ECOLOGY

VOL. 41 JULY, 1960 No. 3

ADAPTATION OF SORENSEN'S K (1948) FOR ESTIMATING UNIT AFFINITIES IN PRAIRIE VEGETATION[1]

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INTRODUCTION

The indigenous vegetation of Southwestern Saskatchewan has evolved under a semi-arid continental climate. Reports by Clarke *et al.* (1942) and Coupland (1958), which considered characteristics of this vegetation, classified the cover as mixed-grass prairie, following the climax concept of Weaver and Clements (1938). However, the cover is not uniform and can be classified into distinct types and sub-types by both edaphic characteristics and moisture gradients. In addition, modifications can be recognized as a result of past and present utilization.

The study being reported at this time is the result of preliminary investigations to establish a classification based on floristic similarity of sites on the basis of species presence. The methods employed follow procedures outlined by Braun-Blanquet (1951); in addition, certain mathematical concepts are introduced to estimate the probability of significant relationships between species, sample sites, or both.

PROCEDURE AND DISCUSSION

Braun-Blanquet's recommended phytosociological precedures were followed to classify 775 site lists containing 230 plant species into floristically similar units. An association table was composed to identify characteristic species; a species was considered to be "characteristic" when it occurred in at least 60% of the site lists included in the floristic unit.

However, similarity between site lists may vary in significance, as one or more of the species whose presence is less than 60% may cause variations of considerable magnitude in the total floristic composition. The significance of similarity between site lists, therefore, cannot be estimated from the association table. These considerations indicated the need for a readily tabulated statistic which would estimate the floristic similarity of sites and which could be tested for probability. Of several statistics considered, three appeared particularly useful and were tested against available data. These were: (1) The Index of Diversity -α, based on Fisher's logarithmic series and as used by Williams (1944, 1947); (2) Kendall's Rank Correlation Coefficient — T, (1948); and (3) Sorensen's Quotient of Similarity — K, (1948) which expresses the percentage similarity of two sites.

The advantages and disadvantages of each are considered.

The Index of Diversity

Williams demonstrated the application of his Index of Diversity to certain biological problems, particularly the extent of association between units and groups of insect populations according to Fisher's logarithmic series. It is applicable to studies where populations are completely randomized, and expresses the principle that in randomly distributed populations an increase in sample size will show an increase in species not encountered in the smaller sample, ad infinitum. Thus, applied to vegetation, an increasing number of samples of a particular community should show an increasing number of species occurring in only one or a few samples, while at the same time the number of species occurring in all or nearly all samples should decrease.

When applied to samples drawn from the vegetation of Southwestern Saskatchewan, the Index of Diversity demonstrated a non-random distribution of plant species, deviating from the logarithmic series especially in the number of species occurring in a large percentage of the samples, and suggesting a marked association between species in samples which had been classified as similar

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by phytosociological procedures. These considerations suggested that other statistics might be more useful.

Kendall's Rank Correlation Coefficient — T

As used in this paper, the Rank Correlation Coefficient — T, is a measure of the association between two sites based on the number of species common to both sites. Its formula is presented together with a 2 x 2 reference table:

$$Tab = \frac{Cw - xy}{\sqrt{(Au)(Bv)}} \qquad (1)$$

$$\begin{array}{cc|c} C & x & A \\ y & w & u \\ \hline B & v & S \end{array} \qquad (2)$$

when $S =$ the number of species listed at N sites
$A =$ the number of species listed at site a
$B =$ the number of species listed at site b
$C =$ the number of species common to a and b
$u = S - A;\ v = S - B;\ x = A - C;\ y = B - C;\ w = u - y = v - x.$

