Vegetation of Prairie Potholes, North Dakota, in Relation to Quality of Water and Other Environmental Factors

GEOLOGICAL SURVEY PROFESSIONAL PAPER 585-D

Prepared by the U.S. Bureau of Sport Fisheries and Wildlife, in collaboration with the U.S. Geological Survey

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By ROBERT E. STEWART *and* HAROLD A. KANTRUD

HYDROLOGY OF PRAIRIE POTHOLES IN NORTH DAKOTA

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VEGETATION OF PRAIRIE POTHOLES, NORTH DAKOTA, IN RELATION TO QUALITY OF WATER AND OTHER ENVIRONMENTAL FACTORS

By ROBERT E. STEWART and HAROLD A. KANTRUD [1]

ABSTRACT

Measurements of specific conductance provide an adequate indication of the average salinity of surface waters in natural ponds and lakes of the northern prairie region. Yearly and seasonal variations in specific conductance were much greater in brackish and subsaline wetlands than in fresh-water areas. The principal vegetational types. Land-use practices of varying brackish to saline wetlands were sulfates and chlorides of sodium and magnesium. In less saline waters, carbonate and bicarbonate salts of calcium and potassium were of greater importance, but as salinity increased, the proportion of these compounds decreased rapidly.

A major environmental factor controlling the establishment of marsh and aquatic vegetation is the permanence of surface water. Permanence is a measure of the extent to which surface water persists at a given site. Varying degrees of water permanence during the growing season led to the establishment of distinct vegetational types, which were differentiated primarily on the basis of community structure or life form of the dominant vegetation.

Salinity of surface waters was closely correlated with differences in species composition of plant communities found in the principal vegetational types. Land-use practices of varying degrees of intensity also had a secondary influence on species composition. Since an unstable water chemistry is characteristic of most prairie ponds and lakes, it is more reliable to use the plant communities as indicators of average salinity than to use single measurements of specific conductance.

Characteristic species of wetland vegetational types occupied the central deeper parts of pond and lake basins or occurred as concentric peripheral bands. The wetland vegetational types are wetland low-prairie, wet-meadow, shallow-marsh emergent, deep-marsh emergent, fen emergent, submerged and floating, natural drawdown, cropland drawdown, and cropland tillage vegetation. Combinations of species (plant associations) within these vegetational types were placed in one of six salinity categories designated as fresh, slightly brackish, moderately brackish, brackish, subsaline, and saline. Salt tolerance apparently varied greatly among the various marsh and aquatic plants since the number of species represented in moderately brackish to saline communities decreased markedly with increased salinity of the surface water environment.

INTRODUCTION

The influence of surface-water chemistry upon the species composition and distribution of marsh and aquatic plants in northern prairie areas was noted by several investigators. A general classification of lakes and sloughs in North Dakota, formulated by Metcalf (1931), was based in part on salinity. In this classification, many wetland plant communities [2] were listed according to their relationship to salinity. Rawson and Moore (1944) arranged the common rooted aquatic plants of prairie lakes in Saskatchewan in order of their tolerance to increasing salinity. Moyle (1945) categorized the aquatic flora of Minnesota into three primary groups on the basis of median chemical conditions associated with the component species. These groups were also subdivided according to the entire range of chemical conditions tolerated by each species.

The actual physiology of salt tolerance in marsh and aquatic plants is very complex, involving the effects of specific constituent ion(s) and the osmotic inhibition of water absorption by the roots. The effects of specific ions may involve both toxic and nutritional factors (Bernstein and Hayward, 1958). Bolen (1964) concluded that the ecological influences of water chemistry were not directly important to plant life in shallow spring-fed western marshes. Instead, he considered water-chemistry factors as causative agents for many of the soil characteristics which determined vegetational zonation.

[1] U.S. Bureau of Sport Fisheries and Wildlife, Northern Prairie Wildlife Research Center, Jamestown, N. Dak.

[2] Usage in the present report of plant communities and other generalized ecological terms such as associations, ecotones, dominants, and so on, follow definitions by Hanson (1962).

In 1960, ecological studies of waterfowl habitat were begun in North Dakota by the senior author of the present report. These studies indicated that the relationships of water salinity to vegetation represent a major factor that could be useful in developing a detailed wetland classification. During cooperative water-quality investigations conducted by the U.S. Bureau of Sport Fisheries and Wildlife and the U.S. Geological Survey on ponds in North Dakota in 1962, possible correlations were noticed between measurements of specific conductance and the occurrence of certain plant communities. Since the field technique for measuring specific conductance is simple and rapid, this parameter was chosen as the initial water-chemistry factor to be investigated. Specific conductance may be considered as a corollary measurement to salinity. This report deals primarily with the relationships between salinity of surface water, as interpreted from measurements of specific conductance, and wetland vegetation. The effects on vegetation of other environmental factors, including land use, also are discussed.

Specific conductance was determined by use of a portable impedance bridge with an automatic temperature-compensating cell. Measurements normally were taken throughout the ice-free period from water samples collected at the surface near the central, deepest part of a pond or lake. The water depth at the sampling site was usually recorded, and the relative abundance (as determined by visual estimates) of various plant species represented was noted in detail.

Nearly 1,600 specific-conductance measurements were taken during 1963–66 in approximately 450 ponds, lakes, and fens in two physiographic regions, known as the Coteau du Missouri and the drift plain (fig. 1) of east-central North Dakota. These regions include ponds and lakes of primary importance to waterfowl that may be arranged in order of increasing water permanence as follows: Ephemeral (class 1), temporary (class 2), seasonal (class 3), semipermanent (class 4), and permanent (class 5). Smaller numbers of alkali ponds and lakes (class 6) and fens (class 7) were sampled also. Surface water remained in these wetlands a few days in the early spring in the case of some ephemeral (class 1) ponds; water was continuously present in permanent (class 5) ponds and lakes. For

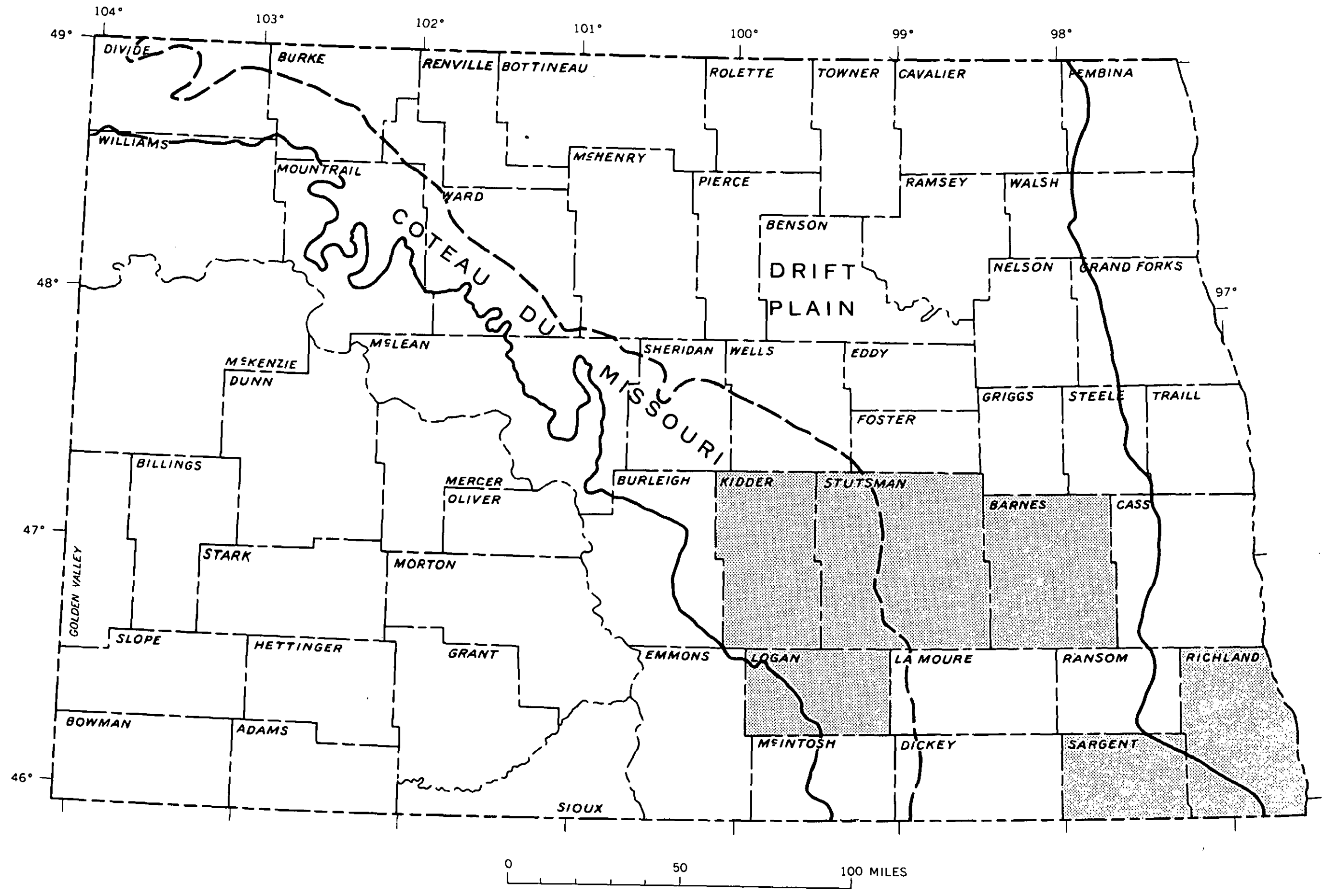

FIGURE 1.—Principal prairie pothole region of North Dakota. Boundaries of two physiographic regions, the drift plain and Coteau du Missouri, are shown, and locations of counties referred to in text are shaded.

further details of this wetland classification, refer to Stewart and Kantrud (1971); that report takes precedence over a preliminary paper on this subject (Stewart and Kantrud, 1969).

The majority of specific-conductance measurements were of samples taken from ponds and lakes on stagnation (dead-ice) moraine and outwash areas in the Coteau du Missouri of Stutsman, Kidder, and Logan Counties as part of intensive investigations of waterfowl habitat made during the period 1961–65. These investigations included approximately 825 measurements on 198 ephemeral, temporary, and seasonal ponds; 685 measurements on 198 semipermanent ponds and lakes; and 40 measurements on 20 permanent and alkali ponds and lakes. In 1966, 38 measurements were made on samples taken from a total of 25 temporary and seasonal ponds on the drift plain of Stutsman and Barnes Counties. In addition, specific conductance of surface water was determined in several ponds, lakes, and fens that contained plant communities not duplicated elsewhere.

To corroborate conclusions concerning the relationships between salinity of surface water and occurrence of various plant communities, detailed water analyses also were undertaken. In 1965, water samples from 158 ponds and lakes in east-central North Dakota were analyzed by the water-quality laboratory of the U.S. Geological Survey in Lincoln, Nebr. These samples included 45 from seasonal ponds, 100 from semipermanent ponds and lakes, nine from permanent lakes, and four from alkali lakes. Since then, water samples from about 200 additional ponds and lakes have been analyzed by the chemistry laboratory at the Northern Prairie Wildlife Research Center in Jamestown, N. Dak.

INFLUENCE OF ENVIRONMENTAL FACTORS

Typical plant communities in prairie pond and lake basins having undisturbed bottom soils can be grouped into seven major vegetational types. These consist of distinct assemblages of plant species and are characterized by differences in community structure or life form. These wetland vegetational types are referred to as wetland low-prairie, wet-meadow, shallow-marsh emergent, deep-marsh emergent, fen emergent, submerged and floating aquatic, and natural drawdown vegetation. Two additional vegetational types were also present in cropland basins with bottom soils that had been disturbed by plowing and cultivation. These are designated as cropland drawdown vegetation (vegetation developing on exposed mud flats) and cropland tillage vegetation (vegetation developing on tilled dry soil).

Unless the environment had been modified by agricultural land use, the presence of these major vegetational types correlated directly with differences in water permanence and indirectly with water depth. Certain wetlands contained only one vegetational type; other wetlands contained two, three, or more types in distinct zones that exhibited differences in average water depth. When two or more of these zones were present, one zone usually occupied the central, deeper part of the pond basin, while the others formed concentric peripheral bands. Within a vegetational type, or zone, the characteristic plant species were found as a general mixture or were represented by one, two, or more communities, each composed of one or more species. The spatial relationships of these major vegetational types or zones in various types of potholes are treated in detail in another report (Stewart and Kantrud, 1971).

Major differences in species composition of the characteristic plant communities within most of the major vegetational types, or zones, could be correlated with differences in average salinity of surface water. Distinctive communities of plants could be correlated with fresh, slightly brackish, moderately brackish, brackish, subsaline, and saline ranges of water quality. (These communities are described in detail under "Major Vegetational Types.") However, measurements of specific conductance, used to indicate differences in salinity, were found to fluctuate widely within many individual ponds and lakes. Thus, many plant communities that were indicative of differences in normal ranges of salinity also persisted temporarily over extreme ranges of salinity that exceeded the normal limits. Since water conditions were unstable in most prairie ponds and lakes, plant communities were more reliable indicators of average salinity than were single measurements of specific conductance.

