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A PRELIMINARY CLASSIFICATION OF WETLAND PLANT COMMUNITIES IN NORTH-CENTRAL MINNESOTA

By

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ABSTRACT

A classification of wetland plant communities was developed for a study area in north-central Minnesota in order to analyze data on waterfowl use of habitat that were gathered by radio telemetry. The classification employs features of several earlier classifications in addition to new classes for bogs and lakeshore communities. Brief descriptions are given for each community, and the important plant species are listed. Discriminant function analysis was used for 40 plant species. Seventy-five percent of the stands studied were classified correctly by this technique. Average probabilities of assignment to communities were calculated and helped to identify distinct and poorly defined communities as well as the relationship among communities.

INTRODUCTION

The system described here was designed with the primary purpose of placing areas of wetland vegetation into categories that would be meaningful for analysis of data concerning waterfowl use. These data were gathered on a study area in north-central Minnesota by means of radio-telemetry, and the method of analysis required the preparation of maps on which all wetland areas could be divided into discrete units as described by Gilmer et al. (in press). This is not an entirely new classification, but rather a modification of existing systems described by Martin et al. (1953), Stewart and Kantrud (1971) and Gilmer (1971). Although the classification is restricted both in purpose and in the geographic region to which it may be applied, portions of the system as well as the methodology used to describe the types may have general value in studies of wetlands outside the immediate study area.

The classification proposed by Martin et al. (1953) and used by Shaw and Fredine (1956) is the system that has been most generally used in waterfowl research and management. This system fulfilled one of our requirements in that it can be used to describe areas of vegetation and is not restricted to discrete wetlands. The classes, however, are far too broad for detailed investigation of use of habitat by waterfowl, and many biologists find it of limited value. The classification described by Stewart and Kantrud (1971) has sufficient detail for research but, for us, had the disadvantages of being restricted to the glaciated prairie and of omitting many of the wetland types most important in our area. Their classification is strictly of wetland basins. In the prairies, for which it was designed, the wetland basins tend to be discrete, whereas in our area, basins consist of a complex of plant communities often in association with large lakes and river systems.

Structure of Classification

The basic unit of our classification is the stand, which we define as an area of wetland vegetation with sufficient uniformity and size so as to be recognizable both on the ground and on aerial photographs. Stands with similar botanical and physical characteristics were grouped into communities in the sense of Curtis (1959:477), "...groups of stands with sufficient characters in common to produce studiable assemblages." Wetlands, such as lakes and rivers, are often large and contain diverse communities that are related only by the fact that they lie in the same basin or channel; therefore, we grouped lake and river communities into wetland complexes when we thought that these complexes would be meaningful for the analysis of waterfowl-use data. In some cases our communities are closely related to, or contained within, wetland types described by other authors (Table 1). We have attempted to indicate some of these relationships through the selection of community names.

Table 1. Comparison of communities described in this study with existing wetland classification.

Community	Stewart and Kantrud (1971)	Martin et al. (1953)
(1) Ephemeral	(I) Ephemeral (E) 1/	(1) Seasonally flooded basins or flats (I)
(2) Temporary	(IIA) Temporary-fresh (E)	(1) Seasonally flooded basins or flats (R) (2) Fresh meadows (R)
(3) Seasonal-closed	(IIIA-1) Seasonal-fresh, cover type 1 (E)	(3) Shallow fresh marshes (R) (4) Deep fresh marshes (R)
(4) Seasonal-patchy	(IIIA-2) Seasonal-fresh, cover type 2 (E)	(3) Shallow fresh marshes (R) (4) Deep fresh marshes (R)
(5) Seasonal-open	(IIIA-3) Seasonal-fresh, cover type 3 (E)	(3) Shallow-fresh marshes (R) (4) Deep fresh marshes (R) (5) Open fresh marshes (R)
(6) Semipermanent-closed	(IVA-1) Semipermanent-fresh, cover type 1 (E)	(3) Shallow-fresh marshes (R) (4) Deep fresh marshes (R)
(7) Semipermanent-patchy	(IVA-2) Semipermanent-fresh, cover type 2 (E)	(3) Shallow fresh marshes (R) (4) Deep fresh marshes (R)
(8) Semipermanent-open	(IVA-3) Semipermanent-fresh, cover type 3 (E)	(3) Shallow fresh marshes (R) (4) Deep fresh marshes (R) (5) Open fresh marshes (R)
(9) Shrub swamp	-	(6) Shrub swamp (E)
(10) Hardwood swamp	-	(7) Wooded swamp (I)
(11) Circumneutral bog - sedge phase	(VII) Fen (alkaline bog) ponds (R)	(2) Fresh meadows (I)
(12) Circumneutral bog - shrub phase	-	-
(13) Circumneutral bog - ericaceous phase	-	-
(14) Acid bog	-	(8) Bogs (E)
(15) Softwood swamp	-	(7) Wooded swamp (I)

1/ E = equivalent type. R = related type. I = our type included in theirs.

Study Area

Data for this classification were gathered within the Chippewa National Forest on a study area 25 square miles (65 sq. km.) in area and situated 12 miles (19.3 km.) east of Bemidji, Minnesota. The area is glaciated and has till deposits in the north and east and outwash in the south and west (Goltz 1969). Small wetlands are numerous, and the area is surrounded by large lakes. The Mississippi River flows through the southern portion. Dominant forest types are pines (Pinus banksiana, P. resinosa, P. strobus), 1/ aspen (Populus tremuloides, P. grandidentata, P. balsaminifera), northern hardwood (Acer saccharum, Tilia americana), and oaks, (Quercus ellipsoidalis, Q. macrocarpa). Hydric sites are dominated by black spruce (Picea mariana) and tamarack (Larix laricina). A detailed description of the study area was given by Gilmer (1971:4-14).

The field work for this study could not have been completed without the help of D. S. Gilmer, I. J. Ball, J. H. Riechmann, R. S. Stott, and T. C. Clodfelter. R. E. Stewart furnished guidance and criticism in developing the classification. We are indebted to D. A. Davenport for assistance with computer programing. V. A. Adomaitis and J. A. Shoesmith performed chemical analyses. P. F. Springer made a critical review of the manuscript.