The significance of any T_{ab} coefficient can be determined by the Chi² test when A, B and S are known. This requires the calculation of a coefficient of significance (T_e), which is a function of probability. The formulae to estimate T_e are indicated in equations 3, 4, 5 and 6:

$$\text{Chi}^2 = \frac{(Cw - xy)^2\, S}{(Au)(Bv)} \qquad (3)$$

or for the purpose of this study:

$$Cw - xy = \sqrt{\frac{Chi^2\,(Au)(Bv)}{S}} \qquad (4)$$

To illustrate the calculations assume that $S = 100$, A and B both equal 40, u and v each equal 60, and Chi² at $P = 0.001$ for 2df equals 13.82. Substitution of these values in equations (4) and (1) will estimate a T_e coefficient:

$$Cw - xy = \sqrt{\frac{13.82\ (2400)^2}{100}} = 892 \qquad (5)$$

and

$$T_e = \frac{892}{\sqrt{(2400)^2}} = 0.3717 \qquad (6)$$

All combinations of A and B where S equals 100 will estimate a T_e of 0.3717. Thus all T_{ab} coefficients greater than 0.3717 will indicate a significant relationship between any two sites ($P \geqq 0.001$); a smaller coefficient would indicate a lack of association between sites. However, to classify 775 sites by the T statistic, it would be necessary to calculate innumerable coefficients, because T_e has to be calculated for each successive smaller value of S and for each different combination of A and B. It is simpler to classify the sites into groups by phytosociological procedures, and test the sites within each apparent unit for similarity. Further, a more simple calculation would speed the procedure, and for this reason Sorensen's Quotient of Similarity was investigated.

Sorensen's Quotient of Similarity — K

K is a variation of Jaccard's (1902) coefficient of community. It is calculated according to the following formula:

$$K_{ab} = \frac{2C}{A + B} \times 100 \qquad (7)$$

The simplicity of the calculation favors the use of K to estimate similarity of sites on the basis of species composition. Unfortunately, the distribution of K seems to be very complex and has not been worked out. Sorensen ignores this by establishing arbitrary values for similarity, and if a K_{ab} quotient is greater than the arbitrarily selected value, the sites being compared are considered similar. However, a minimum quotient for similarity might be set at 30, 50, or 70, any one of which might be as significant as the other.

Relationship Between T and K

Because T is a test to estimate the degree of deviation from expected coincidence, and K is a measure of similarity of two sites, it was postulated that a relationship existed between T and K. If this was so, then a quotient for significance (Ke) could be estimated for any K_{ab}. One more calculation is thus required, one to estimate C_e, which is the least number of species common to two sites that can be considered sociologically similar. With the illustration used previously, where $Cw - xy = 892$, C_e would equal 24.91. Thus, Ke (the lowest quotient for K_{ab} which could be considered significant when $S = 100$ and A and B both equal 40) would be obtained by substituting 24.91 for C in equation 7. The calculation is as follows:

$$Ke = \frac{24.91 \times 2}{(40 + 40)} \times 100 = 62.3 \qquad (8)$$

Application and Results

Three premises were proposed to test the postulation of the T and K relationship. These were:

(1) That K is a reliable quotient to estimate the floristic similarity of two sites,

(2) That it is not justifiable to arbitrarily select a minimum value for Ke as Sorensen has done, but should be estimated from data, and,

(3) That significant K quotients can be employed to define phytosociological units.

Reliability of K

A relationship was established between T and K, and for any two populations a and b it was possible to plot T and K values against each other (Figures 1 and 2). However, when one population was replaced by a third with fewer or more species, the curve was no longer valid. This result demonstrated that Ke would depend on the sum of A and B. Furthermore, curves for one value of S were not valid at other levels, as Ke is also dependent on the magnitude of S. Therefore, an arbitrarily selected value for Ke can express entirely different relationships at different S levels even when A and B are constant.

The latter condition is illustrated in Figure 1 where A, B, and C are constant, but four S values are tested ($S = 50$, 75, 100, and 200); in addition, K_{ab} and Ke quotients are recorded on each curve. It will be noted that when S equals 50 or 75 a K_{ab} of 50 is not significant and barely so when $S = 100$. However, when S is increased to 200, a K_{ab} of 50 is well above Ke—the estimate for significance.

Thus, when the influence of the variables A and B, and S are recognized and calculations conducted to assess the variations introduced, K appears to be a satisfactory quotient to estimate similarity or dissimilarity of units of vegetation.