Extreme yearly and seasonal fluctuations in water depth are characteristic of most northern prairie ponds and lakes. As a consequence, the total acreage of wetlands with a specified water depth varies greatly (fig. 2). Variations in water depth of an individual pond or lake also often result in corresponding changes in salinity. Reductions in specific conductance were caused by dilution of surface waters. Dilution appeared to be related to increasing water depths which resulted both from inflow of surface runoff from the watersheds and from precipitation falling directly on pond surfaces. In many ponds, an increase in water depth was accompanied by actual loss of salts due to the flushing action of overflow or spill. An increase in specific conductance was usually associated with decreases in water depth caused by evapotranspiration. However, in a few of the less saline ponds, an increase in salinity occurred

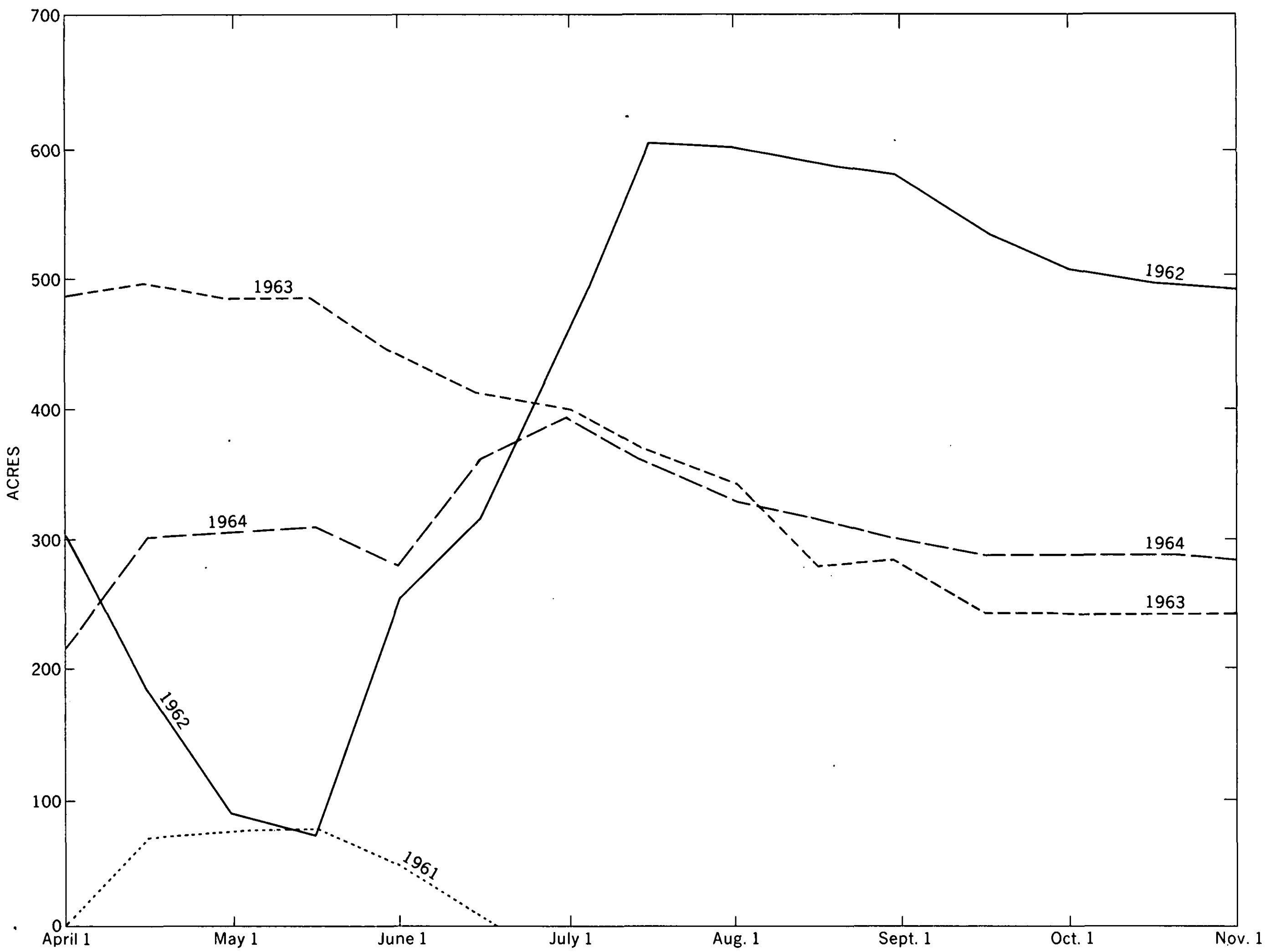

FIGURE 2.—Total acreage of ponds with a water depth of 12 inches or more in Stutsman County study areas (3 sq mi) during 1961–64.

without a corresponding decrease in water depth. This increase was probably due to salts in ground-water or spring inflow; concentrations of salts, in general, are greater in seepage than in surface inflow.

Table 1 shows semiannual changes in specific conductance from the fall of 1963 to the fall of 1966 as related to variations in water depth in five typical semipermanent ponds. Each of these ponds contained distinctive plant communities that were indicative of differences in average salinity. Specific conductance varied little in the fresh and slightly brackish ponds, more greatly in the moderately brackish pond, and quite drastically in the ponds classified as brackish and subsaline.

Seepage outflow undoubtedly accounted for some of the water loss in most ponds at higher elevations, be-

TABLE 1.—*Seasonal variations in specific conductance, in micromhos per centimeter at 25° C, with corresponding maximum depth of water, in feet, at five semipermanent (Class 4) ponds*

Pond	Salinity range, as indicated by plants	1963		1964				1965				1966			
		Fall		Spring		Fall		Spring		Fall		Spring		Fall	
		Conductance	Depth	Conductance	Depth	Conductance	Depth	Conductance	Depth	Conductance	Depth	Conductance	Depth	Conductance	Depth
1	Fresh	345	2.0	325	2.8	350	4.2	310	5.0	445	4.2	285	6.2	355	4.2
2	Slightly brackish	1,070	1.5	580	2.5	955	3.0	760	3.9	870	3.3	645	4.4	1,100	2.9
3	Moderately brackish	4,670	1.2	3,100	1.4	2,100	2.5	1,450	4.8	2,010	3.2	1,660	6.3	1,800	4.4
4	Brackish	18,000	.1	6,800	.2	5,100	1.1	4,200	1.5	4,350	1.4	2,150	2.8	2,790	2.2
5	Subsaline	(Dry)	(Dry)	12,000	.8	17,200	.6	25,000	.8	25,000	.2	3,100	2.5	7,500	1.8

cause most of these ponds are in glacial till. These ponds tended to be fresh since seepage provided a mechanism for the removal of dissolved solids (Eisenlohr and Sloan, 1968). Consequently, changes in water depth did not cause significant variations in specific conductance. Conversely, most ponds at lower elevations, and particularly those in glacial outwash sediments, were subject to greater seepage inflow. Since there was no effective means for removal of the accumulated salts, these ponds generally were more saline than ponds at higher elevations. Drastic changes in specific conductance often occurred in these low-elevation ponds of greater salinity since salt concentrations were alternately diluted, owing to increasing water depth, and concentrated, as the result of water losses caused by evapotranspiration.

In a few wetlands, the occurrence of marginal pockets of seepage inflow was found to create specific-conductance gradients of several hundred micromhos across the ponded waters. These salinity gradients often corresponded to changes in species composition of marsh and aquatic vegetation.

TABLE 2.—*General water-quality factors in prairie ponds and lakes*

[Figures represent mean values from four typical ponds or lakes in the indicated range of salinity]

Salinity range, as indicated by plants	Specific conductance (micromhos per cm at 25° C)	Concentration of dissolved solids; residue at 180° C (ppm)	Loss on ignition (ppm)	pH
Fresh	225	155	34	7.3
Slightly brackish	995	670	130	8.2
Moderately brackish	2,160	1,550	130	8.2
Brackish	6,410	5,570	415	7.9
Subsaline	25,800	26,400	985	8.1
Saline	31,800	32,200	1,370	8.7

More detailed chemical analyses of surface-water samples from a selected number of ponds included measurements of concentrations of dissolved solids, loss on ignition, and pH (table 2). These measurements, along with specific-conductance measurements, were compared to show their relationship to various plant communities that are indicative of differences in average salinity of surface water. The concentration of dissolved solids correlated closely with changes in vegetational species composition. Loss on ignition exhibited a fairly well defined relationship to plant communities, particularly in the higher salinity categories. Loss on ignition, which is indicative of organic content, was especially high in subsaline and saline ponds and lakes. The fertility of these waters was evident in the field from the tremendous production of invertebrate animal life. Little relationship could be found between pH and the occurrence of indicator plant communities, although the lowest readings occurred in the fresh ponds and the highest readings in subsaline and saline ponds and lakes. All water samples that were analyzed in detail were found to be either circumneutral or alkaline, with pH ranging from 6.5 to 9.8.

Mean values of the principal cations and anions of surface water in selected ponds having different degrees of salinity are compared with specific conductance in table 3. Changes in concentrations of magnesium and sulfate ions were found to parallel changes in specific conductance and species composition of plant communities quite closely. In ponds ranging from fresh to subsaline, a gradual increase in concentrations of sodium and chloride occurred. In saline ponds, a very high concentration, particularly of sodium ions, was measured. The four major cations—calcium, magnesium, sodium, and potassium—were nearly of equal importance in ponds containing fresh and slightly brackish surface water, while bicarbonates and sulfates were the predominant anions. The principal salts represented in surface water of moderately brackish, brackish, subsaline, and saline ponds and lakes were sulfates and chlorides of sodium and magnesium.

In general, the results established gradients in specific conductance that are corollary to changes in a number of major water-chemistry factors and that can provide an adequate index of species composition and ecological distribution of marsh and aquatic plants in northern prairie ponds and lakes.

MAJOR VEGETATIONAL TYPES

The principal types of wetland vegetation are compared with variations in salinity and other environ-

TABLE 3.—*Principal ionic constituents and specific conductance of surface water from prairie ponds and lakes*

[Figures represent mean values from four typical ponds or lakes in the indicated range of salinity. Chemical values are in parts per million; specific conductance, in micromhos per centimeter at 25°C]

Salinity range, as indicated by plants	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	Specific conductance
Fresh	25	15	9	44	170	0	32	14	295
Slightly brackish	86	62	42	38	340	55	200	19	1,010
Moderately brackish	99	150	235	31	445	40	775	33	2,100
Brackish	50	310	1,020	140	450	260	2,340	235	6,320
Subsaline	205	540	1,380	175	610	480	9,310	1,050	12,200
Saline	210	2,240	39,100	870	880	715	27,300	6,320	37,500

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mental factors in this section. (See figs. 4, 9, 20, 27, 35, and 37, and tables 4, 5, 6.) A correlation was often apparent between species composition of plant communities and different degrees of surface-water salinity. The approximate normal and extreme ranges in specific conductance of surface water found in these correlative plant communities are shown below:

Salinity range	Specific conductance (micromhos per cm at 25° C)	
	Normal range	Extreme range
Fresh	<40–500	<40–700
Slightly brackish	500–2, 000	300–2, 200
Moderately brackish	2, 000–5, 000	1, 000–8, 000
Brackish	5, 000–15, 000	1, 600–18, 000
Subsaline	15, 000–45, 000	3, 500–70, 000
Saline	45, 000–100, 000+	20, 000–100, 000+

The component plants of each major vegetational type, listed in the figures and tables referred to above, are grouped as primary or secondary species to show their relative importance. Primary species are plants that are frequently common or abundant under appropriate ranges of salinity; secondary species although frequently present under these conditions, are seldom more than fairly common. These ratings of abundance as applied to individual plant species are defined as follows:

Abundance rating	*Definition*
Abundant	Areal coverage (shading effect[1]) of more than 50 percent of surface water or bottom soils.
Common	Areal coverage (shading effect) of 10–50 percent of surface water or bottom soils.
Fairly common	Areal coverage (shading effect) of 1–10 percent of surface water or bottom soils.

[1] Area covered by downward vertical projection of shade due to plant growth.

Many species of minor numerical importance are not included in the tables.

With the exception of a few extralimital species, the identities and Latin names of vascular plants are according to the eighth edition of Gray's manual (Fernald, 1950). A few western species of vascular plants, not treated in Gray's manual, follow the nomenclature used by Stevens (1963). Names of algae are according to Smith (1950); names of mosses and liverworts follow Conard (1956). Altogether, 194 plant species are listed in the tables. Voucher specimens for all of these are preserved in the herbarium at the Northern Prairie Wildlife Research Center, Jamestown, N. Dak.

WETLAND LOW-PRAIRIE VEGETATION

In certain shallow wetlands, typical low-prairie vegetation occupied the entire basin, including the central, deeper parts of the pond. In this type of basin, surface water was normally present only in the early spring for a few days or sometimes for a week or two immediately following the snowmelt runoff. The rate of seepage outflow from these ponds was very rapid, since their porous bottom soils were well above the water table and, therefore, usually were of relatively low moisture content (C. E. Sloan, oral commun. 1966). As a consequence, surface water disappeared abruptly soon after thawing of the bottom frost seal. Occasionally, following excessive runoff, the peripheral zones of low-prairie vegetation that surrounded deeper ponds and lakes (which contained other types of wetland vegetation) were also inundated for brief periods.

Specific-conductance measurements of samples from ponds containing centrally located low-prairie vegetation were all within the normal fresh-water range. Typical plant species that characterize wetland low-prairie vegetation are listed in table 4 and are shown in figure 3.

TABLE 4.—*Characteristic plant species of wetland low-prairie vegetation*

Primary species	
Poa pratensis (Kentucky bluegrass).	*Solidago altissima* (tall goldenrod).
Agropyron trachycaulum (slender wheatgrass).	*Aster ericoides* (smallflower aster).
Anemone canadensis (Canada anemone).	*Ambrosia psilostachya* (perennial ragweed).
Symphoricarpos occidentalis (wolfberry).	
Secondary species	
Panicum virgatum (switchgrass).	*Zizia aptera* (golden alexanders).
Andropogon gerardi (big bluestem).	*Helianthus maximiliani* (narrowleaf sunflower).
Carex brevior (fescue sedge).	*Artemisia ludoviciana* (white sage).
Zigadenus elegans (smooth camas).	*Taraxacum officinale* (common dandelion).
Lilium philadelphicum (red lily).	*Agoseris glauca* (prairie false dandelion).
Rosa woodsii (western rose).	*Crepis runcinata* (scapose hawksbeard).
Glycyrrhiza lepidota (wild licorice).	

WET-MEADOW VEGETATION

Wet-meadow vegetation occupied zones in the central areas of many of the more shallow pond basins and commonly occurred as peripheral bands in most of the deeper ponds and lakes. Water loss owing to seepage outflow was fairly rapid from these vegetation zones; surface water usually persisted for only a few weeks following the early spring snowmelt and occasionally for several days following heavy rainstorms during late spring, summer, and fall. Species that characterized

FIGURE 3.—Wetland low-prairie vegetation. Principal dominant is *Solidago altissima* (tall goldenrod). August 8, 1962, Stutsman County, N. Dak.

wet-meadow zones were fine-textured grasses, rushes, and sedges of relatively low height. Many species of forbs also were commonly associated with them.

