Prediction of Weight Composition from Point Samples on Clipped Herbage[1]

HAROLD F. HEADY AND GEORGE M. VAN DYNE[2]

Professor of Forestry (Range Management) and Research Nutritionist, University of California, Berkeley and Davis.

Highlight

Percentage botanical composition by weight can be estimated from composition determined with the laboratory point method, if differences among species, seasons of growth, and botanical composition are taken into account.

Weight of herbage is an attribute of individual plants and plant communities that has been measured since the beginning of intensive pasture and range studies. Many procedural variations in weight sampling have been suggested (Brown, 1954; U.S. Forest Service, 1958). While total herbage weight is frequently reported, percentage species composition on a weight basis is seldom given because hand separation is time consuming and, therefore, expensive. Pechanec and Pickford (1937) suggested weighing the whole sample and estimating the parts. Although estimates can be corrected and the estimators trained by double sampling techniques (Wilm et al., 1944), ocular estimates have personal bias.

Field point sampling of foliage and basal cover is frequently used to determine percentage species composition. Recently, laboratory point sampling has been employed to determine composition of forage samples taken from fistulated animals (Van Dyne and Torell, 1964). Reports are scarce of attempts to estimate percentage weight composition with point sampling. Heady and Torell (1959) presented graphs which suggested that field points, laboratory points, and weights by hand separation gave similar species compositions. Harker, et al. (1964) found that percentage species composition by the microscopic point method gave a satisfactory estimate of composition on a dry weight basis in controlled mixtures of a coarse grass and sweet potato vines.

Field time is more limited than laboratory time in many range investigations. Proportional species weights in the field and in animal diets have more meaning in certain studies than proportions based on cover. Therefore, techniques for rapid and accurate estimating of weight composition are needed.

The purpose of this study was to develop and test equations which predict percent weight composition (Y) from percent point composition (X). Several questions were examined in analyzing point-weight relationships: (1) Is transformation of the variates necessary? (2) Are prediction equations adjusted through the origin superior to those not through the origin? (3) Are separate prediction equations needed for individual species or can they be grouped conveniently without losing precision? (4) Can prediction equations developed for immature plants be used for mature plants? (5) Does variation in vegetational composition affect the usefulness of prediction equations?

Materials and Methods

Vegetation. — The plant material analyzed came from four adjacent enclosures on the Hopland Field Station in Mendocino County, California. Various degrees of mulch removal and seeding in the enclosures resulted in vegetation with different species composition

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[2] *Present address: Radiation Ecology Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.*

(Table 1). Full description of the treatments and results were discussed by Heady and Torell (1959). The resident annual and soft chess enclosures were highest in grass because mulch was left in place in the former and only partially removed in the latter. Soft chess (*Bromus mollis* L.) was seeded in the soft chess enclosure. Where all mulch was removed, broadleaf filaree (*Erodium botrys* Bertol.) was of greatest percent weight. Seeding bur clover (*Medicago hispida* Gaertn.) and removing part of the mulch resulted in vegetation with a large clover portion and the least filaree. Thus, the point-weight relationships in this paper were developed for mixed annual vegetation in which soft chess, filaree, and bur clover contributed 91 to 96 percent of the total weight. Wider variations among these species than is shown in Table 1 occur in the California annual type between locations and between years (Heady, 1961).

Sampling. — Ten plots each one ft^2 were clipped in each enclosure on five dates in 1958: February 1, March 6, April 2, May 2, and July 8. These dates covered essentially the whole growing season in the annual grass type. The ten clipped samples for each date were composited and thoroughly mixed. From each composite sample, ten sub-samples were analyzed with 50 points that were taken with a binocular microscope technique described by Heady and Torell (1959) and illustrated by Harker et al. (1964). Point analyses were made on fresh herbage as it came from the field in order to minimize shattering. Each subsample was hand separated into species, dried, and weighed.

Table 1. Percentage botanical composition by weight in four enclosures averaged for five sampling dates between February and July, 1958.

Enclosure	All[1] gr.	B. mol.	E. bot.	M. his.
Resident annual	42	34	57	<1
Soft chess	35	31	54	10
Filaree	22	20	68	7
Bur clover	29	26	34	37

[1] All gr. = all grasses; B. mol. = *Bromus mollis;* E. bot. = *Erodium botrys;* M. his. = *Medicago hispida.*

Results

Equation Selection

Several types of transformations were made to determine whether the regression lines were linear, curved, or unduly influenced by percentages. Typical results are shown for grasses clipped in February with a sample size of 81 (Table 2).