REFERENCE TABLE

WHEN S=	A+B=	C=	T	K ⊙	Te AT P=.001	Ke ⊗	Ce
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
50	20	10	.1667	50	.583	.7175	14.35
75	20	10	.318	50	.479	.5805	11.61
100	20	10	.375	50	.3717	.4975	9.95
200	20	10	.444	50	.263	.34	6.8

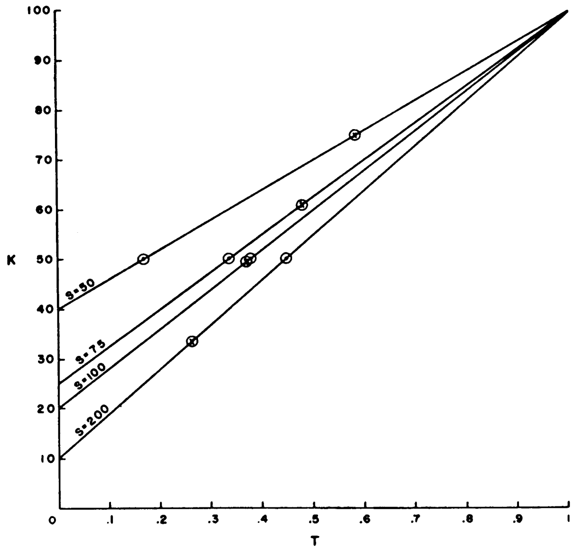

FIG. 1. Relationship between K and T with four values of S. (50, 75, 100, 200).

That it is not Justifiable to Choose Arbitrarily a Minimum Value for Ke

In most studies one would be working with a constant S and variables A, B, and C. Such would likely represent a unit of vegetation comprising several species lists. When studying data representing these conditions it was found that a single estimate of Ke could not be established. A fairly wide range of values had to be observed dependent on the magnitude of A and B; in turn each combination had to be tested for the significance of its quotient. The test can be done quickly by constructing a graph where curves are plotted for the highest, lowest, and a few intermediate sums of A and B (as in Figure 2); the significance of most other A and B combinations can be interpolated with a reasonable degree of accuracy.

Several A and B combinations with a constant S ($S = 100$) are presented in Figure 2. The

REFERENCE TABLE

A	B	A+B	C	S	T	K	Te ⊙	Ke	Ce
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
40	40	80	30	100	.583	75	.3717	62.3	24.19
30	40	70	21	100	.40	60	.3717	58.3	20.4
30	30	60	15	100	.285	50	.3717	56.	16.8
20	25	45	15	100	.464	60	.3717	47.2	11.8
17	40	57	17	100	.554	59.6	.3717	48.1	13.7
17	17	34	10	100	.508	58.8	.3717	48.2	8.1
20	20	40	10	100	.375	50	.3717	49.75	9.95

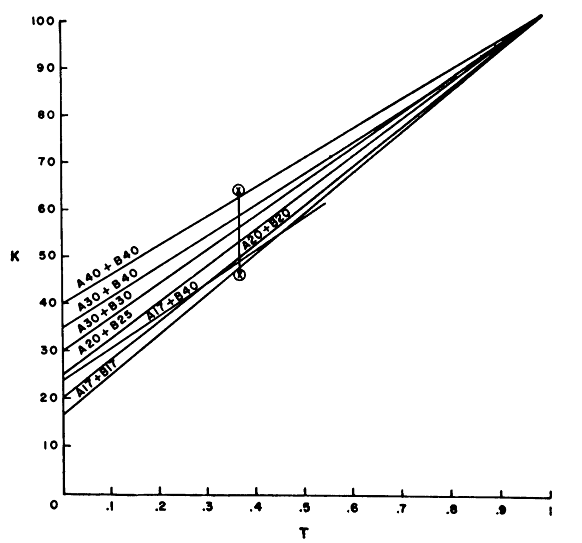

FIG. 2. Relationship between K and T when S = 100, and A + B variable.

curves illustrate that an arbitrary selection of Ke is not justifiable despite a constant level of T_e. It will be noted that all K_{ab} quotients listed in the reference table of Figure 2 are equal to or greater than the minimum selected by Sorensen to establish his 1st Order ($K \geqq 50$), yet when the K_{ab} quotients are compared to those for Ke, one of the seven populations has a K_{ab} rating below Ke (compare columns 7 and 9 in the reference table of Figure 2).