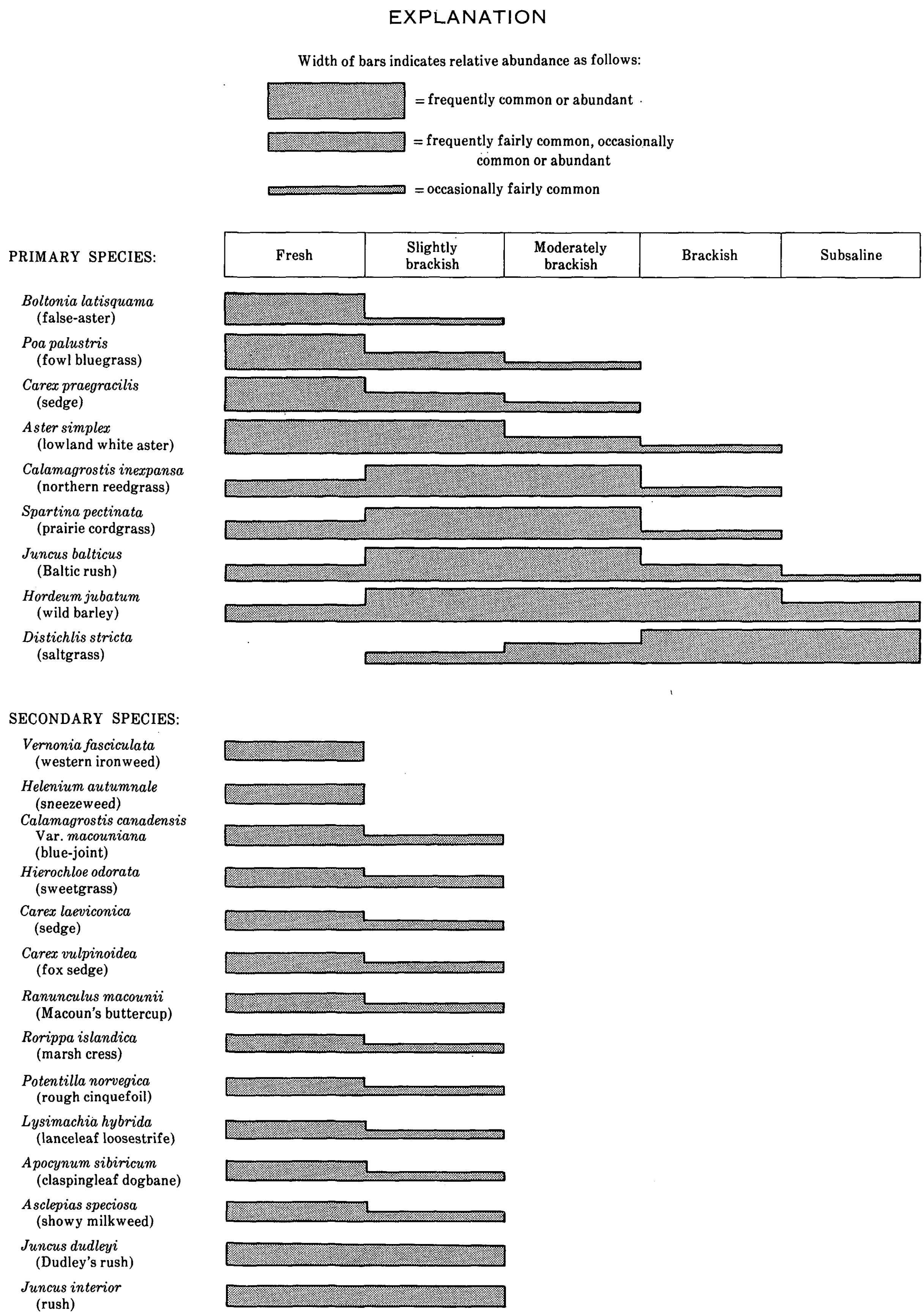
Wet-meadow vegetation which occurred in the central areas of shallow-pond basins appeared to be restricted to fresh or slightly brackish wetlands. Peripheral bands of wet-meadow vegetation commonly occurred around the deeper, more permanent ponds and lakes having a salinity ranging from fresh to subsaline. Species composition of wet-meadow vegetation as related to variations in salinity of surface water is shown in figure 4. Photographs of typical communities are shown in figures 5–8.

Grazing, cultivation, and, to a lesser extent, other land-use factors often had a noticeable secondary effect on the species composition of wet-meadow vegetation, particularly when the vegetation occurred in fresh, slightly brackish, or moderately brackish wetlands. *Hordeum jubatum*, *Juncus balticus*, *Spartina pectinata*, and most species of forbs tended to increase with light to moderate grazing pressure, while many other species, including *Poa palustris*, *Calamagrostis inexpansa*, and sedges (*Carex* spp.) were adversely affected. Species of wet-meadow vegetation in brackish and subsaline ponds were largely unaffected by grazing, except for certain secondary species, notably *Atriplex patula* and *Muhlenbergia asperifolia*, which generally showed a decrease in abundance. A few species in fresh or slightly brackish wet-meadow zones increased in abundance in cropland ponds that had been recently cultivated. These species included *Carex sartwellii*, *C. vulpinoidea*, *Juncus dudleyi*, *J. torreyi*, *Rumex mexicanus*, *Ranunculus macounii*, *Rorippa islandica*, *Potentilla norvegica*, and *Artemisia biennis*.

SHALLOW-MARSH EMERGENT VEGETATION

Most of the typical dominant emergent species of shallow-marsh vegetation were grasses or grasslike plants that were intermediate in height and coarseness when compared with emergents of wet meadow and deep marsh. Shallow-marsh emergent vegetation dominated the central areas of pond basins that normally maintained surface water for an extended period in spring and early summer but frequently were dry during late summer and fall. Under similar water conditions near the margins of deeper, more permanent ponds and lakes, this vegetative zone also occurred regularly as concentric bands between zones of wet-meadow and deep-marsh vegetation. In shallow alkali ponds and lakes, shallow-marsh zones often bordered the intermittent open water or the exposed mud of the alkali flats.

Shallow-marsh vegetation which occurred in the central areas of pond basins was largely restricted to fresh, slightly brackish, and moderately brackish wetlands. In the more permanent ponds and lakes with outer bands of shallow marsh, surface water was found to range from fresh to subsaline. When the water of alkali lakes is high enough to inundate the marginal shallow-marsh zones, it is usually only subsaline; when surface water is restricted to the central alkali flats during lower water levels, it is saline. In general, water in shallow-marsh zones of brackish and subsaline ponds and lakes tended to be shallower and of less permanence than water in shallow-marsh zones of the fresher ponds


EXPLANATION
Width of bars indicates relative abundance as follows:
= frequently common or abundant
= frequently fairly common, occasionally common or abundant
= occasionally fairly common
PRIMARY SPECIES:
Fresh
Slightly brackish
Moderately brackish
Brackish
Subsaline
Boltonia latisquama (false-aster)
Poa palustris (fowl bluegrass)
Carex praegracilis (sedge)
Aster simplex (lowland white aster)
Calamagrostis inexpansa (northern reedgrass)
Spartina pectinata (prairie cordgrass)
Juncus balticus (Baltic rush)
Hordeum jubatum (wild barley)
Distichlis stricta (saltgrass)
SECONDARY SPECIES:
Vernonia fasciculata (western ironweed)
Helenium autumnale (sneezeweed)
Calamagrostis canadensis Var. macouniana (blue-joint)
Hierochloe odorata (sweetgrass)
Carex laeviconica (sedge)
Carex vulpinoidea (fox sedge)
Ranunculus macounii (Macoun's buttercup)
Rorippa islandica (marsh cress)
Potentilla norvegica (rough cinquefoil)
Lysimachia hybrida (lanceleaf loosestrife)
Apocynum sibiricum (claspingleaf dogbane)
Asclepias speciosa (showy milkweed)
Juncus dudleyi (Dudley's rush)
Juncus interior (rush)

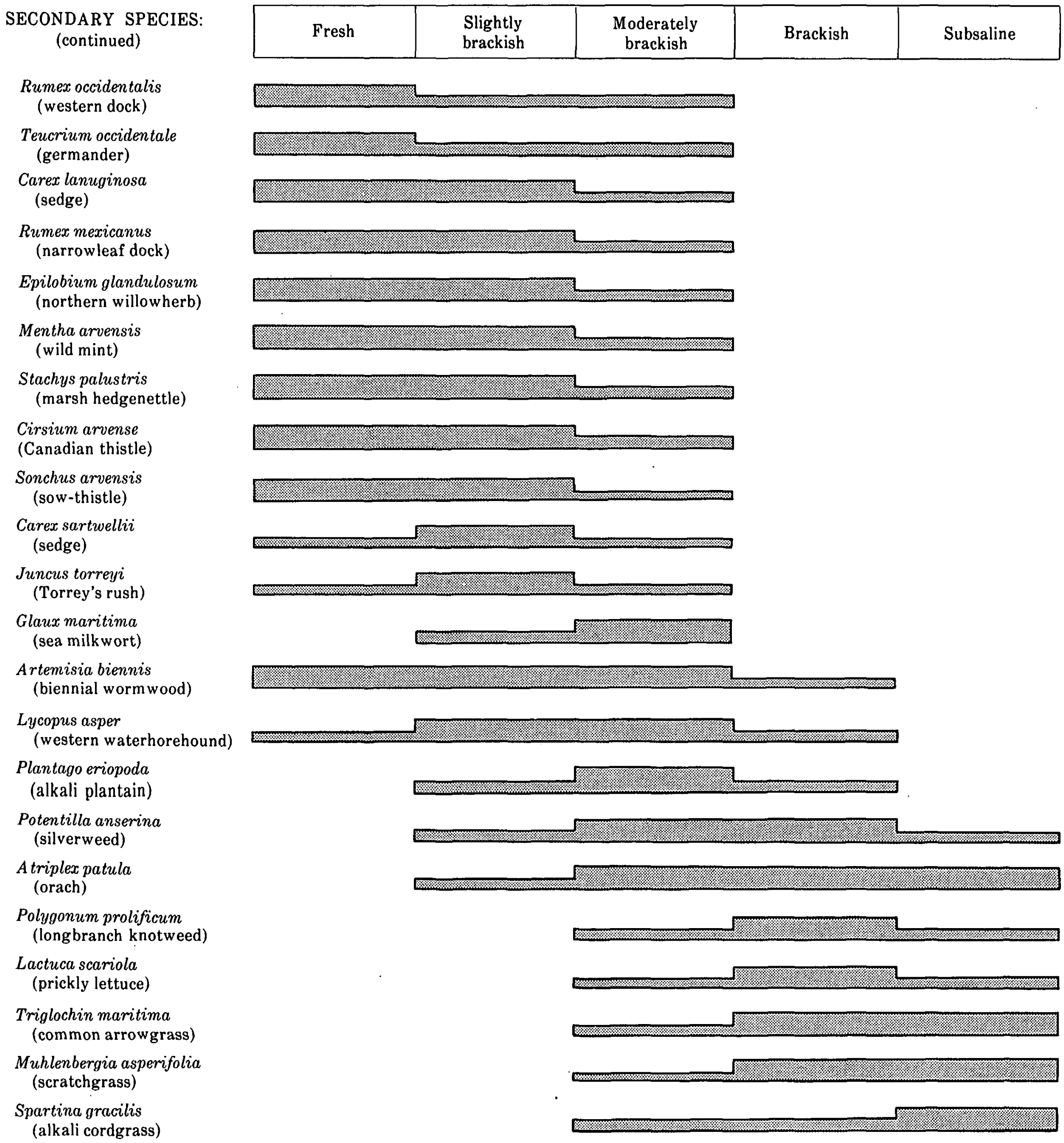


FIGURE 4.—Characteristic plant species of wet-meadow vegetation.

and lakes. Nevertheless, the spatial relationship of shallow marsh to wet meadow and deep marsh remained the same, regardless of salinity.

Differences in species composition of shallow-marsh emergents as related to varying degrees of salinity could be represented as a continuum of overlapping species that showed gradual changes in dominance or abundance. The characteristic species of plant communities occurring under these variable conditions are listed in figure 9 and are shown in figures 10–18.

In zones of fresh, slightly brackish, and moderately brackish shallow-marsh vegetation, certain variations in species composition of dominant emergent plants were also due to the secondary influence of land use.

FIGURE 5.—Wet-meadow vegetation typical of fresh-water ponds. *Poa palustris* (fowl bluegrass) forms the principal dominant; *Vernonia fasciculata* (western ironweed) and *Boltonia latisquama* (false-aster) are the associated forbs. August 9, 1962, Stutsman County, N. Dak.

FIGURE 6.—Wet-meadow vegetation of a slightly brackish semipermanent pond. *Hordeum jubatum* (wild barley) forms the principal dominant. August 4, 1961, Stutsman County, N. Dak.

Predominant species as related to land use are as follows:

Land use	Predominant species
Fresh shallow-marsh zones	
Undisturbed	*Carex atherodes.*
Mowed	*Carex atherodes* and *Scolochloa festucacea.*
Lightly grazed	*Carex atherodes* and *Glyceria grandis.*
Moderately and heavily grazed	*Glyceria grandis* and (or) *Sparganium eurycarpum.*
Burned	*Polygonum coccineum.*
Cultivated bottom soils in cropland	*Alisma triviale, Alopecurus aequalis, Beckmannia syzigachne,* and *Polygonum coccineum.*
Slightly brackish shallow-marsh zones	
Undisturbed	*Carex atherodes* and *Scolochloa festucacea.*
Mowed	*Scolochloa festucacea.*
Lightly grazed	*Carex atherodes.*
Moderately grazed	*Carex atherodes* and *Eleocharis palustris.*
Heavily grazed	*Eleocharis palustris.*
Burned	*Polygonum coccineum.*
Cultivated bottom soils in cropland	*Alisma triviale, Alopecurus aequalis, Beckmannia syzigachne,* and *Polygonum coccineum.*
Moderately brackish shallow-marsh zones	
Undisturbed and mowed	*Scolochloa festucacea.*
Lightly, moderately, and heavily grazed.	*Eleocharis palustris* and (or) *Scirpus americanus.*
Cultivated bottom soils in cropland	*Alisma gramineum* and *Beckmannia syzigachne.*

These relationships were not always apparent, since not only the kind but also the degree of land use was important; and when changes in land use occurred, the response of vegetation often was somewhat delayed.

Certain species of forbs, including *Alisma triviale* and *Sium suave*, were frequently common in untilled shallow-marsh zones but apparently had little relationship to land use. Usually, these species reached their best development shortly after surface water was replenished following drought periods. One species, *Scirpus nevadensis*, listed as one of the dominants of subsaline shallow-marsh vegetation (fig. 9), appeared to be restricted to marginal bands of shallow marsh in alkali ponds and lakes or subsaline permanent ponds and lakes. Another shallow-marsh dominant, *Scirpus americanus*, was usually prevalent only on sandy soils.

DEEP-MARSH EMERGENT VEGETATION

Deep-marsh emergent species with associated open-water submerged vegetation dominated the central areas of pond basins that ordinarily maintained surface water throughout the spring and summer and frequently into fall and winter. During drought years, however, water in these basins often disappeared as early as midsummer. Wetlands of this type are designated as semipermanent ponds or lakes. Under similar water conditions along the margins of permanent ponds and lakes, zones of deep-marsh emergents often occurred also as concentric peripheral bands. The structure or life form of deep-marsh vegetation was quite distinct in that emergent species were generally coarser and taller than corresponding emergent species in other types of wetland vegetation.