METHODS

Stands of wetland vegetation were delineated and mapped from multispectral photography (Cowardin and Myers in press). Stands of vegetation were then located by means of the photographs, hand compass, and pacing. During the field survey, each plant species within a stand was described in terms of the percent of areal coverage and placed into one of the following categories: 0 = absent; 1 = rare, a few scattered individuals; 2 = occasional, less than 1 percent; 3 = fairly common, 1 - 10 percent; 4 = common, 11-50 percent; 5 = abundant, 51-100 percent. Plant abundance was described both for the stand as a whole and for the deepest, central portion of the stand. This method has the disadvantages of being partially subjective and somewhat imprecise, but has the decided advantage of speed which allowed a far larger sample of stands to be analyzed than would have been possible if more refined methods such as quadrats were used. All classification was conducted by the senior author during July and August, 1968-1972. The timing of the survey probably introduced some bias by not giving sufficient importance to early - and late-blooming species.

In wetland stands surveyed in 1968-70, a water sample was gathered from the surface, preserved with chloroform and chemically analysed at the Northern Prairie Wildlife Research Center. No samples were taken in 1971-72.

1/ Nomenclature used in this paper follows Fernald (1950)

By examination in the field, stands were assigned to communities according to their physical and botanical characteristics. Species used as indicators of permanence by Stewart and Kantrud (1971) were used whenever possible to help classify communities equivalent to theirs.

For community descriptions (Appendices A - O), plants were ranked in importance by averaging the abundance categories for each plant in all stands assigned to a community. Only the plants of the deepest, central portion of the wetland were used for ranking. For the purpose of description, characteristic plants appearing in wetlands were limited to those species with average abundance value greater than 0.3.

In order to describe the distribution of the common plant species among the communities, an index of abundance was developed. We divided the number of stands in which a species occurred in a given community by the sample size for that community in order to obtain a frequency of occurrence. This frequency divided by the sum of frequencies for all communities furnished an index to the abundance of that species as an indicator of that community.

The following hypothetical example illustrates the procedure used for calculating frequency of occurrence and index of abundance:

Community	A	B	C	Total
Sample size	5	10	25	40
Stands with plant	5	5	5	15
Frequency of occurrence	100.0	50.0	20.0	170.0
Index of abundance	58.8	29.4	11.8	100.0

A discriminant function analysis (e.g. Tatsuoka 1970) was applied to the abundance data in order to study several aspects of the classification: (1) how well the communities describe natural associations of species, (2) the relationship between different communities, (3) which plants best separate communities, and (4) which wetlands stands are intermediate between types. Data were processed on an IBM 360 Model 50 computer by means of a Biomedical Computer Program (Dixon 1968).

Forty plant species were chosen for use in the discriminant analysis by first eliminating all species that occurred in less than four stands, except where all those stands were in the same community. This reduced the number of plants under consideration from 241 to 129. Of the remaining 129 species, 40 were chosen by determining which species first entered the stepwise discriminant analysis.

RESULTS

Description of the Communities

Communities without permanent water

These communities include all wetlands that can become dry, at least during drought conditions. The communities were separated primarily on water permanence and in many cases are equivalent to wetland types of either Martin et al. (1953) or Stewart and Kantrud (1971) (Table 1). Communities were further separated on the basis of the amount of emergent cover present, a separation similar to the cover types described by Stewart and Kantrud (1971:10-11). Plant species are generally similar to those found by Stewart and Kantrud but there are important differences. For example, wetlands in our area are fresh (specific conductance seldom exceeds 300 µmhos). Also, the area is forested, so tree and shrub vegetation forms an important component of several types.

The numbers and total acreage of stands in each community were highly variable, and communities 6 and 7 (Semipermanent - closed, and Semipermanent - patchy) were rare on our study area (Table 2).

Chemical characteristics of water samples from stands without permanent water are presented in Table 3. The characteristic plants for communities 1-15 are presented in Appendices A-O.

Community 1. Ephemeral -- Occurs in small depressions where water is held by frozen ground in early spring. The water disappears soon after the thaw in late April or early May. The flora is highly variable and composed primarily of non-wetland species.

Community 2. Temporary -- Occurs in small depressions throughout the study area. Basins are usually dry by late May but are often replenished by heavy rains later in the season. This community is intermediate between ephemeral and shrub swamp. It is also closely related to hardwood swamp which is generally more permanent and has swamp hardwood tree species with crown closure greater than 50 percent.

Community 3. Seasonal - closed -- Occurs most commonly in depressions in moraine or till plains but occasionally on outwash. The deepest portion has a closed cover of emergent, shallow-marsh vegetation. Stands usually hold water until late July. The most common plant species are coarse-leaved sedges such as Carex lacustris.

Table 2. Number and size of non-permanent wetland stands occurring on a 25-square-mile study area in north-central Minnesota.

Community	Number Stands	Median Size (acres)	SIQR 1/	Total (acres)	Number Plant Surveys
(1) Ephemeral	11	0.96	0.53- 1.38	1.4	6
(2) Temporary	61	0.88	0.49- 1.26	6.7	18
(3) Seasonal-closed	77	1.41	0.76- 2.49	18.5	47
(4) Seasonal-patchy	9	6.00	2.25- 11.25	7.6	8
(5) Seasonal-open	132	1.78	0.97- 2.48	33.0	63
(6) Semipermanent-closed	5	2.75	1.75- 3.38	1.3	5
(7) Semipermanent-patchy	5	6.00	3.75- 7.25	11.4	5
(8) Semipermanent-open	9	13.00	6.12- 16.25	18.8	7
(9) Shrub swamp	124	11.75	3.83- 35.50	426.6	48
(10) Hardwood swamp	89	1.09	0.59- 1.81	19.6	14
(11) Circumneutral bog - sedge phase	77	33.5	14.0 - 71.0	488.2	31
(12) Circumneutral bog - shrub phase	61	19.00	7.75- 39.25	216.6	23
(13) Circumneutral bog - ericaceous phase	31	11.00	5.25- 20.75	51.8	24
(14) Acid bog	37	18.25	8.75- 39.25	149.9	27
(15) Softwood swamp	44	42.50	21.50-101.50	438.7	11
Total	772			1890	

1/ Semi-interquartile range was used as measure of dispersion because of highly skewed distribution of size measurements.