It follows, therefore, that a value for Ke cannot be chosen arbitrarily to estimate affinity between populations. However, when a Ke quotient is estimated for each set of populations being compared, the statistic can be employed with surety.

That K Can be Employed to Define Phytosociological Units

Because there is considerable reference to Sorensen's report in the discussion which follows, a summary of his procedure to utilize the K quotient is presented. Sorensen worked with fifty lists of the vegetation of Denmark; these were compared and K_{ab} quotients for all possible combinations were calculated and tabulated. Lists, where the populations had high similarity ($K \geqq 50$), were grouped to create "Groups of the 1st Order." Groups of the 1st Order were compared with each other, and the combinations with $K \geqq 40$ were again grouped to form "Groups of the 2nd Order." Groups of the 3rd and 4th Orders were organized respectively on the basis of $K \geqq 30$ and $K \geqq 20$. With this arrangement Sorensen's 1st Order groups represented the smaller sociological units (associations and sub-associations), while his 2nd and 3rd Orders united associations into alliances and orders. The groups of his 4th Order were inconclusive and no recognized sociological unit was apparent. Thus Sorensen attempted to establish sociological units (associations, alliances, orders, and classes) by using a mathematical concept instead of arranging his lists by classical procedures.

On the other hand the precedure employed for the studies conducted in Southwestern Saskatchewan arranged site lists into "groups" by the use of association tables and employed the mathematical analyses to estimate the validity of the allocations. For each group, comprising apparently similar sites, all possible K quotients were calculated and tabulated as in Tables I and III. A value for T_e was estimated, while Ke was calculated for the greatest, least, and a few intermediate A and B sums, and plotted as in Figure 2. Thus a range of Ke values was obtained to estimate the significance of the K_{ab} quotients. This procedure has been termed an "Array" analysis to distinguish it from the "Order" of Sorensen.

One, two, or more Array analyses may be undertaken for each "group." In the analysis of the 1st Array the calculations are based on all species (S) from all sites (N), and as S is usually large, both T_e and Ke values will be relatively small. If all K quotients are greater than Ke then all sites allocated to the "group" being studied will belong to a sociological unit.

A 2nd Array analysis is then undertaken for each group. In this calculation only those sites (N) showing relationships in the 1st Array analysis and the species (S) for those sites are included. Thus, it is necessary again to calculate T_e and Ke for the highest and lowest sums of A and B; because S is smaller both T_e and Ke will be greater. If certain combinations of sites have K quotients below Ke, the sites concerned will be set aside and re-examined; if the K quotients are all greater than Ke, then all sites will be retained in the original arrangement. After 2nd Array analysis the related populations can be described, and rearrangements of all sites can be completed with confidence. Applications of the "Array" procedure follow using material drawn from Sorensen's report and with original data from Saskatchewan studies.

Data from Sorensen's Report.—In his analysis Sorensen worked with 50 plant lists ($N = 50$) comprising 226 species ($S = 226$). When these data were studied by 1st Array analysis it was determined that the lists in Sorensen's 1st Order groups "a" and "e" were related with Ke values of 35 to 45; Sorensen described "a" and "e" as belonging to the related orders Arrhenatheretalia and Molinietalia; they comprised 15 lists (N = 15) containing 113 species ($S = 113$). The lowest A and B sum between any two of the 15 lists was 62, the greatest 98. When the lists of the "a" and "e" groups were studied for similarity in 2nd Array analysis, minimum Ke values of 48.4 to 63.3 were necessary to estimate significant relationships.