Zones of deep-marsh emergent vegetation were nearly always present in the deeper ponds and lakes having salinity ranging from slightly brackish to subsaline. During years of above-average water conditions, these vegetational zones also were found locally in some of the deep fresh-water ponds. Normally, however, surface water in fresh-water ponds was not maintained long enough for establishment of deep-marsh species owing to greater water-loss from seepage outflow. When these zones occurred in ponds and lakes containing slightly brackish, moderately brackish, brackish, or subsaline water, an inverse relationship was apparent between increasing salinity and average water depths. Therefore, lesser degrees of water permanence characterized deep-marsh zones of greater salinity.

Detailed information concerning the relationship of specific conductance of surface water to dominant emergent species in deep-marsh communities is presented in figure 19. These data are based on measurements made during the early summer of 1965 when water levels were slightly higher than average. Ponds sampled were on the Coteau du Missouri in the western half of Stutsman County, eastern half of Kidder County, and northeastern quarter of Logan County. In the communities designated as *Typha* spp.–*Scirpus acutus* and *S. acutus*–*S. paludosus*, the indicated species were codominant. In the community designated as *S. paludosus*–*S. acutus*, *S. paludosus* was the chief dominant (comprising 80 to 95 percent of emergent growth) with lesser amounts of *S. acutus*.

Noticeable differences in species composition of dominant emergent vegetation in deep-marsh communities, represented by a continuum of overlapping species, can be correlated with gradients in salinity range, as shown in figure 20. Some of the species listed in this figure were common only in ponds disturbed by man's activities or as pioneering species in shallow open-water areas, recently flooded, following periods of drought. These species included *Scirpus fluviatilis* and *S. validus*. In slightly brackish deep-marsh zones in southeastern North Dakota, particularly in Richland and Sargent Counties, cattails, chiefly *Typha angustifolia* and *T.* "*glauca*," were more prevalent than else-

FIGURE 7.—Wet-meadow vegetation of a brackish semipermanent pond. *Hordeum jubatum* (wild barley) and *Distichlis stricta* (saltgrass) form the dominant plant community. August 8, 1962, Stutsman County, N. Dak.

FIGURE 8.—Wet-meadow vegetation of a subsaline semipermanent pond, dominated by *Distichlis stricta* (saltgrass). August 8, 1962, Stutsman County, N. Dak.

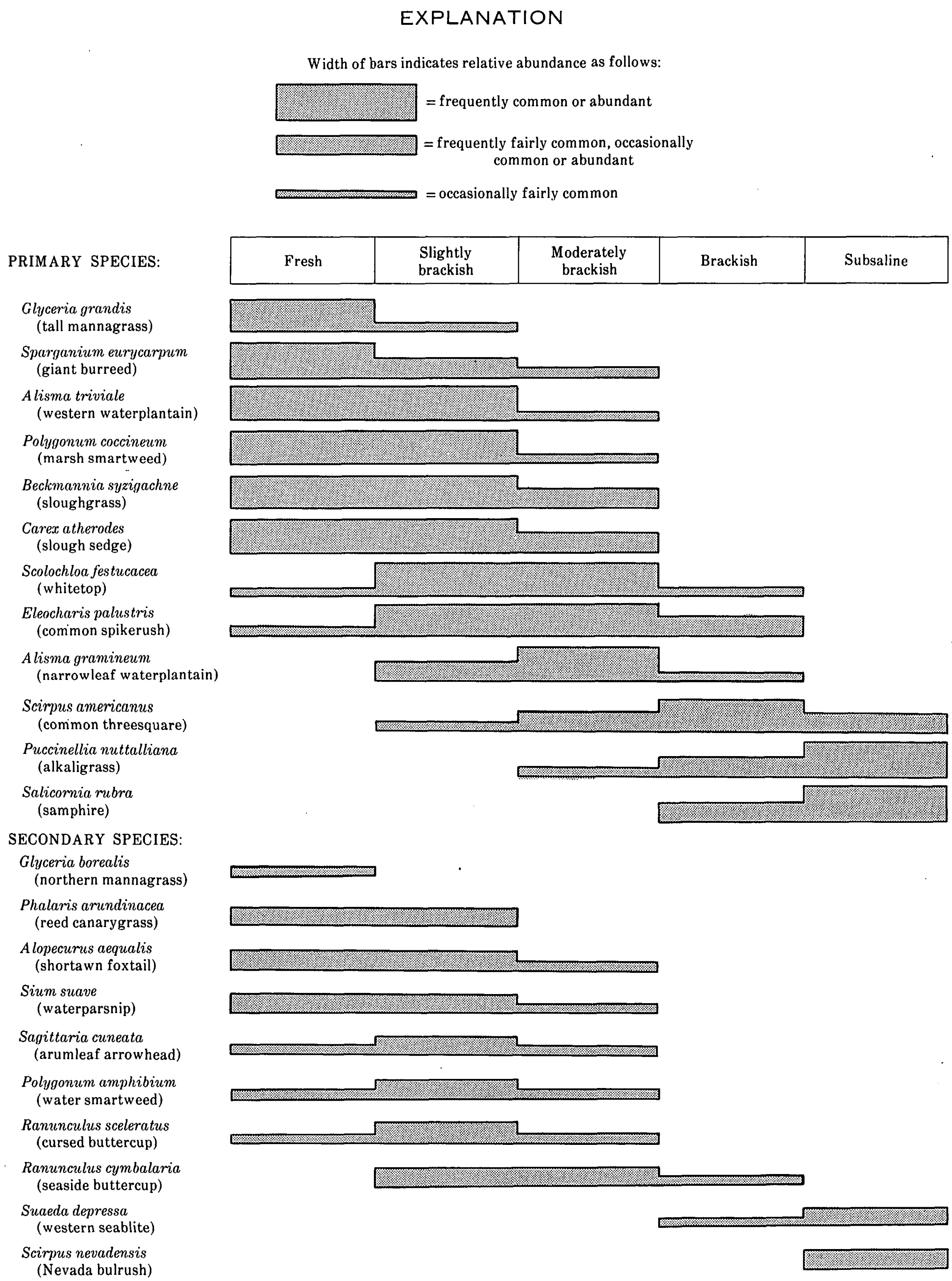


FIGURE 9.—Characteristic plant species of shallow-marsh emergent vegetation.

FIGURE 10.—Shallow-marsh emergent vegetation in a fresh seasonal pond with *Glyceria grandis* (tall mannagrass) as principal dominant species. July 13, 1964, Stutsman County, N. Dak.

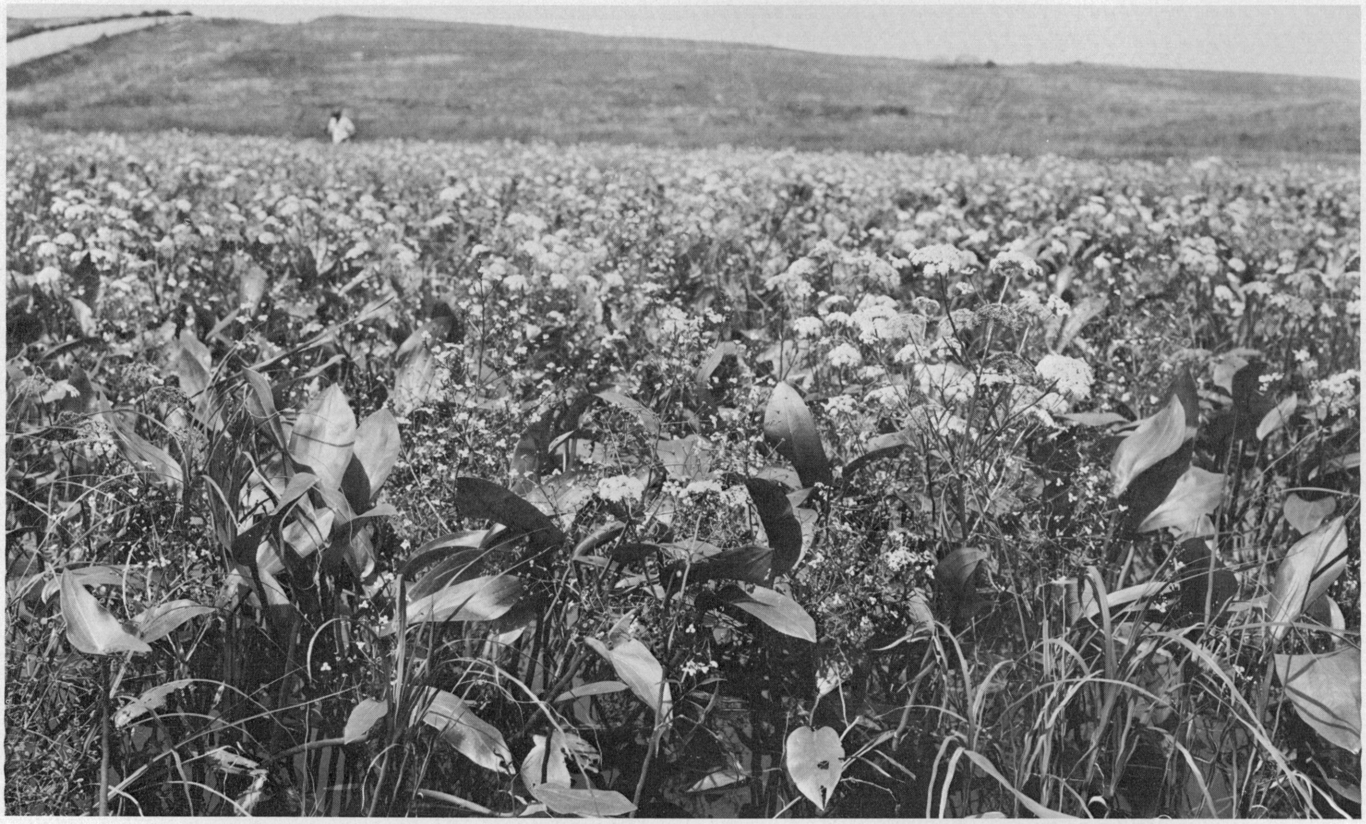


FIGURE 11.—Shallow-marsh emergent vegetation in a fresh seasonal pond with *Sium suave* (waterparsnip) and *Alisma triviale* (western waterplantain) as dominant species, and scattered *Carex atherodes* (slough sedge). August 7, 1962, Stutsman County, N. Dak.

FIGURE 12.—Shallow-marsh emergent vegetation in a fresh seasonal pond with *Carex atherodes* (slough sedge) as the principal dominant species. July 13, 1964, Stutsman County, N. Dak.

FIGURE 13.—Shallow-marsh emergent vegetation in a fresh seasonal pond with *Sparganium eurycarpum* (giant burreed) as the principal dominant species. August 8, 1962, Stutsman County, N. Dak.

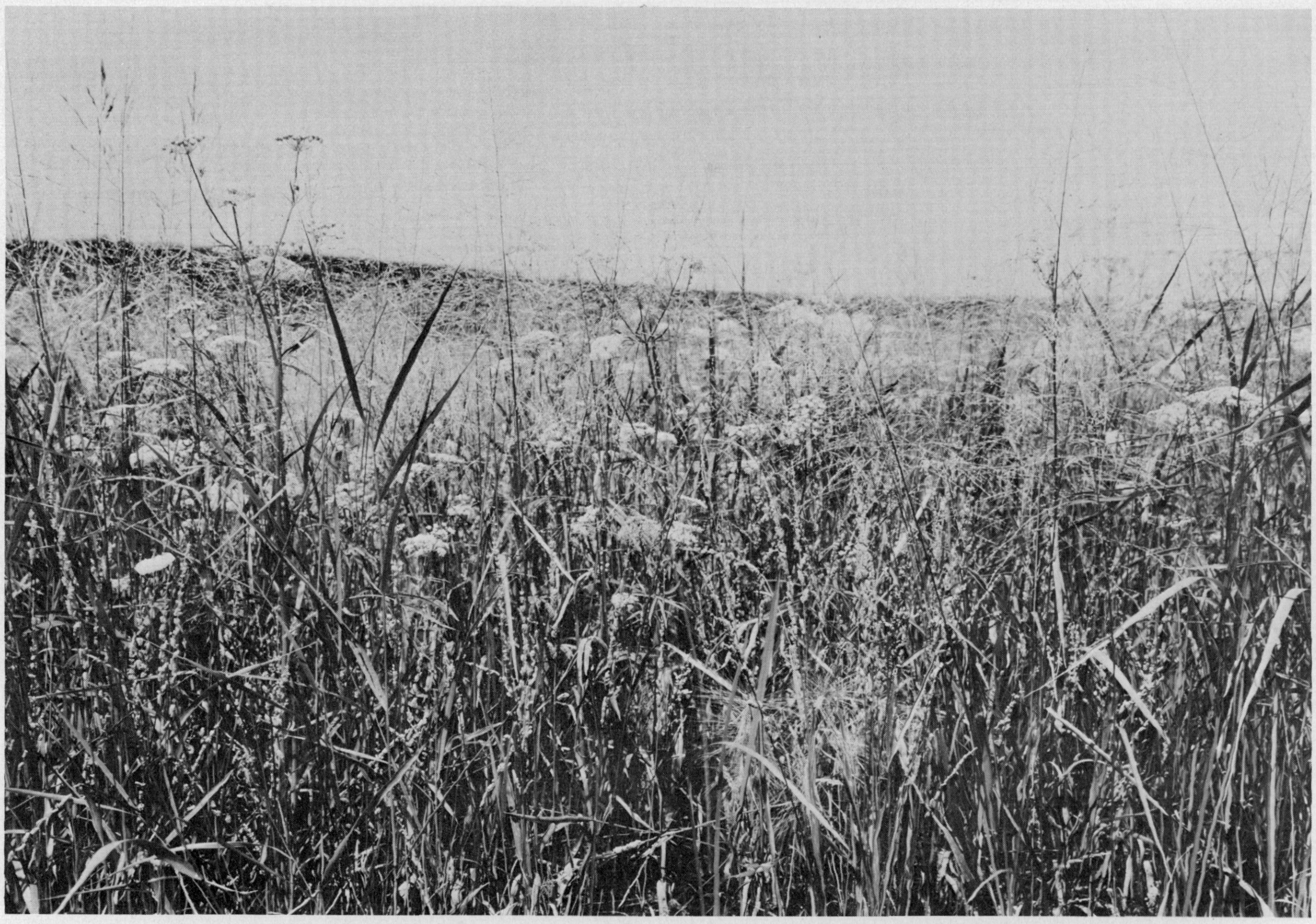


FIGURE 14.—Shallow-marsh emergent vegetation in a slightly brackish seasonal pond with *Glyceria grandis* (tall mannagrass), *Beckmannia syzigachne* (sloughgrass), and *Sium suave* (waterparsnip) as dominant species, and scattered *Scolochloa festucacea* (whitetop). July 31, 1962, Stutsman County, N. Dak.

