Carex aquatilis*, *C. lacustris*, *C. prarisa*, *C. scoparia*, *C. stipata*, *Eleocharis compressa* and *Calamagrostis canadensis* also occurred in waters with mean conductivity values in the fresh water range.

Aquatic plant species known to tolerate brackish and saline conditions include Potamogeton pectinatus, Ruppia maritima, Scirpus acutus, S. maritimus, S. pungens, Phragmites australis and Puccinellia nuttalliana. All were found to extend into the subsaline range along with Lycopus asper, Carex lanuginosa, C. stricta and Eleocharis macrostachya. Of these plants, Stewart and Kantrud (1972) found that only Lycopus asper, Potamogeton pectinatus and Scirpus acutus were also located in fresh water. This study found that the conductivity ranges of all but Ruppia maritima and Puccinellia nuttalliana extend into the fresh range, showing the great tolerance of these plants to variable chemical regimes.

Most of the plants, excluding those found only in fresh conditions, occurred in habitats that had large ranges for conductivity. This is explained in large part by the fact that many lakes and ponds of the northern Great Plains, notably those with little or no natural outflows, are subject to extreme yearly and seasonal fluctuations in water level, and solute concentrations vary accordingly, increasing as water levels recede. Because of these extreme changes, the aquatic plants inhabiting these environments must be tolerant of variations in salinity, as well as changes in water level, in order to survive.

Most of the plants proved quite tolerant of large ranges in alkalinity. Although several species were found in the low range, they were not confined to this range, and in fact, were often found in waters with very high alkalinities. Twenty-two species were found only in water with high alkalinity. This is not surprising since many lakes and ponds in the northern Great Plains fall into the high alkalinity range. Of these twenty-two species, fifteen were found at less than ten sites. These are Marsilea vestita, Nuphar luteum, Myriophyllum verticillatum, Mimulus guttatus, Sagittaria latifolia, Potamogeton crispus, P. filiformis, P. gramineus, P. natans, Najas flexilis, Acorus calamus, Wolffia columbiana, Carex aquatilis, C. rostrata and Zinania aquatica. It is possible that with more sample sites, these species might have been found in waters with lower alkalinity.

For the most part, pH values tend to increase with increasing conductivity. The four species that have mean pH values very close to neutral (7.00), Potamogeton gramineus, Scirpus heterochaetus, Calamagrostis canadensis and Glyceria grandis, were also found to occur in the fresh water range for conductivity. The plants occurring only in the alkaline range of pH, however, were not all found in the brackish to subsaline ranges for conductivity. Although Ruppia maritima, Scirpus maritimus and Puccinellia nuttalliana fall into both alkaline and subsaline categories, the list of plants in the alkaline range also includes plants found consistently in fresh water. These are Mimulus guttatus, Potamogeton natans, Najas flexilis, Eleocharis compressa and Scirpus microcarpus. For this reason it is difficult to make associations not only between pH and aquatic plant occurrence, but also between pH and conductivity.

As stated previously, selection of plants for the study was based partly on the direct association of the plants with surface water. Submergent plants are in most direct association with water and are undoubtedly the most affected by water chemistry. For this reason, McCarraher (1977) in his study of Nebraska Sandhill lakes, concentrated on submergent species in his study of the association between plants and water quality. Table 1 shows some of the common submergent aquatic plant species encountered by McCarraher, along with his measurements of pertinent water chemistry factors. Conductivity values are not included, since his measurements are not readily convertible to micromhos/cm.

Most of McCarraher's values are quite comparable to the values found in this study. Only Potamogeton pusillus, Ceratophyllum demersum and Utricularia vulgaris show noticeable differences in the alkalinity values of their habitats, but even these are not extreme. Values for pH from the two studies were slightly less comparable than the values for alkalinity. This can probably be explained by the fact that McCarraher (1977) collected water quality measurements over an entire year, whereas data for this study were collected only during the summer months. Values for pH vary greatly both seasonally and diurnally.

In this study, Potamogeton pectinatus and Ruppia maritima were found to be most tolerant to great variation in conductivity. McCarraher (1977) found these species to be the most tolerant of waters with high alkalinity and pH values. Even though most of the aquatic plants in this study were found to tolerate wide ranges in conductivity, total alkalinity and pH, these two species seem able to survive in extremely harsh chemical conditions, where other aquatic plants fail to become established.

Table 1. Selected submergent aquatic plants and the means of total alkalinity and pH values of surface waters where they occur.

	McCarraher		Sletten	
	Total alkalinity (mg/l$CaCO_3$)	pH	Total alkalinity (mg/l$CaCO_3$)	pH
Potamogeton pectinatus	1940.72	8.52	1993.38	8.20
Potamogeton natans	526.40	8.78	362.11	8.13
Potamogeton pusillus	443.47	8.77	929.97	7.99
Myriophyllum exalbescens	555.45	8.85	1337.39	8.38
Ceratophyllum demersum	508.26	8.78	1008.68	7.89
Utricularia vulgaris	1720.10	8.88	753.88	7.61
Najas flexilis	425.71	8.74	461.45	8.88

CONCLUSIONS

This study has shown the distribution of certain aquatic plants throughout the northern Great Plains, as well as their tolerance to the surface water chemistry parameters of conductivity, total alkalinity and pH. Some plant species previously identified by Stewart and Kantrud (1972) as being tolerant of saline water, notably *Potamogeton pectinatus* and *Ruppia maritima*, have been reaffirmed by this study. Several of the species exhibit greater ranges of values for the water chemistry parameters than those found by Stewart and Kantrud, showing the great tolerance of these plants to the variable water regimes so typical of the waters of the northern Great Plains.

The information gathered in this study will aid in establishing desirable aquatic vegetation in newly created wetlands in the Great Plains. Statistical studies must follow to detect possible correlations between aquatic plant occurrence and surface water chemistry, especially in relation to specific ions contributing to conductivity. With these correlations established, the interpretation of water quality from wetland vegetation would become more exact.

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