Referring to Table I it is evident that only one list (#16) has doubtful relationship to the others after 1st Array analyses, but when 2nd Array affinities are studied, it is necessary to remove four lists (#16, 17, 27, and 28), as few of their K_{ab} quotients approach those necessary for estimated significance. The remaining lists form a group in which each list is related to at least three other lists and thus form a recognizable sociological unit.

TABLE I. K_{ab} Values of Plant Populations According to Population Numbers Assigned by Sorensen 1948

Plant Population Numbers															
35	26	7	5	1	2	36	31	15	13	8	17	28	16	27	Plant Population Numbers
..	61	60	56	52	54	53	57	53	43	54	47	42	38	53	35
	..	67	62	49	55	50	51	56	50	61	41	34	24	53	26
		..	81	54	57	56	51	58	49	59	50	36	30	48	7
			..	63	63	58	53	64	54	66	48	37	27	55	5
				..	72	73	52	60	55	67	55	45	35	51	1
					..	75	67	60	55	65	55	47	36	53	2
						..	63	64	56	58	57	57	45	49	36
							..	55	60	46	58	49	49	56	31
								..	61	58	49	46	38	50	15
									..	49	51	45	50	41	13
										..	50	42	27	56	8
											..	52	56	44	17
												..	54	40	28
													..	26	16
														..	27

Ke for 1st Array 35-45
Ke for 2nd Array 48.4-63.3

Characteristic species by classes, alliances, and associations listed in Sorensen's 1st Order groups "a" and "e" are presented in Table II, together with their presence ratings in the eleven population lists. These data have been compared to classifications of the vegetation of Western Europe by Westhoff *et al.* (6) and Knapp (7)[3], and it is evident from the comparison that the association can be classified as follows:

TABLE II. Characteristics (kensoorts) of the Sociological Units "a" and "e" of Sorensen wiht Constancy Percentages

Sociological Unit	Species and Percentage Constancy	
Class: Molinieto—Arrhenatheretea	Poa pratensis	100
	Festuca rubra	100
	Agrostis tenuis	100
	Plantago lanceolata	100
	Anthoxanthum odoratum	91
	Rumex acetosa	73
	Leontodon autumnalis	82
	Cerastium caespitosum	91
	Stellaria graminea	82
	Bellis perennis	73
	Potentilla reptans	55
	Trifolium dubium	46
	Trifolium pratense	36
	Polygala vulgaris	27
	Prunella vulgaris	27
	Holcus lanatus	27
	Ranunculus acer	18
	Centaurea jacea	9
	Vicia cracca	27
	Dactylis glomerata	46
	Festuca pratensis	9
	Potentilla erecta	9
Alliance: Arrhenatherion elatioris	Bromus mollis	55
	Avena pubescens	27
Association: Lolieto—Cynosuretum	Cynosurus cristatus	82
	Phleum pratense	55
	Trifolium repens	100
Sub-association: Lolieto—Cynosuretum luzuletosum campestris	Luzula campestris	100
	Hieracium pilosella	100
	Lotus corniculatus	64
	Ranunculus bulbosus	100
Class: Brometo—Corynephoretea	Achillea millefolium	100
	Festuca ovina	91
	Galium verum	82
	Cerastium semidecandrum	46
	Viola canina	46
	Campanula rotundifolia	63
	Arenaria serpyllifolia	46
	Thymus chamaedrys	36
	Hypochoeris radicata	36
	Aira praecox	36
	Carex caryophyllea	36
	Cirsium acaule	18
	Sedum acre	18
	Trifolium arvense	9
	Trifolium medium	27
	Potentilla argentea	9
	Artemisia campestris	9
	Ononis spinosa	9

[3] Although the classifications established by Westhoff *et al.* and Knapp are in general agreement, one author may mention local or regional characteristics which the other does not recognize for that particular unit. The classification presented in Table 2 recognizes contributions from both authors.

Class: Molinieto-Arrhenatheretea Tx. 1937.
Alliance: Arrhenatherion elatioris (W. Koch 1926) Tx. 1937.
Association: Lolieto-Cynosuretum (Br.-Bl. et deL. 1936) Tx. 1937.