Community 4. Seasonal - patchy -- Occurs in situations similar to Community 3 and is like that community except that the emergent, shallow-marsh vegetation occurs as dense or scattered clumps. Stands usually hold water until early August or mid-August.

Community 5. Seasonal - open -- Occurs in situations similar to Communities 3 and 4 and is like these except that in this community the center of the stands have little or no emergent shallow-marsh vegetation. Stands usually hold water until late August or early September

Community 6. Semipermanent - closed -- Occurs in deeper basins than Communities 3-5 and is more common in moraine than outwash plains. The deepest portion of the stands have a closed cover dominated by deep-marsh species. They usually hold water until late fall and may be wet throughout the year.

Table 3. Chemical characteristics of water samples from wetland stands without permanent water in north-central Minnesota. 1/

Community	Sample Size	Median pH	Median Cond. 2/	Median TDS 3/	Median OM 4/
(2) Temporary	2	7.5	855.5	223.5	98.0
(3) Seasonal-closed	15	7.2 (6.5-7.7)	80.0 (62.3-192.8)	162.0 (90.4-291.8)	63.0 (55.3-129.8)
(4) Seasonal-patchy	4	7.2 (6.9-7.5)	88.0 (72.5-105.0)	117.5 (94.5-139.5)	61.5 (40.5-96.5)
(5) Seasonal-open	31	7.2 (6.6-7.7)	97.0 (56.3-137.8)	133.0 (94.3-192.0)	55.0 (43.3-98.8)
(6) Semipermanent-closed	1	7.1	49.0	78.0	48.0
(7) Semipermanent-patchy	3	6.2	41.0	80.0	46.0
(8) Semipermanent-open	6	7.9 (7.5-8.1)	165.0 (94.3-185.0)	156.0 (101.0-206.8)	45.5 (34.0-66.0)
(9) Shrub swamp	9	7.1 (6.7-7.8)	116.0 (108.8-144.3)	187.0 (150.8-259.8)	66.0 (54.8-136.3)
(10) Hardwood swamp	6	7.4 (7.3-7.6)	88.0 (71.0-350.0)	127.0 (120.0-223.0)	52.0 (35.0-84.0)
(11) Circumneutral bog - sedge phase	16	7.5 (6.8-8.0)	114.0 (64.0-176.5)	160.0 (113.0-195.5)	55.5 (37.0-80.0)
(12) Circumneutral bog - shrub phase	11	7.2 (5.3-7.7)	150.0 (98.3-204.8)	242.0 (145.3-330.8)	55.3 (117.0-200.8)
(13) Circumneutral bog - ericaceous phase	8	4.7 (4.5-5.2)	53.5 (40.0-86.0)	214.5 (93.5-214.5)	90.0 (57.5-145.5)
(14) Acid bog	9	4.4 (4.1-5.3)	71.0 (55.8-88.3)	220.0 (181.8-267.8)	166.0 (106.8-185.3)

1/ Semi-interquartile ranges for all measurements shown in parentheses. No range calculated for sample size less than 4. No samples obtained from types 1 and 15.

2/ Specific conductance in μmhos.

3/ Total dissolved solids in ppm.

4/ Organic matter in ppm.

Community 7. Semipermanent - patchy -- Occurs in basins primarily in till plain and outwash. Basins are generally larger than those of communities 3-6. Their deepest portions have scattered or dense patches of emergent, deep-marsh vegetation. They usually hold water throughout the year and are dry only under moderate drought conditions.

Community 8. Semipermanent - open -- Occurs in medium-sized basins in moraine and outwash and is similar to Community 7 except that the central, deepest portion of the stands has little or no emergent vegetation. The deepest portion of the stand may have submerged, deep-marsh vegetation or may be without vegetation. These stands become dry only under severe drought conditions.

Community 9. Shrub swamp -- Occurs throughout the study area in small pockets and depressions as well as adjacent to circumneutral bogs and softwood swamps. Stands comprise parts of large wetland complexes. They have a dense overstory of shrubs covering more than 50 percent of the deepest zone. Permanence is highly variable depending on size and depth, but stands generally become dry by mid-summer.

Community 10. Hardwood swamp -- Occurs predominantly in small depressions within northern hardwood or aspen forest types. Crown closure is greater than 50 percent over the deepest portion of the stand. Stands often have deep pools that may hold water until late August.

Community 11. Circumneutral bog - sedge phase -- Occurs either in large flat basins within till plains and outwash, or on large flat areas bordering rivers and lakes. Stands are found on organic soils and are often highly quaking underfoot. The soil is generally saturated throughout the year and may be flooded in the spring. The vegetation is dominated by fine-leaved sedges such as Carex lasiocarpa. The water has a pH near neutrality.

Community 12. Circumneutral bog - shrub phase -- This community is intermediate between Communities 9 and 11 and is often situated between stands of these communities, although it may occur in isolated depressions. The community is similar to Community 11 but has shrubs other than those of acid bogs covering 20-50 percent of the area. The water has a pH near neutrality.

Community 13. Circumneutral bog - ericaceous phase -- This type is intermediate between Communities 11 and 14 and is often found as a ring peripheral to acid bog stands. It is also similar to Community 11 but is characterized by small distinct patches and clumps of ericaceous bog plants and Sphagnum spp. moss totaling 20 to 50 percent of the area. The water is more acid than in Communities 11 and 12, because this community is transitional between Communities 11 and 14.

Community 14. Acid bog -- Occurs throughout the area, often in association with softwood swamps. The community is characterized by ericaceous shrubs and Sphagnum spp. moss covering 50-100 percent of the area. Tree cover is less than 20 percent.

Community 15. Softwood swamp -- Occurs in low-lying areas throughout the study area. It is typified by coniferous trees covering 20-100 percent of the area.

Communities with permanent water

The communities described above are often found in association with communities that have permanent water. We have found it useful to group communities having permanent water into wetland complexes that are meaningful for the analysis of wetland use by waterfowl. Lake complexes were classified on the basis of the physical and botanical characteristics of shorelines. River complexes were classified by the ratio of emergent vegetation to water in the channel:

Bog lake complexes - The shoreline is composed of 80 to 100 percent bog communities (11-14).