FIGURE 15.—Shallow-marsh emergent vegetation in a slightly brackish semipermanent pond with *Scolochloa festucacea* (whitetop) as dominant species. *Scirpus acutus* (hardstem bulrush) is seen as the dark zone of deep-marsh emergent vegetation in the background. July 31, 1962, Stutsman County, N. Dak.

FIGURE 16.—Shallow-marsh emergent vegetation in a slightly brackish semipermanent pond with *Eleocharis palustris* (common spikerush) as the dominant species. Deep-marsh vegetation in background dominated by *Typha latifolia* (common cattail) at left and *Scirpus acutus* (hardstem bulrush) at right. August 8, 1962, Stutsman County, N. Dak.

FIGURE 17.—Shallow-marsh emergent vegetation in a brackish semipermanent pond with *Scirpus americanus* (common three-square) as the single species represented. Deep-marsh species dominating the central pond area in the background include *Scirpus acutus* (hardstem bulrush) and *S. paludosus* (alkali bulrush). July 28, 1964, Stutsman County, N. Dak.

where in the State. In this same area, *Scirpus acutus* was comparatively scarce. Photographs of characteristic deep-marsh communities that occur in wetlands having varying ranges of salinity are shown in figures 21–25.

Land-use factors had a rather limited influence on species composition, except during drought years, when noticeable changes in dominant emergent species occurred, particularly in slightly brackish and moderately brackish deep marsh. Under both average and high-water conditions, a mixture of cattails (including *Typha latifolia* and *T.* "*glauca*") and *Scirpus acutus* represented the principal dominant species in slightly brackish deep marsh. During drought years, this zone was often subject to heavy grazing, and as a consequence, cattails were largely eliminated while nearly pure stands of *S. acutus* gradually developed. Extensive local stands of *S. validus* became established in ponds that had been severely trampled by cattle. *S. acutus* also occurred as the sole dominant of numerical importance in grazed moderately brackish deep marsh. In natural ungrazed deep-marsh zones of this salinity range, nearly pure stands of *S. acutus* were found in the deeper parts, while stands of *S. paludosus* or mixtures of *S. paludosus* and *S. acutus* were characteristic of the shallower parts that adjoined the shallow-marsh zone. Brackish deep-marsh zones differed from moderately brackish deep-marsh zones in that a mixture of *S. acutus* and *S. paludosus* was predominant throughout the brackish zones. Apparently, species composition of deep-marsh vegetation in brackish and subsaline ponds and lakes was unaffected by grazing.

Heavy siltation of ponds in cropland areas was frequent owing to erosion of topsoils on the watersheds. Under these conditions, *Scirpus fluviatilis* often predominated in slightly brackish deep marsh. Occasionally, during drought conditions, slightly brackish deep-marsh zones were plowed and cultivated for agricultural purposes. When surface water was replenished on these disturbed areas, pioneering species such as *S. fluviatilis* or *S. validus* became established and remained as the principal dominants during the initial successional stages.

FEN EMERGENT VEGETATION

Fen zones can be described as quagmires with floating or quaking surface mats of emergent vegetation. Some fen zones contain springs, which issue from raised mounds of wet organic material that are covered with mats of dense vegetation. Emergent vegetation characteristic of fens occasionally dominated the central areas of pond basins but more frequently occurred as isolated pockets along the margins of other ponds and lakes. The habitat occupied by some of these species (*Salix candida*, *Aster junciformis*, and *Carex sartwellii*) was described by Fernald (1950) as calcareous bog. The spring waters analyzed were generally of the calcium bicarbonate type. Surface water was sometimes lacking in this zone, although the bottom soils were normally saturated by alkaline ground-water seepage. Most bottom soils in the deeper parts had the consistency of soft muck or ooze. Grazing of fens produced hummocks, especially in outer, marginal areas. Specific-conductance measurements of surface water indicated that fens were in the slightly brackish salinity range.

Fen pockets, adjoining the more typical basin wetlands, were most frequent along the margins of brackish, subsaline, and saline ponds and lakes. In these locations, fens were often the result of seeps on gently sloping terrain adjacent to a pond or lake. Ordinarily, a progressive increase in specific conductance took place as water moved down slope, and this was reflected by corresponding changes in species composition of wetland plants; typical fen species gradually merged with and were replaced by those species characteristic of various salinity ranges in other zones.

Characteristic plant species in fens are listed in table 5. Many of the dominant species listed are plants that correspond in structural type (identical species may be represented) to prevalent emergent species that are typical of deep-marsh, shallow-marsh, or wet-meadow zones. Plants of these principal structural types usually were found as a general mixture or in a mosaic pattern, with mixed or single species of each structural type occurring as irregular disjunct patches. However, in a few fens, a definite zonation was apparent. In these fens, the tall, coarser stemmed species inhabited the deeper or more boggy central parts; the short, fine-stemmed species were found in the shallow marginal areas; and plants of intermediate height occupied the intervening bands.

The coarser and taller emergent species in fens included *Phragmites communis* or *Typha latifolia* in undisturbed areas and *Scirpus validus* in areas that had been heavily grazed. Typical plants of intermediate height that were similar in appearance to shallow-marsh dominants included *Carex aquatilis*, *C. rostrata*, and *Cicuta maculata*. *Carex atherodes* and *Glyceria striata* were sometimes major species in this group, especially in plant communities that represented ecotones between fens and shallow-marsh vegetation. Woody shrubs, such as *Salix interior* and *S. candida*, also were

FIGURE 18.—Shallow-marsh emergent vegetation in a subsaline semipermanent pond. Slender plants on right are *Puccinellia nuttalliana* (alkaligrass). Several individuals of *Suaeda depressa* (western seablite) are seen rising above the dense mat of *Salicornia rubra* (samphire). August 3, 1962, Stutsman County, N. Dak.

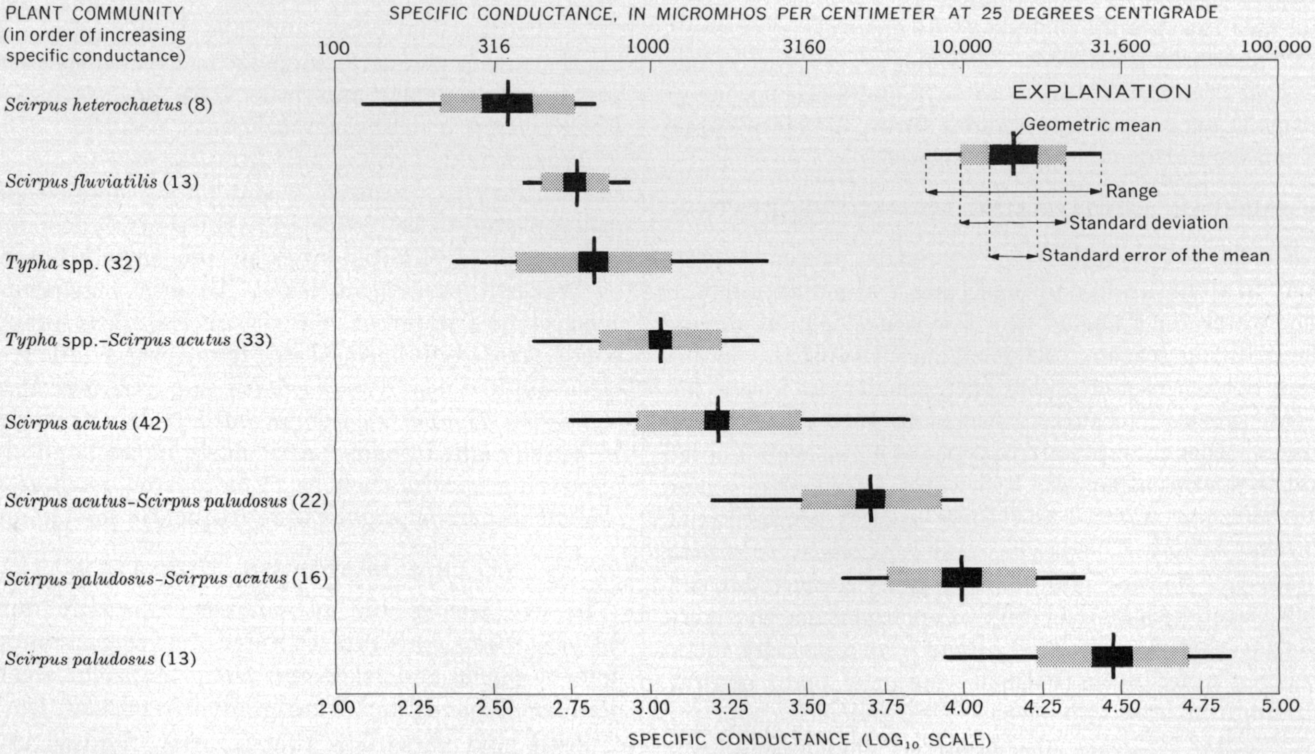


FIGURE 19.—Relationship of dominant deep-marsh emergent communities to specific conductance of pond water. Number of ponds sampled for each community is shown in parentheses. For details, see page D11.

TABLE 5.—*Characteristic plant species of fen emergent vegetation*

Primary species	
Typha latifolia (common cattail).	*Carex aquatilis* (water sedge).
Glyceria striata (fowl mannagrass).	*Salix interior* (sandbar willow).
Phragmites communis (phragmites).	*Salix candida* (hoary willow).
Scirpus validus (softstem bulrush).	*Cicuta maculata* (common waterhemlock).
	Aster junciformis (rush aster).
Secondary species	
Triglochin maritima (common arrowgrass).	*Parnassia palustris* (bog star).
Deschampsia caespitosa (tufted hairgrass).	*Viola nephrophylla* (kidney-leaf violet).
Calamagrostis inexpansa (northern reedgrass).	*Epilobium leptophyllum* (willowherb).
Muhlenbergia glomerata (marsh muhly).	*Lysimachia thrysiflora* (tufted loosestrife).
Eleocharis calva (slender spikerush).	*Gentiana procera* (small fringed gentian).
Eriophorum angustifolium (tall cottongrass).	*Asclepias incarnata* (swamp milkweed).
Scirpus atrovirens (dark-green bulrush).	*Scutellaria epilobiifolia* (marsh skullcap).
Carex sartwellii (sedge).	*Lobelia kalmii* (Kalm's lobelia).
Carex interior (sedge).	*Eupatorium maculatum* (Joe-pye weed).
Carex aurea (golden sedge).	*Solidago graminifolia* (narrowleaf goldenrod).
Carex lanuginosa (sedge).	*Helianthus rydbergii* (clustered sunflower).
Carex rostrata (beaked sedge).	
Juncus torreyi (Torrey's rush).	
Ranunculus septentrionalis (swamp buttercup).	

frequent. Short or fine-stemmed species that resembled wet-meadow plants include *Calamagrostis inexpansa*, *Muhlenbergia glomerata*, *Eriophorum angustifolium*, *Scirpus atrovirens*, *Juncus torreyi*, and many species of sedge (*Carex* spp.) and slender forbs. A typical stand of fen vegetation is shown in figure 26.

SUBMERGED AND FLOATING AQUATIC VEGETATION

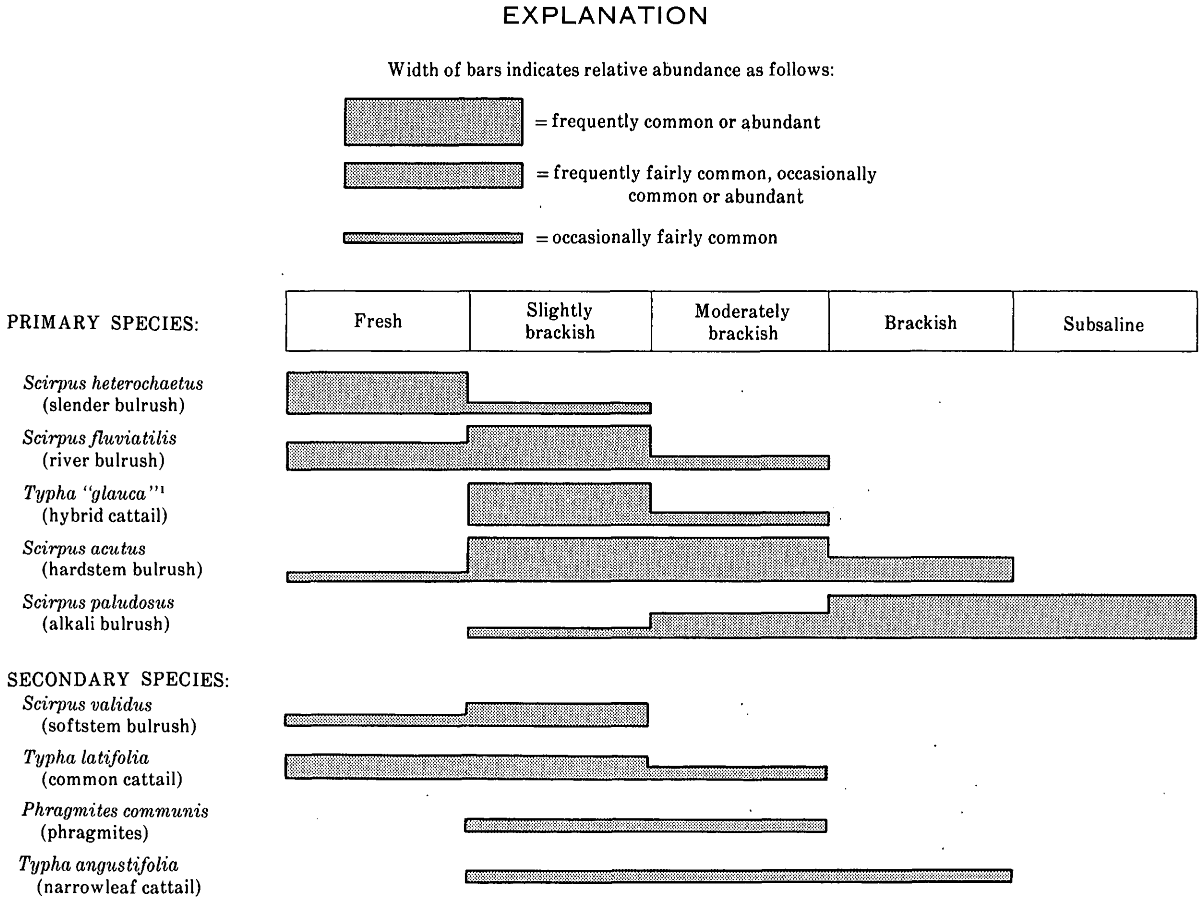
Submerged and floating vegetation occurred regularly in all natural ponds and lakes that maintained surface water for a period of a few weeks or more during the growing season. The great majority of the species were bottom-rooted plants with submerged leaves, but a few species had surface leaves as well. Free-floating plants, other than primitive types of algae, were limited to two species of aquatic liverworts, *Riccia fluitans* and *Ricciocarpus natans*, and three species of duckweed, *Lemna minor*, *L. trisulca*, and *Spirodela polyrhiza*. These free-floating plants were largely restricted to surface water with an overstory of emergent marsh plants. Bottom-rooted submerged plants were generally found in open-water areas without emergent plant growth, although at least two species, *Drepanocladus* spp. and *Utricularia vulgaris*, also occurred commonly as subdominants in the aquatic understory of emergent vegetation.