The occurrence of certain species, notably, *Luzula campestris, Hieracium pilosella* and *Ranunculus bulbosa* suggest that the unit is not the typical association but a sub-association which has been described as follows:

Sub-association: Lolieto-Cynosuretum luzuletosum campestris Tx. 1937.
Ecology: Lean pasture, on somewhat drier and poorer soils than the Lolieto-Cynosuretum typicum. On diluvial sand- and loam-soils; also on alluvial river- and dune-sand. Westhoff *et al.* (1946).

Data from Southwestern Saskatchewan—Seven hundred and seventy-five lists ($N = 775$) comprising 230 species ($S = 230$) were compiled from 1955 to 1957. These data were classified by phytosociological procedures to establish classes, orders, alliances, and associations. Twenty-three of the 775 lists were classified as follows:

Class: Astragaleto-Stipetea
Order: Astragaleto-Stipetalia comatae
Alliance: Erigonion flavi 4
Association: Astragaletum caespitosi

The 23 lists were studied by Array analyses to establish characteristics not apparent from the Association Table. K_{ab} quotients were calculated and are presented in Table III. A T_e coefficient was calculated, while Ke quotients were estimated. As all K_{ab} quotients were greater than Ke, the 1st Array analysis indicated strong relationships between the 23 sites and that the vegetational covers were

TABLE III. K_{ab} Values Calculated for 23 Populations Classified as association Astragaletum caespitosi of the alliance Eriogonion flavi

Group I Lists						Group II Lists						Group III Lists				Group IV Lists							Plant Lists
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
.	86	77	78	77	68	70	79	82	83	74	73	67	68	73	62	55	57	57	50	52	52	50	1
	.	84	75	68	70	69	70	79	74	76	70	65	65	75	68	61	53	60	53	58	49	50	2
		.	91	76	73	74	68	76	67	68	69	68	68	77	67	68	53	58	55	63	49	47	3
			.	82	70	72	70	78	68	70	70	69	69	74	64	65	55	50	52	60	50	50	4
				.	83	79	73	76	72	79	77	76	72	73	71	64	60	54	53	62	58	55	5
					.	71	75	78	74	81	74	72	78	74	73	66	60	45	58	58	60	57	6
						.	81	74	80	77	84	74	75	76	74	53	59	50	52	59	60	58	7
							.	83	89	76	79	68	74	74	68	56	60	50	52	55	61	60	8
								.	85	84	82	71	77	82	71	58	50	53	58	62	53	55	9
									.	80	83	67	73	73	67	58	55	55	58	57	60	61	10
										.	80	68	70	75	68	61	65	60	53	60	58	61	11
											.	77	73	74	77	61	65	62	63	57	62	60	12
												.	92	89	80	70	55	55	64	70	58	50	13
													.	90	77	75	62	55	60	69	67	61	14
														.	82	52	62	53	58	70	55	52	15
															.	70	63	50	55	65	55	52	16
																.	70	66	79	76	71	71	17
																	.	71	70	65	78	79	18
																		.	71	65	65	66	19
																			.	81	68	67	20
																				.	73	70	21
																					.	80	22
																						.	23

Ke for 1st Array 35-43 ($S = 230$)
Ke for 2nd Array 72.2-77 ($S = 47$)

representative of the association Astragaletum caespitosi.

However, 2nd Array analysis ($N = 23$, $S = 47$) showed that K_{ab} quotients of 72.2 to 77 were necessary for significant similarity of sites. As K_{ab} quotients of the lists from 7 sites were below the required range, they were set aside from the original grouping and reclassified (Lists #17 to 23, Group 4, Tables III and IV).

The 2nd Array analysis demonstrated that further sub-division of the remaining 16 lists was possible. Consequently, three groups—I, II, and III were established according to the similarity of the sites. These groupings can be explained ecologically. Group I lists are comprised of species which characterize strongly-eroding sites where the environment provides only minimum needs for the association, while the species found in Group II lists are indicative of less severe erosion. Those of Group III are indicative of an environment near the optimum for the association, and represent an eroded form of the Festuca scabrella Association of Moss and Campbell (8). Group IV sites show little or no erosion, and could represent the last stage of the association in transition to a higher type of grassland.