Intermediate lake complexes - These complexes are intermediate between bog lakes and sand lakes. The shoreline is composed of 50-80 percent bog communities (11-14) or with shores grading from deep marsh to shallow marsh aquatics.

Sand lake complexes - The shoreline has less than 50 percent bog communities (11-14). Fifty percent or more of the shoreline is characterized by sandy or boulder-strewn beaches or shallows. Some areas may have steep banks with overhanging brush.

River channel complexes - Permanent flowing water in which less than 50 percent of the cross section of the river contains emergent vegetation.

River marsh complexes - Permanent flowing water in which more than 50 percent of the cross section of the river contains emergent vegetation.

The communities within these habitat complexes have permanent water and were divided on the basis of the dominant species of emergent vegetation. All stands with submerged vegetation were included within Community 16 (open water), because of the difficulty in delineating these stands on aerial photographs. Lakeshore communities were classified on the basis of both physical characteristics and the vegetation within one chain (20.1 m.) of the shoreline. The shoreline classification was modeled after and used for the same reason as the classification described by Gilmer (1971:23) who demonstrated that shorelines should be considered separately from the communities on either side. Communities with permanent water are described below:

Community 16 - Open water -- Includes any area that is without emergent and emersed (floating leaved) vegetation at all times during the year. Stands with submerged beds of vegetation were included in this community.

Community 17 - Bulrush -- Includes any stands of emergent vegetation dominated by hardstem bulrush (Scirpus acutus).

Community 18 - Phragmites -- Includes any stand of emergent vegetation dominated by reed grass (Phragmites communis).

Community 19 - Wild rice -- Includes any stand of emergent vegetation dominated by wild rice (Zizania aquatica). These stands were classified on the basis of the presence of wild rice during the height of its development. For analysis of waterfowl use data in spring, they were classed as open water (Community 16).

Community 20 - Emersed aquatics -- Includes any stand dominated by aquatic vegetation with floating leaves, such as Nuphar, Nymphaea, and Potamogeton.

Community 21 - Other emergents -- Includes all stands of emergent vegetation which can not be classified as 17, 18 or 19.

For uniformity in numbering, shoreline communities begin with number 30; therefore, numbers 22-29 are not used in this classification. The communities used to describe shorelines (Table 4) are self explanatory. The description starts with the stand in the lake and ends with the physical type of shoreline.

Most of the stands in permanent water were classified from aerial photographs, and no plant lists were prepared for communities 16-69 because the complexity and vast number of stands made botanical surveys impractical.

Important plants of the communities

In order to understand the importance of each species within each community, we examined the indices of abundance for each of the 40 species (Table 5) used in the discriminant analysis. These data demonstrate that some of the most common species, such as Carex lacustris, are not particularly valuable for classification because they occur in almost all communities.

Discriminant Analysis

Discriminant analysis was developed by Fisher (1936) in order to provide a rigorous basis for using quantitative data for taxonomic purposes. It presupposes a correct assignment of individuals to groups, and determines how the groups can best be distinguished on the basis of a set of measurements. It is most useful (Gower 1969) in situations where distinctions between groups are not clear-cut and where gradation between groups may occur. This is the usual situation with the classification of plant communities.

Table 4. Communities used to describe shorelines of lakes.

Community	One Chain (20.1 m.) Strip in Lake	Shoreline
30	Water - river mouth	
31	Water - sand or gravel beach	
32	Water - deep marsh aquatics - shallow marsh aquatics	
33	Water - bog mat	
34	Water - sand bar - shrub swamp	
35	Water - sand bar - pond	
36	Water - overhanging - brush	
37	Water - steep bank	
38	Water - rock and boulder	
39	Water - residential	
40-49	Bulrush - (same as shown for types 33-39)	
50-59	Phragmites - (same as shown for types 30-39)	
60-69	Wild rice - (same as shown for types 30-39)	

For the purpose at hand, wherein a classification has already been assumed, discriminant analysis offers several advantages:

(1) Being a multivariate technique, it makes fuller use of the data than do univariate approaches such as indices of abundance (Table 5). Moreover, it takes into account the differing precision of variables and also interrelationships among them.

(2) By applying the discriminant functions to the data on which they are based, one determines whether or not each observation is correctly classified by the procedure. Moreover, a "probability" is calculated which reflects the likelihood of that observation belonging to each of the groups. The observation is assigned to the group for which its probability is greatest (Table 6). This resubstitution of the original data into the model is useful for several purposes. The most immediate use is to point out observations that may contain obvious errors. A quick examination of those observations that the method assigned to a group very distinct from the group to which it belonged often reveals a transcribing error in the data. We applied discriminant analysis to our raw plant data and field-checked all stands that were misclassified by the method. In this way we detected several recording errors and several cases where important species had been omitted from stand descriptions. These errors were corrected, and the analysis was rerun.

Table 5. Indices of abundance[1] for 40 species of plants occurring in 16 communities on a study area in north-central Minnesota.