Species composition of submerged and floating vegetation was closely correlated with salinity of surface water, as shown in figure 27. Views of typical ponds are shown in figures 28–34. Many species were intolerant of any appreciable salt concentrations and were prevalent only in fresh or slightly brackish ponds and lakes. These included *Potamogeton gramineus*, *P. pusillus*, *P. richardsonii*, *Ceratophyllum demersum*, *Callitriche palustris*, and *Myriophyllum exalbescens*. At the other extreme, in saline surface water of alkali ponds and lakes, *Ruppia maritima* was the only vascular plant represented; it developed whenever surface water was maintained for a few weeks during the summer. Several submerged species, including *Chara* spp., *P. pectinatus*, and *Zannichellia palustris*, usually reached their best development under conditions of intermediate salinity such as those found in moderately brackish and brackish ponds and lakes. Vegetation characteristic of subsaline surface water was especially sensitive to periodic variations in salinity. During the growing season, temporary changes in species composition often took place as the result of dilution associated with higher water levels. On these occasions, extensive beds of *R. maritima* were replaced by luxuriant growths of *P*, *pectinatus* and *Chara* spp.

Most species of aquatic plants occurred in semipermanent ponds and lakes and also in open-water areas near shorelines of permanent lakes. A few species were restricted to seasonal ponds and lakes that persisted during the spring and early summer but frequently became dry in late summer and fall. These species included *Potamogeton gramineus*, *Callitriche palustris*, *Myriophyllum heterophyllum*, and *Marsilea mucronata*. Two species, *Ruppia occidentalis* and *Potamogeton vaginatus*, appeared to be restricted to the central, deep open-water zone of slightly brackish, moderately brackish, or brackish permanent lakes. Aquatic vegetation in open surface water of fens or other slightly brackish ponds, strongly influenced by ground-water inflow, was often limited to *Drepanocladus* spp., *Ceratophyllum demersum*, *Hippuris vulgaris*, and *Utricularia vulgaris*. In heavily silted ponds, particularly in cropland areas, pioneering species such as *Potamogeton pusillus* and *Ranunculus trichophyllus* were frequently predominant.

NATURAL DRAWDOWN VEGETATION

In late spring and in summer, especially during drought years, open surface water occurring in semipermanent ponds and lakes and along marginal areas of permanent ponds and lakes gradually recedes, leaving exposed mud flats. This process often resulted in the development of drawdown vegetation composed of annual species (mostly forbs) that require exposed mud



[1]Recent investigations show this form to be hybrid of *Typha latifolia* and *Typha angustifolia*

FIGURE 20.—Characteristic plant species of deep-marsh emergent vegetation.

or bare soil for germination. After the drawdown vegetation became established, ponds and lakes were occasionally replenished by runoff from heavy rains, and the characteristic drawdown species then appeared as plant emergents. Following periods of unusually high water levels, a similar successional sequence sometimes took place in seasonal ponds that became dry.

Under appropriate conditions, drawdown vegetation became well established in ponds and lakes whose salinity ranged from fresh to subsaline. Species composition was directly related to variations in salinity as indicated in figure 35. A view of drawdown vegetation in a brackish semipermanent pond is shown in figure 36. *Kochia scoparia* was the only drawdown species that could tolerate the high salt concentrations of subsaline ponds and lakes, and there it was restricted to parts of dry basins that were occupied by stunted or dead growth of *Scirpus paludosus*. The exposed salt-crusted open mud flats of subsaline and saline ponds and lakes were devoid of emergent vegetation of any kind.

CROPLAND DRAWDOWN VEGETATION

In cropland areas, most shallow-pond basins were cultivated whenever the water disappeared and the bottom soils became dry—that is during a drawdown situation. In some of these basins, the wet periods lasted through late spring or early summer, subsequently leaving exposed mud flats. As a consequence, a type of drawdown vegetation soon became established that was quite distinct from drawdown vegetation found in natural untilled pond basins. Most of the characteristic species, which are listed in figure 37, are coarse introduced annual weeds and grasses. A view of cropland drawdown vegetation is shown in figure 38.

Water in these ponds, when replenished by heavy rains in summer or early fall, was found to range from fresh to moderately brackish. No appreciable differences in species composition of drawdown vegetation were noted in basins with fresh or slightly brackish sur-

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FIGURE 21.—Deep-marsh emergent vegetation in a fresh semipermanent pond, represented here by *Scirpus heterochaetus* (slender bulrush). A submerged aquatic species, *Utricularia vulgaris* (common bladderwort), can be seen in the open water. July 30, 1965, Stutsman County, N. Dak.

FIGURE 22.—Deep-marsh emergent vegetation in a slightly brackish semipermanent pond. The taller, darker *Typha "glauca"* (hybrid cattail) shown on the left is codominant with the shorter *T. latifolia* (common cattail) on the right. July 15, 1965, Stutsman County, N. Dak.

FIGURE 23.—Deep-marsh emergent vegetation in a moderately brackish semipermanent pond. *Scirpus acutus* (hardstem bulrush) comprises the single dominant species. August 8, 1962, Stutsman County, N. Dak.

FIGURE 24.—Deep-marsh emergent vegetation in a brackish semipermanent pond. Codominant species include *Scirpus acutus* (hardstem bulrush, taller, darker growth) and *S. paludosus* (alkali bulrush, shorter, lighter growth). August 7, 1962, Stutsman County, N. Dak.

FIGURE 25.—Deep-marsh emergent vegetation in a subsaline semipermanent pond, represented by a single species, *Scirpus paludosus* (alkali bulrush). August 2, 1962, Stutsman County, N. Dak.

FIGURE 26.—Fen emergent vegetation; principal dominants include *Carex aquatilis* (water sedge) and *Calamagrostis inexpansa* (northern reedgrass) with scattered *Salix candida* (hoary willow). This association is typical of many fens found in North Dakota. September 8, 1964, Clearwater County, Minn.

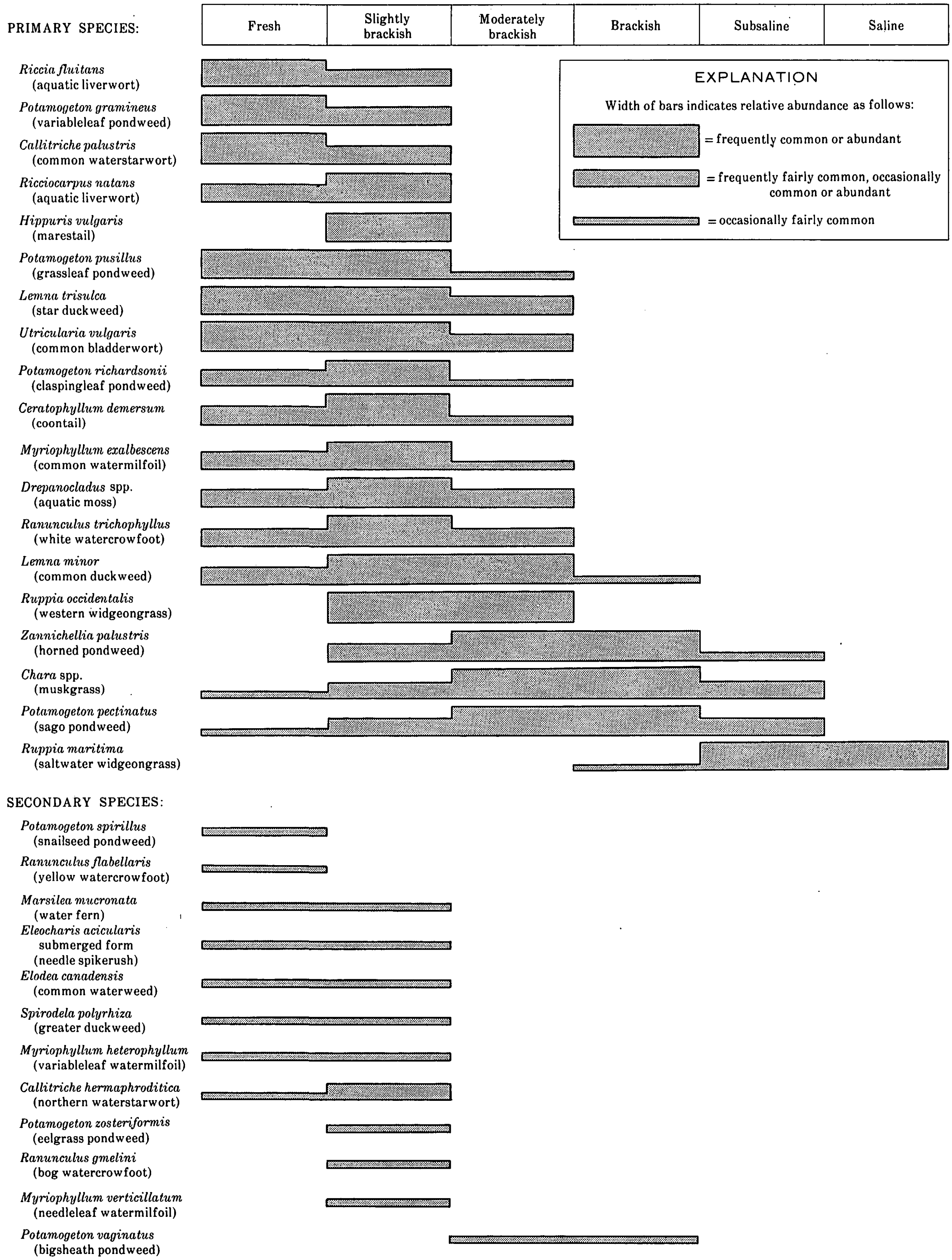

FIGURE 27.—Characteristic plant species of submerged and floating vegetation.

FIGURE 28.—Submerged and floating vegetation in a fresh seasonal pond. The oval floating leaves and grasslike submerged leaves are *Potamogeton gramineus* (variableleaf pondweed), a freshwater species. Longer floating leaves are those of *Glyceria grandis* (tall mannagrass) just prior to their becoming erect and emerging from the water. August 19, 1964, Stutsman County, N. Dak.

FIGURE 29.—Submerged and floating vegetation in a slightly brackish semipermanent pond. Shown is *Potamogeton richardsonii* (claspingleaf pondweed); in this species, only the fruiting heads appear at surface. July 30, 1965, Stutsman County, N. Dak.

FIGURE 30.—Submerged and floating vegetation in a slightly brackish seasonal pond. Shown is *Utricularia vulgaris* (common bladderwort) in bloom. July 15, 1965, Stutsman County, N. Dak.

FIGURE 31.—Submerged and floating vegetation in a heavily silted slightly brackish seasonal pond. Shown is a dense bed of *Ranunculus trichophyllus* (white watercrowfoot) in bloom. June 1966, Stutsman County, N. Dak.

FIGURE 32.—Submerged and floating vegetation in a fen pond. Shown are beds of *Drepanocladus* spp. (aquatic moss) and scattered *Utricularia vulgaris* (common bladderwort) in bloom. July 13, 1964, Stutsman County, N. Dak.

face water. However, species found in basins with moderately brackish surface water were more limited in number and also exhibited different degrees of abundance.

In many cropland basins, drawdown species were associated with pioneering plants that were representative of early successional stages of wet-meadow or shallow-marsh vegetation. Characteristic wet-meadow species found in these situations included *Carex sartwellii*, *C. vulpinoidea*, *Juncus dudleyi*, *J. torreyi*, *Rumex mexicanus*, *Ranunculus macounii*, *Rorippa islandica*, *Potentilla norvegica*, and *Artemisia biennis*. The principal pioneering shallow-marsh species were represented by *Alisma triviale*, *Alopecurus aequalis*, *Beckmannia syzigachne*, and *Polygonum coccineum*.

CROPLAND TILLAGE VEGETATION

Some shallow-pond basins in agricultural areas lost their surface water in the early spring, and the cropland soil thus exposed remained dry for several weeks or more during the growing season. Basins of this type ordinarily were cultivated as soon as the bottom soils were dry and then were either planted with small grain or row crops or were allowed to remain in summer fallow. In those left fallow, a type of weedy growth characteristic of moist soil in fallow fields or neglected crop fields rapidly developed. The principal tillage plants involved are listed in table 6. Later in the season, these shallow basins were occasionally reflooded for brief periods by fresh-water runoff resulting from heavy rains.

TABLE 6.—*Characteristic plant species of cropland tillage vegetation*

Primary species	
Setaria glauca (yellow foxtail).	*Kochia scoparia* (kochia).
Polygonum convolvulus (wild buckwheat).	
Secondary species	
Agropyron smithii (western wheatgrass).	*Melilotus alba* (white sweetclover).
Agropyron repens (quackgrass).	*Melilotus officinalis* (yellow sweetclover).
Salsola kali (Russian-thistle).	*Androsace occidentalis* (fairy candelabra).
Amaranthus retroflexus (rough pigweed).	*Ellisia nyctelea* (waterpod).
Thlaspi arvense (pennycress).	*Erigeron canadensis* (horseweed
Brassica kaber (field mustard).	*Iva xanthifolia* (false ragweed).
Descurainia sophia (flixweed).	
Rosa arkansana (prairie rose).	