As a corollary to the ecological notes, the abundance and frequency of *Astragalus caespitosus* (the indicator for the association) are stated for each of the 23 sites at the bottom of Table IV. It will be observed that its abundance increases from Groups I and III, but is negligible in Group IV.

Thus, on the basis of recognized phytosociological procedures and the Array analyses described, the 23 lists were classified as follows:

Group I. Lists 1-6, Tables III and IV.
Sub-association: Astragaletum caespitosi-Astragaletosum triphylli.
Ecology: Strongly eroded, highly calcareous soils, gravelly sandy-loam or light loam; open vegetation.
Soil Characteristics: pH 8.69; organic matter 1.23%; moisture holding capacity 40%; saturation of base exchange capacity 63%.

Groups II and III. Lists 7-16, Tables III and IV.
Association: Astragaletum caespitosi
Ecology: Eroded, highly calcareous soil, gravelly sandy-loam or light loam; open vegetation.
Soil Characteristics: pH 8.27-8.20; organic matter 3.20-3.43%; moisture holding capacity 50-56%; saturation of base exchange capacity 58-60%.

Group IV. Lists 17-23, Tables III and IV.
Sub-association: Bouteloueturn gracilis-Astragaletosum caespitosi.
Ecology: Lightly to moderately eroded soils, calcareous, sandy-loam to loam; often somewhat gravelly. Vegetation discontinuous.
Soil Characteristics: pH 8.05; organic matter 4.40%; moisture holding capacity 61%; saturation of base exchange capacity 55%.

TABLE IV. Characteristics (kensorts) by Class, Alliance, and Association of the Association Astragaletum caespitosi

Phytosociological Units and Kensorts	Group I Lists						Group II Lists						Group III Lists				Group IV Lists						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Class and order																							
Agropyron dasystachyum	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
Koeleria cristata	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Stipa comata	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Artemisia frigida			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
Gutierrezia diversifolia	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x
Phlox hoodii	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Agropyron smithii			x	x			x																
Calamagrostis montanensis	x			x	x		x	x	x	x		x	x	x	x	x							
Comandra pallida	x	x	x	x	x		x	x	x	x	x	x		x	x	x	x	x			x	x	x
Erigeron caespitosus	x	x	x				x	x	x	x		x	x	x	x	x			x	x	x		
Petalostemon purpureus					x														x	x	x		
Linum lewissi	x		x	x	x	x		x	x				x	x	x		x						
Chrysopsis villosa									x		x	x					x	x	x	x	x	x	x
Alliance: *Eriogonion flavi*																							
Eriogonum flavum	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Haplopappus nuttallii	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
Oxytropis macounii		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
Oreocarya glomerata	x			x	x	x	x	x		x	x	x	x	x				x				x	x
Hymenoxys richardsonii	x	x		x			x	x	x	x	x	x	x	x	x	x							
Muhlenbergia cuspidata					x	x	x					x	x	x		x	x			x	x	x	x
Carex filifolia	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x				x
Artemisia camporum		x	x	x		x							x	x	x	x	x		x	x			
Lesquerella arenosa	x	x	x	x					x	x		x					x		x	x	x		
Musineon divaricatum						x	x	x	x	x	x	x	x	x	x	x							
Senecio canus	x	x	x	x	x	x			x		x		x	x	x	x	x				x		
Sub-association: Astragaletosum triphylli																							
Astragalus triphyllus			x	x	x	x																	
Pentstemon nitidus						x		x	x	x				x			x			x	x	x	x
Petalostemon candidus																	x			x	x		
Erigeron compositus																	x						
Haplopappus armerioides	x	x		x																			
Association: Astragaletum caespitosi																							
Astragalus caespitosis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Townsendia sericea			x	x			x						x	x	x	x	x				x		
Alliance: Boutelouion gracilis																							
Bouteloua gracilis			x	x	x												x	x	x	x	x	x	x
Haplopappus spinulosus																x		x				x	x
Liatris punctata														x			x	x	x			x	x
Carex eleocharis													x	x	x	x	x	x	x	x	x	x	x
Festuca scabrella[1]													x	x	x	x	x						
Gaillardia aristata[1]													x	x	x	x	x	x		x	x		
Abundance and Frequency of Astragalus caespitosis	2.4	2.4	1.3	1.3	1.3	3.3	1.3	3.3	2.3	3.5	2.3	1.2	3.3	3.3	4.3	5.3	+.1	+.2	+.1	+.3	+.3	+.1	+.2

[1] Indication of a more developed order.