Species	Community 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	N[2]
Equisetum sylvaticum	14	32	2						5	29				3	15		20
Larix laricina									7				9	35	51		32
Picea mariana									3				3	37	56		24
Pinus banksiana			2									4	34	60			29
Sagittaria latifolia					3		17	47	5		16	7				6	19
Alnus rugosa		4	5	3		5		4	21	2	2	16	7	9	22		102
Betula pumila		3							17		3	14	15	32	17		59
Carex comosa							48	34	10		8						5
Carex disperma	17	6								7			4	4	63		12
Carex intumescens	25	8							3	64							9
Carex lacustris	3	4	14	12	5	6	6	2	11	2	7	8	10	4	7		161
Carex lasiocarpa			4	13	1	7			6		26	20	16	6			72
Chamaedaphne calyculata			1	5					2		3	5	33	38	14		59
Ledum groenlandicum		4							4			6	12	18	57		26
Agropyron repens	100																2
Alopecurus aequalis				33	23		26		3	9		6					17
Calamagrostis canadensis	4	7	9	9	3			4	18	2	13	16	7	4	5		114
Glyceria borealis		5	2	16	21	17	17	12	4	3		2					52
Phragmites communis									10		90						7
Iris versicolor		26	3		3		13		18	10	7	12	3		6		37
Spirodela polyrhiza					33	8	8	33	17								12
Utricularia intermedia							29				52	13	6				15
Maianthemum canadense	79														21		3
Smilacina trifolia													11	5	84		10
Nuphar variegatum							19	13			6					62	14
Fraxinus nigra	22	4	3						5	55					12		23
Circaea alpina															100		6
Potentilla palustris		1	11	11	3	4	4		14		12	16	12	4	8		129
Populus tremuloides	44	36								9			11				10
Salix discolor		6	6		3		7	5	29	5	8	20	3		7		83
Salix gracilis		6	6		2	5	5	8	19	4	13	22	9				101
Ribes hirtellum										28					72		6
Sparganium chlorocarpum			5		5	43		46	2								11
Typha latifolia			5	4	3	28	17	4	5		17	13	6				68
Ulmus americana	28	9	4		1				4	36				3	15		18
Sium suave		6	5	7	18	21	16	8	5	15	1						84
Potamogeton foliosus					17		30	43								10	11
Potamogeton gramineus				8	8	13		19	3		34	3				13	34
Sphagnum sp.				5	1		7		1		5	3	18	31	30		55
Drepanocladus sp.			4						7			15	43	32			16

1/ See text
2/ Total number of stands with species present

Table 6. Number of stands assigned to communities by discriminant analysis of plant abundance values for 40 species.[1/]

Community Assigned in Field	Number Assigned by Discriminant Analysis															Total Stands	% Classified Correctly
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	4	2														6	67
2		13	2	1	2											18	72
3		3	34	3	2			1	1	2		1				47	72
4		1		5	1						1					8	63
5		4	5	5	43	3		2			1					63	68
6						5										5	100
7					1	2	2									5	40
8					2			5								7	71
9		1	2						38	2		4	1			48	79
10					1				1	12						14	86
11			3	3							21	3	1			31	68
12			3						3			15	2			23	65
13			2										21	1		24	88
14													4	23		27	85
15															11	11	100

1/ Number assigned correctly is underlined.

(3) If, as was done in the present study, a stepwise algorithm is used to calculate the discriminant functions, the order in which a variable enters into the model relates to the importance of that variable in separating the groups. This relationship is less exact when the groups are widely disparate in sample size because a variable which distinguishes a group with few samples may enter later than a variable which distinguishes a well-represented group. Also, the ordering of variables can be used to ascertain which variables are superfluous to the classification. These may then be omitted from further data gathering (Norris and Barkham, 1970). We used this technique in reducing to 40 the sample of plant species to be included in the analysis.

(4) It is possible to locate observations which are intermediate between groups by considering the probability of assignment to each group. If, for a particular observation, the probabilities associated with the groups are each about 0.5, that observation would represent an intermediate between those groups. Table 7 illustrates a wetland stand intermediate between Community 9 (shrub swamp) and Community 12 (circumneutral bog - shrub phase). A comparison of the plant species present with those presented in Appendices I and L illustrates the intermediate nature of the stand. Note that Calamagrostis canadensis is ranked high in both communities. Typha latifolia is absent in shrub swamp but ranked highly in circumneutral bog - shrub phase. Cornus stolonifera and Caltha palustris are represented in shrub swamp but absent from circumneutral bog - shrub phase.

(5) Another useful concept arises from averaging those probabilities of classification across all observations in a group. This will suggest which other groups are closely related to that particular group. This procedure was used to illustrate the relationship between plant communities (Figure 1). If the average probability that the observations in a particular group are assigned correctly to that group is near 1.0, it follows that the group is internally consistent and, on the basis of the variables measured, represents a natural grouping. Note the consistency within communities 6, 10, 13, 14, and 15 (Figure 1). The fact that the model was able to assign 74.8 percent of the stands to their proper communities also demonstrates that the communities described are consistent with the groupings of plants occurring in nature. It should be pointed out that if the same model were used to classify additional wetlands, we would not expect an equally high proportion of correct classifications.

The average probabilities demonstrate the relationships between types and identify those types that are poorly defined. Community 15 (softwood swamp) was the best defined; 100 percent of the stands were classified correctly with the use of 40 plant species. Community 7 (semipermanent-patchy) was the most poorly defined; only 40 percent of the stands were

Table 7. Plant abundance values for species in a stand intermediate between Community 9. Shrub swamp and Community 12. Circumneutral bog - shrub phase. 1/ 2/

Species	Abundance in Stand	Mean Abundance Shrub Swamp	Mean Abundance Circumneutral Bog - Shrub Phase
Calamagrostis canadensis	5	2.3	2.5
Alnus rugosa	3	3.0	1.7
Carex aquatilis	3	0.5	0.4
Carex rostrata	3	0.6	0.7
Galium trifidum	3	0.6	0.8
Salix discolor	3	2.8	1.7
Typha latifolia	3	-	1.7
Dryopteris thelypteris	2	1.4	0.8
Cornus stolonifera	2	0.7	-
Caltha palustris	2	0.4	-
Salix gracilis	2	2.7	2.6

1/ Discriminant analysis assigned probability of 9 as 0.34 and probability of 12 as 0.65.
2/ Only plants from the list of the 40 used in discriminant analysis are shown for this stand.

correctly classified. This is probably due in part to the small sample size for this community. The cover types (closed, patchy, and open) are relatively difficult to separate on the basis of the plant abundance. This is as would be expected because these types are closely related (see Figure 1). Communities with shrub cover, Community 9 (shrub swamp) and Community 12 (circumneutral bog - shrub phase) are also related (Figure 1).

CONCLUSIONS

The classification presented here can be used for most wetland communities in north-central Minnesota. It is based on limited data from a small area, and extension to other areas will require modifications and additions. An attempt has been made to adopt the most effective features of existing classifications in order to develop a system that can be used for analysis of radio-telemetry data on waterfowl habitat use.