GUIDE TO PLANT NAMES

[Figure and table numbers refer to lists of characteristic plant species of major vegetative types as follows: table 4, wetland low-prairie; figure 4, wet-meadow; figure 9, shallow-marsh emergent; figure 20, deep-marsh emergent; table 5, fen emergent; figure 27, submerged and floating; figure 35, natural drawdown; figure 37, cropland drawdown; and table 6, cropland tillage]

Scientific name	Common name	Figure	Table
Agoseris glauca (Pursh) Raf.	Prairie false dandelion		4
Agropyron repens (L.) Beauv.	Quackgrass	37	6
smithii Rydb.	Western wheatgrass		6
trachycaulum (Link) Malte	Slender wheatgrass		4
Alopecurus aequalis Sobol.	Shortawn foxtail	9	
Alisma gramineum K. C. Gmel.	Narrowleaf waterplantain	9	
triviale Pursh	Western waterplantain	9	
Amaranthus retroflexus L.	Rough pigweed		6
Ambrosia psilostachya DC.	Perennial ragweed		4
Ammannia coccinea Rothb.	Ammannia	37	
Andropogon gerardi Vitman	Big bluestem		4
Androsace occidentalis Pursh	Fairy candelabra		6
Anemone canadensis L.	Canada anemone		4
Apocynum sibiricum Jacq.	Claspingleaf dogbane	4	
Artemisia biennis Willd.	Biennial wormwood	4	
ludoviciana Nutt.	White sage		4
Asclepias incarnata L.	Swamp milkweed		5
speciosa Torr.	Showy milkweed	4	
Aster brachyactis Blake	Rayless aster	35	
ericoides L.	Smallflower aster		4
junciformis Rydb.	Rush aster		5
simplex Willd.	Lowland white aster	4	
Atriplex patula L.	Orach	4	
Bacopa rotundifolia (Michx.) Wettst.	Waterhyssop	37	
Beckmannia syzigachne (Nutt.) Fern.	Sloughgrass	9	
Bidens cernua L.	Marigold beggarticks	35	
frondosa L.	Common beggarticks	35, 37	
vulgata Greene	Tall beggarticks	35	
Boltonia latisquama Gray	False-aster	4	
Brassica kaber (DC.) L. C. Wheeler	Field mustard		6
Calamagrostis canadensis (Michx.) Nutt.	Blue-joint	4	
inexpansa Gray	Northern reedgrass	4	5
Callitriche hermaphroditica L.	Northern waterstarwort	27	
palustris L.	Common waterstarwort	27	
Carex aquatilis Wahlenb.	Water sedge		5
atherodes Spreng.	Slough sedge	9	
aurea Nutt.	Golden sedge		5
brevior (Dew.) Mackenz.	Fescue sedge		4
interior Bailey	Sedge		5
laeviconica Dew.	do.	4	
lanuginosa Michx.	do.	4	5
praegracilis W. Boott	do.	4	
rostrata Stokes	Beaked sedge		5
sartwellii Dew.	Sedge	4	5
vulpinoidea Michx.	Fox sedge	4	
Ceratophyllum demersum L.	Coontail	27	
Chara spp. Valliant	Muskgrass	27	
Chenopodium album L.	Lamb's quarters	35	
rubrum L.	Red goosefoot	35	
salinum Standl.	Oakleaf goosefoot	35	
Cicuta maculata L.	Common waterhemlock		5
Cirsium arvense (L.) Scop.	Canadian thistle	4	
Crepis runcinata (James) T. & G.	Scapose hawksbeard		4
Cyperus acuminatus Torr. & Hook.	Cyperus	37	
Deschampsia caespitosa L. Beauv.	Tufted hairgrass		5

FIGURE 33.—Submerged and floating vegetation in a brackish semipermanent pond. Shown is a dense bed of *Potamogeton pectinatus* (sago pondweed). *Scirpus paludosus* (alkali bulrush), a deep-marsh emergent species, can be seen in the background. August 6, 1962, Stutsman County, N. Dak.

Scientific name	Common name	Figure	Table
Descurainia sophia (L.) Webb	Flixweed		6
Distichlis stricta (Torr.) Rydb.	Saltgrass	4	
Drepanocladus spp. (C. M.) Roth	Aquatic moss	27	
Echinochloa crusgalli (L.) Beauv.	Wild millet	37	
Eleocharis acicularis (L.) R. & S.	Needle spikerush	27, 35, 37	
calva Torr.	Slender spikerush		5
engelmanni Steud.	Engelmann's spikerush	37	
palustris (L.) R. & S.	Common spikerush	9	
Ellisia nyctelea L.	Waterpod		6
Elodea canadensis Michx.	Common waterweed	27	
Epilobium glandulosum Lehm.	Northern willowherb	4	
leptophyllum Raf.	Willowherb		5
Erigeron canadensis L.	Horseweed		6
Eriophorum angustifolium Honckeny	Tall cottongrass		5
Eupatorium maculatum L.	Joe-pye weed		5
Gentiana procera Holm.	Small fringed gentian		5
Glaux maritima L.	Sea milkwort	4	
Glyceria borealis (Nash) Batchelder	Northern mannagrass	9	
grandis S. Wats.	Tall mannagrass	9	
striata (Lam.) Hitchc.	Fowl mannagrass		5
Glycyrrhiza lepidota (Nutt.) Pursh	Wild licorice		4
Gratiola neglecta Torr.	Hedge hyssop	37	
Helenium autumnale L.	Sneezeweed	4	
Helianthus maximiliani Schrad.	Narrowleaf sunflower		4
rydbergii Britton	Clustered sunflower		5
Heliotropium curassavicum L.	Seaside heliotrope	35	
Hierochloe odorata (L.) Beauv.	Sweetgrass	4	
Hippuris vulgaris L.	Marestail	27	

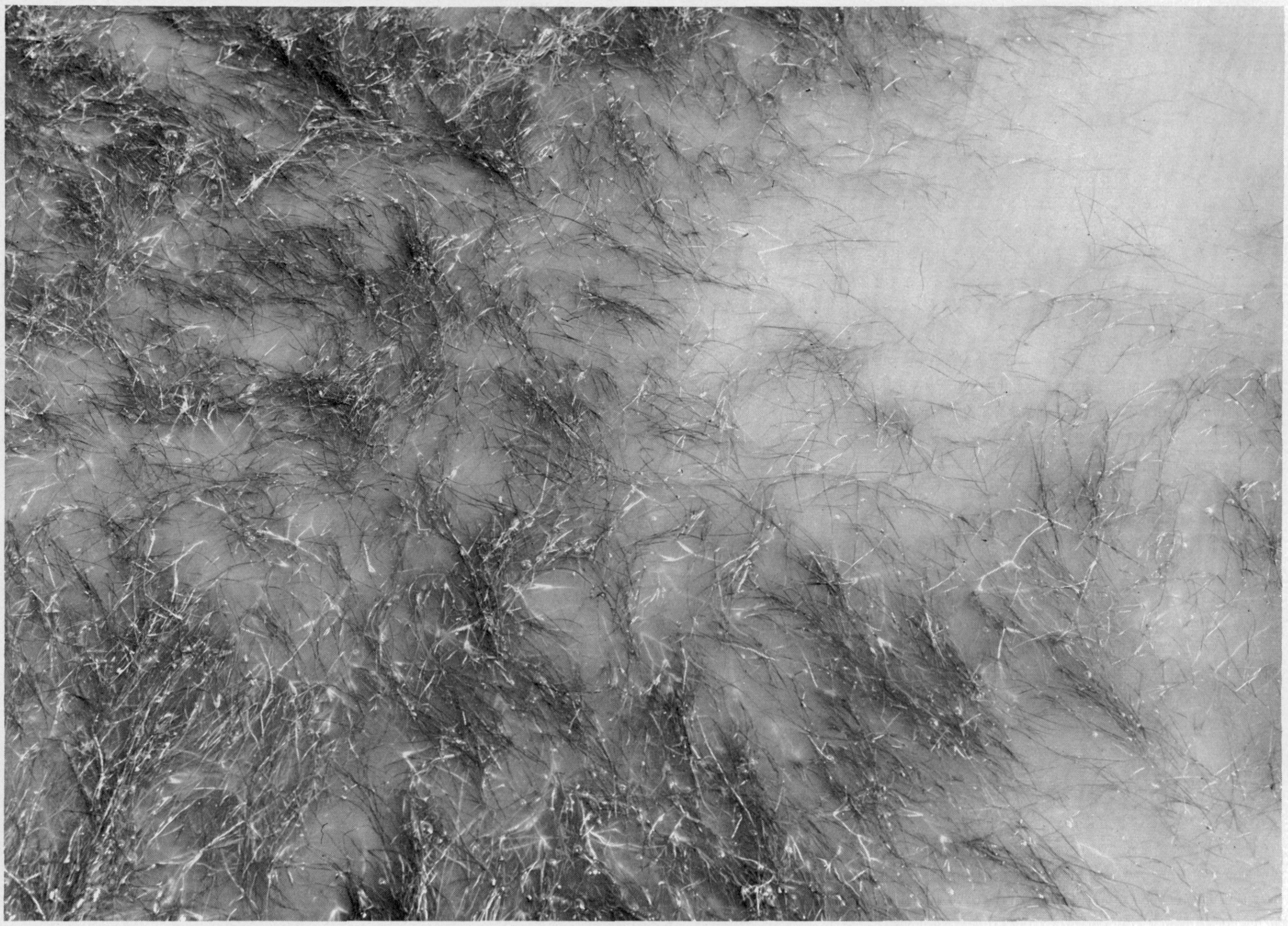

FIGURE 34.—Submerged and floating vegetation in a subsaline semipermanent pond, showing a dense bed of *Ruppia maritima* (saltwater widgeongrass). July 27, 1964, Stutsman County, N. Dak.

Scientific name	Common name	Figure	Table
Hordeum jubatum L.	Wild barley	4, 35, 37	
Iva xanthifolia Nutt.	False ragweed		6
Juncus balticus Willd.	Baltic rush	4	
bufonius L.	Toad rush	35	
dudleyi Wieg.	Dudley's rush	4	
interior Wieg.	Rush	4	
torreyi Coville	Torrey's rush	4	5
Kochia scoparia (L.) Roth	Kochia	35	6
Lactuca scariola L.	Prickly lettuce	4	
Lemna minor L.	Common duckweed	27	
trisulca L.	Star duckweed	27	
Lilium philadelphicum L.	Red lily		4
Limosella aquatica L.	Mudwort	37	
Lindernia dubia (L.) Pennell	False pimpernel	37	
Lobelia kalmii L.	Kalm's lobelia		5
Lycopus asper Greene	Western waterhorehound	4	
Lysimachia hybrida Michx.	Lanceleaf loosestrife	4	
thyrsiflora L.	Tufted loosestrife		5
Marsilea mucronata A. Br.	Water fern	27, 37	
Melilotus alba Desr.	White sweetclover		6
officinalis (L.) Lam.	Yellow sweetclover		6
Mentha arvensis L.	Wild mint	4	

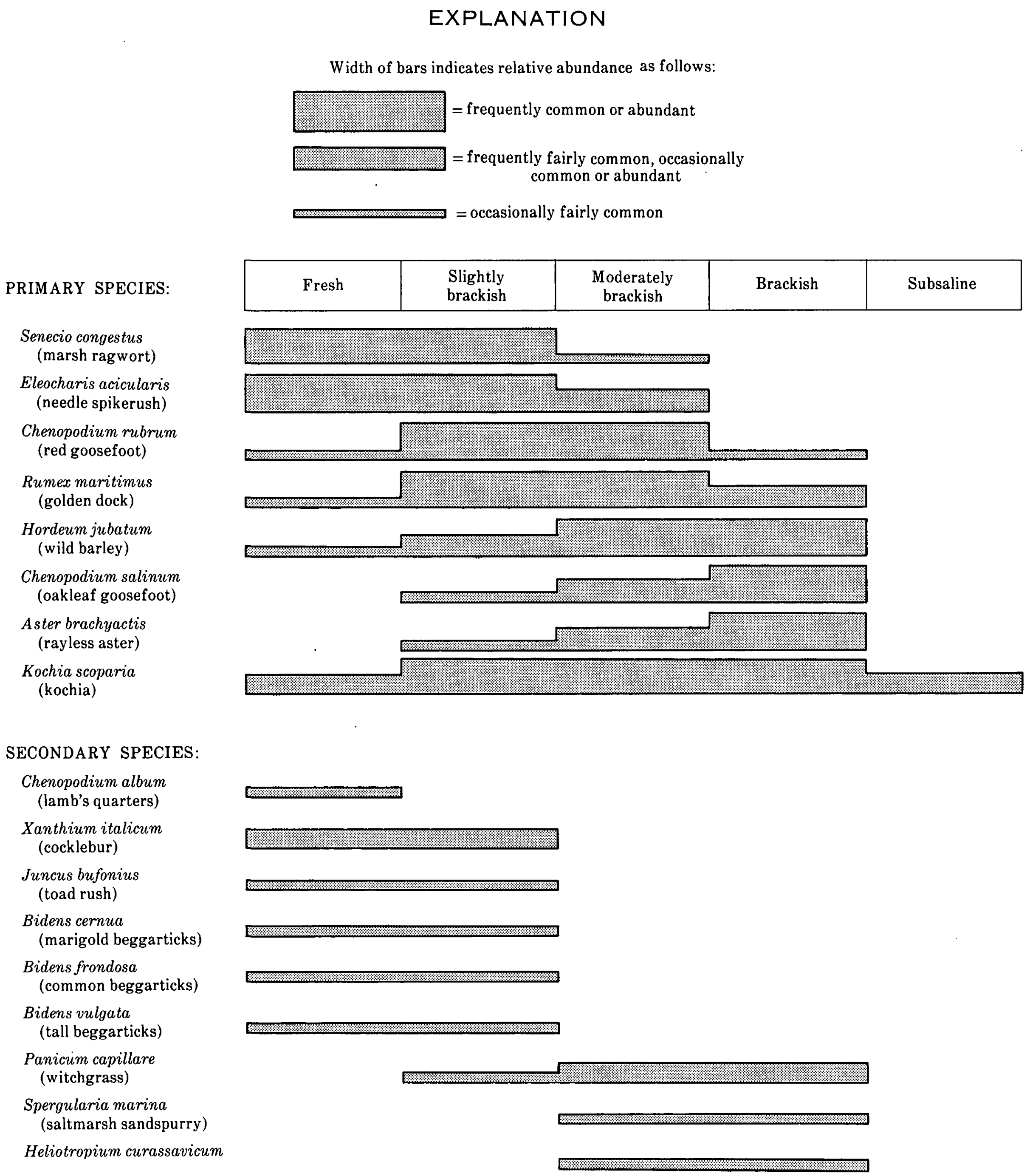

FIGURE 35.—Characteristic plant species of natural drawdown vegetation.