The above divisions of the association Astragaletum caespitosi were not apparent in first floristic ordering. The reclassification demonstrates the usefulness of the mathematical concepts employed, and further, follows the ecological and edaphic characteristics of the units more closely than the original grouping. It is evident that relationships estimated by K can define units of Prairie vegetation.

CONCLUSIONS

In connection with phytosociological studies conducted with indigenous vegetation in Southwestern Saskatchewan, an adaptation of Sorensen's Quotient of Similarity-K, was devised to estimate affinity between sites, according to species presence. The results of the study showed that K, as used by Sorensen, was an unsatisfactory statistic, because the probability of a quotient could not be estimated. This weakness was corrected by developing a technique based on the combined use of Kendall's Rank Correlation Coefficient-T, and Sorensen's Quotient of Similarity-K. It was concluded that the technique could be employed to (1) estimate similarity of sites—both within and between phytosociological units, (2) to group sites according to ecological characteristics with a preciseness not obtainable when only standard phytosociological procedures were employed, and (3) that the small amount of extra time required to calculate T_e and Ke was more than compensated for by the additional information obtained.

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INFESTATION OF CHYTRIDIACEOUS FUNGI ON PHYTOPLANKTON IN RELATION TO CERTAIN ENVIRONMENTAL FACTORS

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INTRODUCTION

The ecological role of the fungi in nature, particularly that of the aquatic fungi, has long been a subject for conjecture and speculation. These aquatic plants, with the bacteria and protozoa, are of great significance in the break-down of dead organic matter and in the returning of nutrient materials into the environment. The abundance and variety of aquatic fungi can be verified by microscopic examination of the silmy surface of an apple, an onion, a rose hip, or a wild cherry fruit which has been immersed for several weeks in natural waters. Kanouse (1925) states that zoospores of members of Saprolegnia, Achlya, and Pythiomorpha are probably present in most fresh water habitats. Weston (1940), who discussed the role of aquatic fungi in hydrobiology suggests that no type of inland water lacks representatives of the Phycomycetes and points out that members of practically all major groups of fresh water organisms are attacked by aquatic fungi.

The only quantitative limnological studies of aquatic Phycomycetes appear to be the investigations of Canter and Lund (1948, 1951, 1953) in the English Lake District. They found that epidemic parasitism of the chytrid *Rhizophydium planktonium* Canter on the diatom *Asterionella formosa* Hass. delays the time of algal maximum or decreases the number of diatoms present during such a period. Parasitism by fungi of one species of algae may favor the development of other phytoplankters. The degree of infection of a population depends on the relative fluctuation in the numbers of fungal and algal cells. When conditions are suitable, a parasite can increase in numbers faster than its host, as evidenced by epidemics which preceded or followed the time at which the maximum numbers of algal cells were present. Often an epidemic occurs at the time of the decline in host maximum, which may cause an appreciable ecological effect since the decline is then earlier than it otherwise would have been. Canter and Lund point out that factors such as the amount of available silica in the water and the duration and intensity of light are difficult to correlate with degree of parasitism.

This investigation was conducted at Frains Lake, Washtenaw County, Michigan, for one year. Two chytridiaceous fungi were studied. One, *Rhizosiphon anabaenae* (Rodhe and Skuja) Canter, was parasitic on the blue-green alga, *Anabaena planktonica* Brunnthaler (Fig. 1; B, C), and the other, *Amphicypellus elegans* Ingold, was saprophytic on dead thecae of the dinoflagellate, *Cera-*