The communities in Minnesota are related to those described by Stewart and Kantrud (1971) on the glaciated prairies. One major difference between the areas is the fact that the wetland communities in our area vary only slightly in salinity, and therefore the subclasses as used by Stewart and Kantrud are unnecessary. There is considerable variation in pH among types,

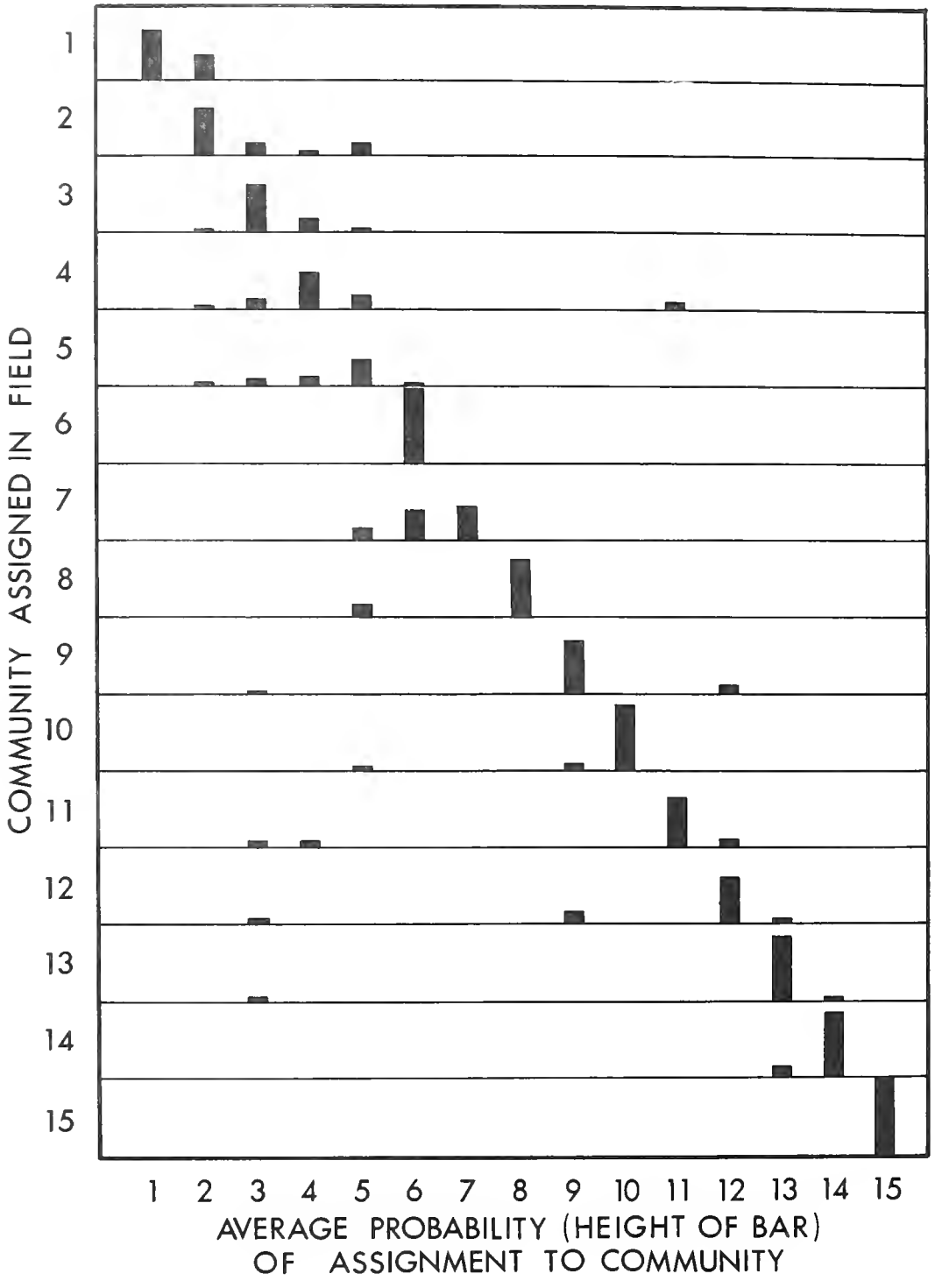

Figure 1. Average probability of assignment of stands to each of 15 plant communities. Probabilities were determined from discriminant function analysis of plant abundance for 40 species.

and the acid bog communities represent the most acid conditions. Although the cover type as used by Stewart and Kantrud is a meaningful concept, cover types in our area are more closely correlated with permanence than in the prairies; the more open wetlands are the most permanent.

Discriminant function analysis proved to be a useful tool for the analysis of plant abundance data, aiding in understanding the relationships among types, and obtaining a quantitative estimate as to which species are most useful as indicators of wetland plant associations. Norris and Barkham (1970) also found discriminant analysis to be a useful analytical tool for studying plant communities. We believe that the quantitative multivariate approach to wetland classification is logical and promising, and we suggest that further data should be gathered over wide areas with maximum variation in ecological types in order to develop wetland classifications that are simple enough to be useful yet reflect the complexity and interrelationships of wetland plant communities.

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Appendix A. Characteristic plants of Community 1. Ephemeral.

Species	Mean Abundance
Agropyron repens 1/	1.7
Calamagrostis canadensis	0.8
Maianthemum canadense	0.8
Fraxinus nigra	0.8
Populus tremuloides	0.8
Trifolium repens	0.8
Equisetum sylvaticum	0.7
Aster sp.	0.7
Ulmus americana	0.7
Poa pratensis 1/	0.7
Impatiens capensis	0.5
Corylus cornuta	0.5
Taraxacum officinale 1/	0.5
Lactuca canadensis	0.5

1/ Plants listed as indicator for type by Stewart and Kantrud (1971).

Appendix B. Characteristic plants of Community 2. Temporary.

Species	Mean Abundance
Calamagrostis canadensis 1/	1.1
Equisetum sylvaticum	0.8
Iris versicolor	0.8
Scirpus pedicellatus	0.8
Carex sp.	0.8
Dryopteris thelypteris	0.7
Scutellaria epilobiifolia	0.7
Populus tremuloides	0.7
Carex lacustris	0.7
Carex vesicaria	0.6
Salix gracilis	0.6
Alnus rugosa	0.6
Spiraea alba	0.6
Polygonum lapathifolium	0.5
Salix discolor	0.5
Sium suave	0.4
Polygonum coccineum	0.4
Glyceria borealis	0.4
Rumex mexicanus 1/	0.4

1/ Plants listed as indicator for type by Stewart and Kantrud (1971).