Scientific name	Common name	Figure	Table
Muhlenbergia asperifolia (Nees & Meyen) Parodi	Scratchgrass	4	--------
glomerata (Willd.) Trin.	Marsh muhly		5
Myriophyllum exalbescens Fern.	Common watermilfoil	27	--------
heterophyllum Michx.	Variableleaf watermilfoil	27	--------
verticillatum L.	Needleleaf watermilfoil	27	--------
Panicum capillare L.	Witchgrass	35, 37	--------
virgatum L.	Switchgrass		4
Parnassia palustris L.	Bog star		5
Phalaris arundinacea L.	Reed canarygrass	9	--------
Phragmites communis Trin.	Phragmites	20	5

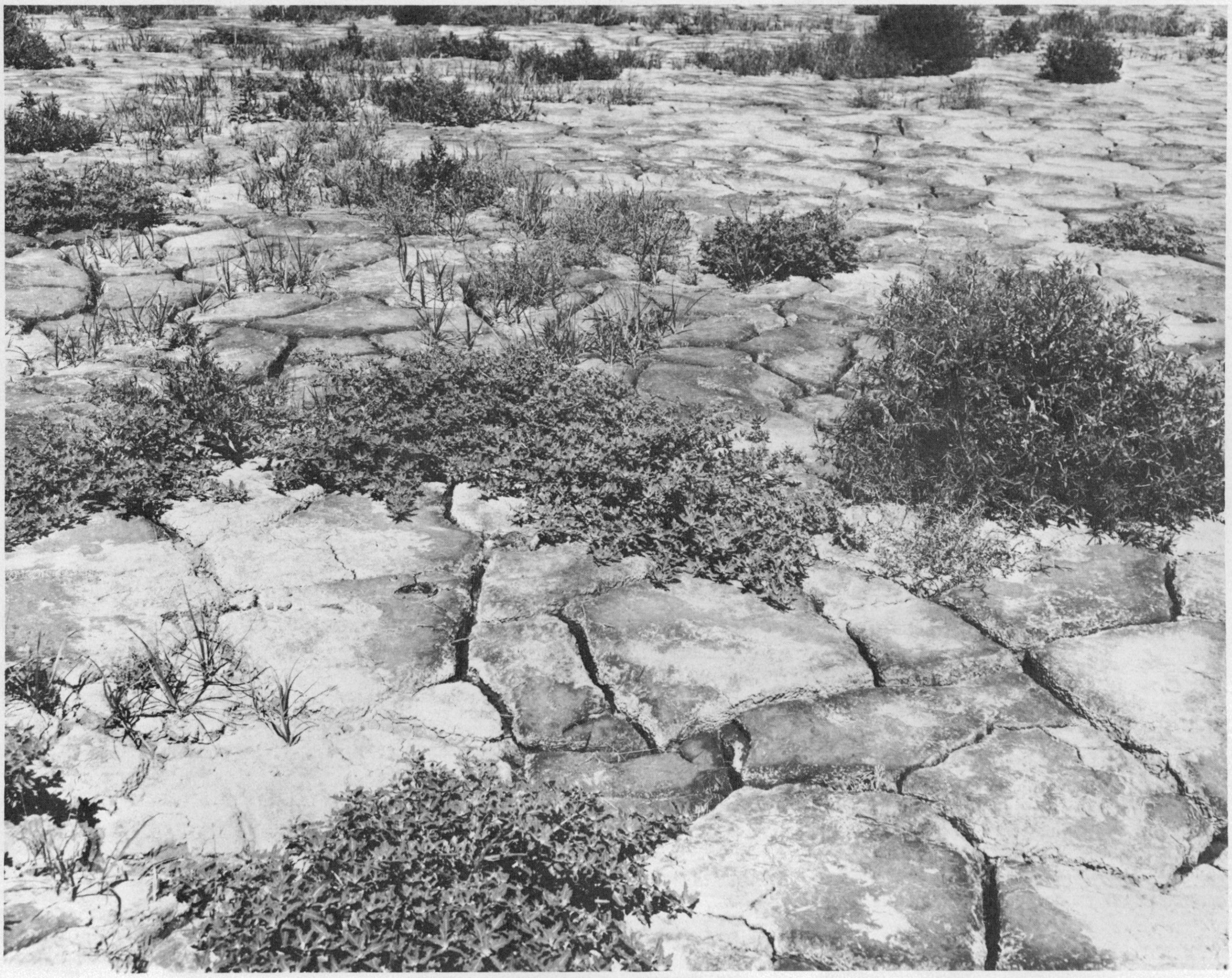

FIGURE 36.—Natural drawdown vegetation in a brackish semipermanent pond during a severe drought. Low pale forbs are *Chenopodium salinum* (oakleaf goosefoot), and larger dark forbs are *Kochia scoparia* (kochia). *Scattered Scirpus paludosus* (alkali bulrush) seedlings have had their growth arrested by lack of water. August 3, 1961, Stutsman County, N. Dak.

Scientific name	Common name	Figure	Table
Plagiobothrys scopulorum (Greene) I. M. Johnston	False-purslane	37	
Plantago eriopoda Torr.	Alkali plantain	4	
major L.	Common plantain	37	
Poa palustris L.	Fowl bluegrass	4	
pratensis L.	Kentucky bluegrass		4
Polygonum amphibium L.	Water smartweed	9	
coccineum Muhl.	Marsh smartweed	9	
convolvulus L.	Wild buckwheat		6
lapathifolium L.	Nodding smartweed	37	
prolificum L.	Longbranch knotweed	4	
Potamogeton gramineus L.	Variableleaf pondweed	27	
pectinatus L.	Sago pondweed	27	
pusillus L.	Grassleaf pondweed	27	
richardsonii (Ar. Benn.) Rydb.	Claspingleaf pondweed	27	
spirillus Tuckerm.	Snailseed pondweed	27	
vaginatus Turcz.	Bigsheath pondweed	27	
zosteriformis Fern.	Eelgrass pondweed	27	

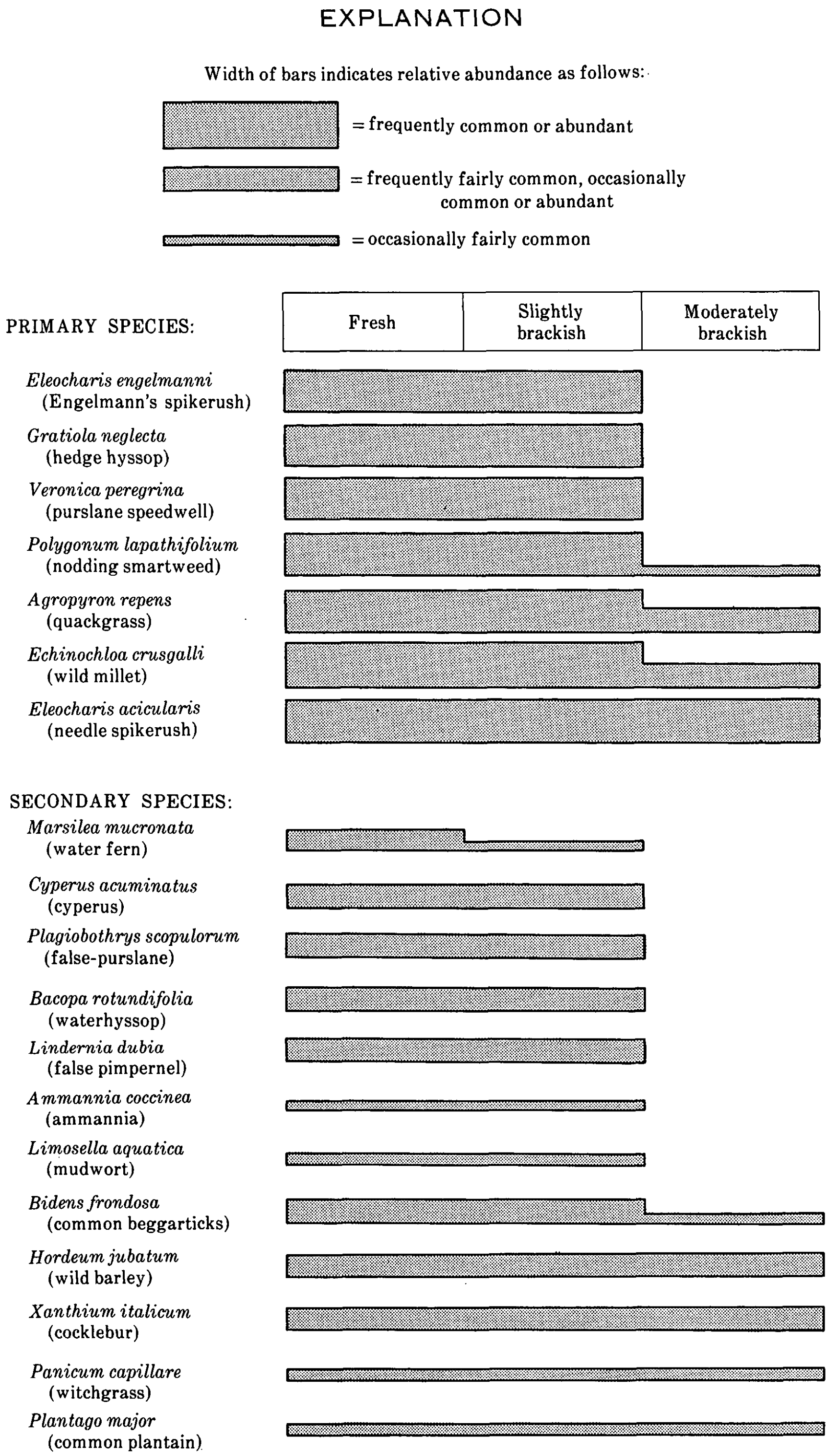

FIGURE 37.—Characteristic plant species of cropland drawdown vegetation. Higher salinities than shown do not occur.

FIGURE 38.—Cropland drawdown vegetation in a fresh seasonal pond. Shown is *Echinochloa crusgalli* (wild millet) in an oatfield. July 30, 1965, Stutsman County, N. Dak.

Scientific name	Common name	Figure	Table
Potentilla anserina L.	Silverweed	4	
norvegica L.	Rough cinquefoil	4	
Puccinellia nuttalliana (Schultes) Hitchc.	Alkaligrass	9	
Ranunculus cymbalaria Pursh	Seaside buttercup	9	
flabellaris Raf.	Yellow watercrowfoot	27	
gmelini DC.	Bog watercrowfoot	27	
macounii Britt.	Macoun's buttercup	4	
sceleratus L.	Cursed buttercup	9	
septentrionalis Poir.	Swamp buttercup		5
trichophyllus Chaix.	White watercrowfoot	27	
Riccia fluitans L.	Aquatic liverwort	27	
Ricciocarpus natans (L.) Corda	Aquatic liverwort	27	
Rorippa islandica (Oeder) Borbas	Marsh cress	4	
Rosa arkansana Porter	Prairie rose		6
woodsii Lindl.	Western rose		4
Rumex maritimus L.	Golden dock	35	
mexicanus Meisn.	Narrowleaf dock	4	
occidentalis S. Wats.	Western dock	4	
Ruppia maritima L.	Saltwater widgeongrass	27	
occidentalis S. Wats.	Western wideongrass	27	
Sagittaria cuneata Sheldon	Arumleaf arrowhead	9	
Salicornia rubra Nels.	Samphire	9	
Salix candida Flugge	Hoary willow		5
interior Rowlee	Sandbar willow		5
Salsola kali L.	Russian-thistle		6
Scirpus acutus Muhl.	Hardstem bulrush	20	
americanus Pers.	Common threesquare	9	
atrovirens Willd.	Dark-green bulrush		5
fluviatilis (Torr.) Gray	River bulrush	20	
heterochaetus Chase	Slender bulrush	20	
nevadensis S. Wats.	Nevada bulrush	9	
paludosus A. Nels.	Alkali bulrush	20	
validus Vahl.	Softstem bulrush	20	5

Scientific name	Common name	Figure	Table
Scolochloa festucacea (Willd.) Link	Whitetop	9	
Scutellaria epilobiifolia A. Hamilton	Marsh skullcap		5
Senecio congestus (R. Br.) DC.	Marsh ragwort	35	
Setaria glauca (L.) Beauv.	Yellow foxtail		6
Sium suave Walt.	Waterparsnip	9	
Solidago altissima L.	Tall goldenrod		4
graminifolia (L.) Salisb.	Narrowleaf goldenrod		5
Sonchus arvensis L.	Sow-thistle	4	
Sparganium eurycarpum Engelm.	Giant burreed	9	
Spartina gracilis Trin.	Alkali cordgrass	4	
pectinata Link	Prairie cordgrass	4	
Spergularia marina (L.) Griseb.	Saltmarsh sandspurry	35	
Spirodela polyrhiza (L.) Schlied.	Greater duckweed	27	
Stachys palustris L.	Marsh hedgenettle	4	
Suaeda depressa (Pursh) S. Wats.	Western seablite	9	
Symphoricarpos occidentalis Hook.	Wolfberry		4
Taraxacum officinale Weber	Common dandelion		4
Teucrium occidentale Gray	Germander	4	
Thlaspi arvense L.	Pennycress		6
Triglochin maritima L.	Common arrowgrass	4	5
Typha angustifolia L.	Narrowleaf cattail	20	
"glauca" Godr.	Hybrid cattail	20	
latifolia L.	Common cattail	20	5
Utricularia vulgaris L.	Common bladderwort	27	
Vernonia fasciculata Michx.	Western ironweed	4	
Veronica peregrina L.	Purslane speedwell	37	
Viola nephrophylla Greene	Kidneyleaf violet		5
Xanthium italicum Moretti	Cocklebur	35, 37	
Zannichellia palustris L.	Horned pondweed	27	
Zigadenus elegans Pursh	Smooth camas		4
Zizia aptera (Gray) Fern.	Golden alexanders		4

REFERENCES

Bernstein, L., and Hayward, H. E., 1958, Physiology of salt tolerance: Plant Physiology Ann. Rev., v. 9, p. 25–46.

Bolen, E. G., 1964, Plant ecology of spring-fed salt marshes in western Utah: Ecol. Mon., v. 34, p. 143–166.

Conard, H. S., 1956, How to know the mosses and liverworts [revised ed. illus.]: Dubuque, Iowa, Wm. C. Brown Co., 226 p.

Eisenlohr, W. S., Jr., and Sloan, C. E., 1968, Generalized hydrology of prairie potholes on the Coteau du Missouri, North Dakota: U.S. Geol. Survey Circ. 558, 12 p.

Fernald, M. L., 1950, Gray's manual of botany [8th ed.]: New York, American Book Co., 1,632 p., illus.

Hanson, H. C., 1962, Dictionary of ecology: New York, Philosophical Library, Inc., 382 p.

Metcalf, F. P., 1931, Wild duck foods of North Dakota lakes: U.S. Dept. Agriculture Tech. Bull. 221, 72 p.

Moyle, J. B., 1945, Some chemical factors influencing the distribution of aquatic plants in Minnesota: Am. Midland Naturalist, v. 34, no. 2, p. 402–420.

Rawson, D. S., and Moore, J. E., 1944, The saline lakes of Saskatchewan: Canadian Jour. Research, v. 22, p. 141–201.

Smith, G. M., 1950, The fresh-water algae of the United States [2d ed. illus.]: New York, McGraw-Hill Book Co., 719 p.

Stevens, O. A., 1963, Handbook of North Dakota plants: Fargo, N. Dak., Reg. Studies Inst., 330 p.

Stewart, R. E., and Kantrud, H. A., 1969, Proposed classification of potholes in the glaciated prairie region, *in* Saskatoon Wetlands Seminar: Ottawa, Canadian Wildlife Service Rept. Ser., no. 6.

———1971, Classification of natural ponds and lakes in the glaciated prairie region: U.S. Bur. Sport Fisheries and Wildlife Resource Pub. 92, 57 p.

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