Appendix C. Characteristic plants of Community 3. Seasonal-closed.

Species	Mean Abundance
Carex lacustris	3.9
Carex rostrata	1.6
Potentilla palustris	1.4
Calamagrostis canadensis	1.1
Polygonum coccineum 1/	0.7
Scirpus pedicellatus	0.6
Typha latifolia	0.5
Salix gracilis	0.5
Sium suave 1/	0.5
Alnus rugosa	0.4
Cicuta bulbifera	0.4
Scutellaria epilobiifolia	0.4
Salix discolor	0.4
Glyceria grandis 1/	0.4

1/ Plants listed as indicator for type by Stewart and Kantrud (1971).

Appendix D. Characteristic plants of Community 4. Seasonal-patchy.

Species	Mean Abundance
Carex lacustris	3.0
Potentilla palustris	1.6
Calamagrostis canadensis	1.3
Carex lasiocarpa	1.1
Carex rostrata	1.0
Polygonum coccineum 1/	1.0
Glyceria borealis	0.9
Utricularia vulgaris	0.9
Sium suave 1/	0.9
Salix pedicellaris	0.8
Alopecurus aequalis 1/	0.5
Typha latifolia	0.5
Bidens sp.	0.5
Ranunculus flabellaris	0.5
Lemna minor 1/	0.4
Typha glauca	0.4
Bidens frondosa	0.4
Polygonum amphibium	0.4
Potamogeton gramineus	0.4
Alisma trivale 1/	0.4

1/ Plants listed as indicator for type by Stewart and Kantrud (1971).

Appendix E. Characteristic plants of Community 5. Seasonal-open.

Species	Mean Abundance
Sium suave 1/	2.2
Glyceria borealis	1.8
Carex rostrata	1.2
Carex lacustris	1.1
Polygonum coccineum 1/	1.0
Lemna minor 1/	0.7
Carex atherodes 1/	0.6
Alopecurus aequalis 1/	0.5
Alisma triviale 1/	0.5
Polygonum amphibium	0.5
Potentilla palustris	0.4
Potamogeton foliosus	0.4
Calamagrostis canadensis	0.4

1/ Plants listed as indicator for type by Stewart and Kantrud (1971).

Appendix F. Characteristic species of Community 6. Semipermanent-closed.

Species	Mean Abundance
Typha latifolia 1/	4.6
Sium suave	3.0
Equisetum fluviatile	1.8
Lemna minor 1/	1.8
Carex lacustris	1.2
Carex rostrata	1.2
Sparganium chlorocarpum	1.2
Utricularia vulgaris	1.0
Glyceria borealis	1.0
Salix gracilis	0.8
Bidens sp.	0.8
Glyceria grandis	0.8
Polygonum coccineum	0.8
Alnus rugosa	0.6
Sparganium minimum	0.6
Eleocharis palustris	0.6
Potamogeton gramineus	0.6
Acorus calamus	0.6
Spirodela polyrhiza	0.4
Lysimachia thyrsiflora	0.4
Aralia nudicaulis	0.4
Carex lasiocarpa	0.4
Alisma triviale	0.4
Scirpus pedicellatus	0.4

1/ Plants listed as indicator for type by Stewart and Kantrud (1971).

Appendix G. Characteristic plants of Community 7. Semipermanent-patchy.

Species	Mean Abundance
Sium suave	2.6
Typha latifolia 1/	2.4
Lemna minor 1/	1.8
Glyceria borealis	1.4
Potamogeton natans	1.4
Carex lacustris	1.0
Typha glauca	1.0
Sphagnum sp.	1.0
Carex sp.	0.8
Eleocharis palustris	0.8
Ranunculus flabellaris	0.8
Sagittaria latifolia	0.6
Salix discolor	0.6
Salix gracilis	0.6
Hypericum virginicum	0.6
Potentilla palustris	0.6
Riccia fluitans 1/	0.6
Dryopteris thelypteris	0.6
Calla palustris	0.6
Carex comosa	0.6
Dulichium arundinaceum	0.6
Nuphar variegatum	0.6
Potamogeton foliosus	0.6
Acorus calamus	0.4
Carex rostrata	0.4
Alopecurus aequalis	0.4
Mentha arvensis	0.4
Epilobium leptophyllum	0.4
Polygonum coccineum	0.4
Scirpus pedicellatus	0.4
Carex stipata	0.4
Glyceria grandis	0.4
Iris versicolor	0.4
Salix amygdaloides	0.4
Salix pedicellaris	0.4
Eleocharis obtusa	0.4
Spirodela polyrhiza	0.4
Polygonum amphibium	0.4

1/ Plants listed as indicator for type by Stewart and Kantrud (1971).

Appendix H. Characteristic plants of Community 8. Semipermanent-open.

Species	Mean Abundance
Lemma minor 1/	1.9
Sparganium chlorocarpum	1.6
Spirodela polyrhiza	1.3
Sagittaria latifolia	1.3
Potamogeton foliosus	1.1
Glyceria borealis	0.9
Glyceria grandis	0.9
Carex lacustris	0.7
Eleocharis palustris	0.7
Potamogeton gramineus	0.7
Utricularia vulgaris 1/	0.7
Salix gracilis	0.7
Potamogeton natans	0.7
Lemna trisulca	0.7
Polygonum amphibium	0.7
Sium suave	0.6
Ranunculus flabellaris	0.6
Carex comosa	0.6
Typha glauca 1/	0.6
Acorus calamus	0.4
Phalaris arundinacea	0.4
Carex atherodes	0.4
Typha latifolia	0.4
Scirpus pedicellatus	0.4
Potamogeton illinoensis	0.4

1/ Plants listed as indicator for type by Stewart and Kantrud (1971).

Appendix I. Characteristic plants of Community 9. Shrub swamp.

Species	Mean Abundance
Alnus rugosa	3.0
Salix discolor	2.8
Salix gracilis	2.7
Calamagrostis canadensis	2.3
Carex lacustris	2.2
Potentilla palustris	1.8
Dryopteris thelypteris	1.4
Betula pumila	1.1
Polygonum coccineum	0.8
Scutellaria epilobiifolia	0.8
Cicuta bulbifera	0.7
Cornus stolonifera	0.7
Carex rostrata	0.6
Lycopus uniflorus	0.6
Galium trifidum	0.6
Iris versicolor	0.6
Campanula uliginosa	0.6
Carex lasiocarpa	0.5
Sium suave	0.5
Carex aquatilis	0.5
Lysimachia thyrsiflora	0.4
Caltha palustris	0.4
Carex sp.	0.4
Impatiens capensis	0.4

Appendix J. Characteristic plants of Community 10. Hardwood swamp.

Species	Mean Abundance
Fraxinus nigra	3.0
Sium suave	1.8
Carex intumescens	1.4
Ulmus americana	1.3
Carex rostrata	1.0
Equisetum sylvaticum	0.9
Carex lacustris	0.5
Polygonum coccineum	0.4
Salix discolor	0.4
Salix gracilis	0.4
Acer rubrum	0.4

Appendix K. Characteristic plants of Community 11. Circumneutral bog - sedge phase.

Species	Mean Abundance
Carex lasiocarpa	3.4
Typha latifolia 1/	1.7
Calamagrostis canadensis	1.7
Potamogeton gramineus	1.5
Potentilla palustris	1.4
Polygonum coccineum	1.4
Salix gracilis	1.3
Carex lacustris	1.3
Campanula uliginosa	0.9
Carex aquatilis 1/	0.9
Utricularia intermedia	0.8
Dryopteris thelypteris	0.7
Utricularia vulgaris	0.7
Carex rostrata	0.6
Lysimachia thyrsiflora	0.5
Galium trifidum	0.5
Phragmites communis 1/	0.5
Salix discolor	0.5
Rumex orbiculatus	0.4
Cicuta bulbifera	0.4
Sagittaria latifolia	0.4
Acorus calamus	0.4
Hypericum virginicum	0.4

1/ Plants listed as indicator of fen as described by Stewart and Kantrud (1971).

Appendix L. Characteristic plants of Community 12. Circumneutral bog - sedge phase.

Species	Mean Abundance
Salix gracilis	2.6
Carex lasiocarpa	2.5
Calamagrostis canadensis	2.5
Potentilla palustris	2.0
Typha latifolia	1.7
Alnus rugosa	1.7
Salix discolor	1.7
Carex lacustris	1.7
Betula pumila	1.3
Dryopteris thelypteris	1.1
Lysimachia thyrsiflora	0.8
Galium trifidum	0.8
Salix candida	0.7
Campanula uliginosa	0.7
Carex rostrata	0.7
Polygonum coccineum	0.7
Salix pedicellaris	0.7
Hypericum virginicum	0.7
Scutellaria epilobifolia	0.6
Epilobium leptophyllum	0.6
Scirpus pedicellatus	0.5
Carex stricta	0.4
Asclepias incarnata	0.4
Lycopus uniflorus	0.4
Cicuta bulbifera	0.4
Rumex orbiculatus	0.4
Carex stipata	0.4
Carex aquatilis	0.4
Utricularia vulgaris	0.4

Appendix M. Characteristic plants of Community 13. Circumneutral bog - ericaceous phase.

Species	Mean Abundance
Chamaedaphne calyculata	3.2
Carex lacustris	2.4
Sphagnum sp.	2.0
Carex lasiocarpa	1.7
Potentilla palustris	1.3
Calamagrostis canadensis	1.2
Betula pumila	1.1
Drepanocladus sp.	1.1
Salix pedicellaris	1.0
Carex oligosperma	1.0
Kalmia polifolia	0.8
Vaccinium oxycoccus	0.8
Salix gracilis	0.8
Scirpus pedicellatus	0.8
Eriophorum spissum	0.8
Alnux rugosa	0.7
Pinus banksiana	0.6
Andromeda glaucophylla	0.5
Typha latifolia	0.5
Betula papyrifera	0.4

Appendix N. Characteristic plants of Community 14. Acid bog.

Species	Mean Abundance
Chamaedaphne calyculata	4.6
Sphagnum sp.	3.7
Betula pumila	2.1
Pinus banksiana	1.6
Larix laricina	1.5
Andromeda glaucophylla	1.3
Kalmia polifolia	1.3
Vaccinium oxycoccus	1.3
Picea mariana	1.2
Ledum groenlandicum	0.9
Carex oligosperma	0.9
Eriophoroum spissum	0.9
Carex lasiocarpa	0.9
Alnus rugosa	0.8
Salix pedicellaris	0.8
Drepanocladus sp.	0.8
Carex lacustris	0.7
Calamagrostis inexpansa	0.5
Betula papyrifera	0.4
Sarracenia purpurea	0.4
Calamagrostis canadensis	0.4

Appendix O. Characteristic plants of Community 15. Softwood swamp.

Species	Mean Abundance
Sphagnum sp.	3.1
Picea mariana	3.0
Ledum groenlandicum	2.9
Larix laricina	2.8
Alnus rugosa	2.8
Smilacina trifolia	1.5
Carex disperma	1.4
Circaea alpina	1.3
Betula pumila	1.2
Carex aquatilis	1.0
Carex lacustris	0.9
Dryopteris spinulosa	0.8
Caltha palustris	0.8
Potentilla palustris	0.8
Chamaedaphne calyculata	0.8
Abies balsamea	0.7
Cornus canadensis	0.7
Scutellaria epilobiifolia	0.7
Ribes hirtellum	0.7
Cornus stolonifera	0.7
Viola sp.	0.7
Viburnum trilobum	0.6
Rubus canadensis	0.6
Vaccinium angustifolium	0.6
Galium asprellum	0.5
Dryopteris thelypteris	0.5
Equisetum sylvaticum	0.5
Aralia nudicaulis	0.5
Carex stipata	0.5
Fraxinus nigra	0.5
Galium trifidum	0.5
Ulmus americana	0.5
Salix discolor	0.5
Salix pedicellaris	0.5
Carex projecta	0.4
Calamagrostis canadensis	0.4
Polygonum coccineum	0.4
Lysimachia thyrsiflora	0.4
Impatiens capensis	0.4
Salix candida	0.4
Rubus pubescens	0.4
Glyceria grandis	0.4

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