Arcsin transformations to correct for percentage distributions gave lesser r^2 values than those calculated from percentages. Square root and logarithmic transformations indicate that linear relationships exist between percentage points and percentage weight because the r^2 values were only slightly larger or smaller than the coefficient when both X and Y were on a linear scale. On the other hand, the standard error of estimate of the linear regression line is somewhat larger than the others. Little is gained by these transformations so percentages as computed from original data were used.

The hypothesis that $Y_i = 0$ when $X_i = 0$, i.e., that zero points equal zero weight, was accepted because r^2 values were somewhat higher when the regression lines were adjusted to pass through the origin (Table 3). In testing this hypothesis, the sample size was 538 for all grasses, 422 for all forbs, 136 for grasses in July, and 113 for forbs in July. The data contained 149 items of $Y_i = >0$ but $X_i = 0$ and 18 items of $Y_i = 0$ but $X_i = >0$. Over 70 percent of these values greater than zero were less than 2 percent. They are small errors in double sampling that bias the results positively because neither percent points nor weights of less than zero could occur. Adjusting the regression lines to pass through the origin corrects for this bias. Between 92 and 95 percent of the variation in percentage weight is accounted for in the variation of percentage points for equations through the origin (Table 3).

Table 3. The relationship (r^2.100) between percent points (X) and percent weight (Y) for equations through or not through the origin.

Data Group	Not Through Origin	Through Origin
All grasses	85	92
All forbs	88	95
Grasses in July	89	93
Forbs in July	86	92

Grasses and Forbs

Individual species varied widely in the ratio of weight to points and in the predictive equations (Figure 1). The dotted lines, Y = X, represents weight composition estimated by point composition on a 1:1 ratio. Generally, all the forbs were above this ratio and all grasses below it. Full regression equations are shown in Figure 1, including the standard error of regression coefficient, standard error of estimate, sample size (N), and r^2 values. The heavy part of each regression line shows the mean percent points ± three standard deviations.

Soft chess composed 48 percent of the point composition in July over all plots and filaree 36 percent. The predictive equations for these two species on each of the five dates was approximately equal to the equations for all grasses and for all forbs on the corresponding dates. For example, the average slope of the regression line for all grasses in July was 0.46 and all forbs 1.50. This suggests that forbs and grasses can be grouped separately if objectives permit.

Table 2. Relationship of percent weight (Y) to percent points (X) with four types of transformations.

Transformation	Equation	Standard error of estimate	r^2 .100
$\sqrt{X+1}$, $\text{Log}_{10}Y$	Y= 0.32+ 0.17X	0.16	83
Arcsin (X+1), $\text{Log}_{10}Y$	= 0.67+ 1.67X	0.18	77
$\sqrt{X+1}$, Y	=—9.96+ 5.91X	6.82	76
Arcsin (X+1), Y	= 1.25+60.8X	6.35	79
X, Y	= 1.21+ 0.66X	6.19	81

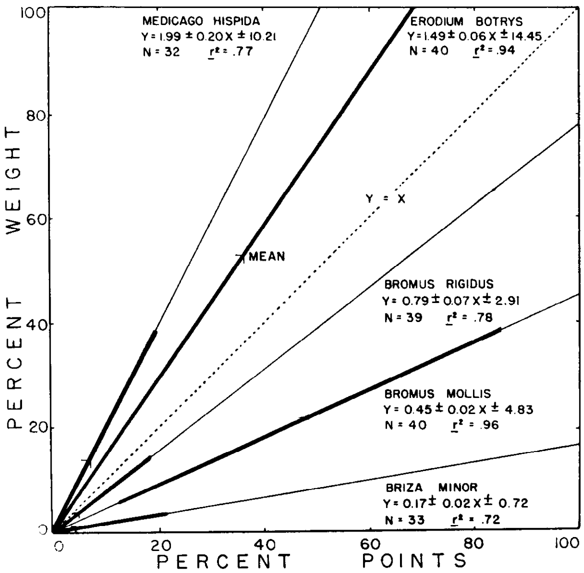

FIGURE 1. Regression of percent weight on percent points for five species over all plots in July. Mean percentage point composition is shown on each regression line.

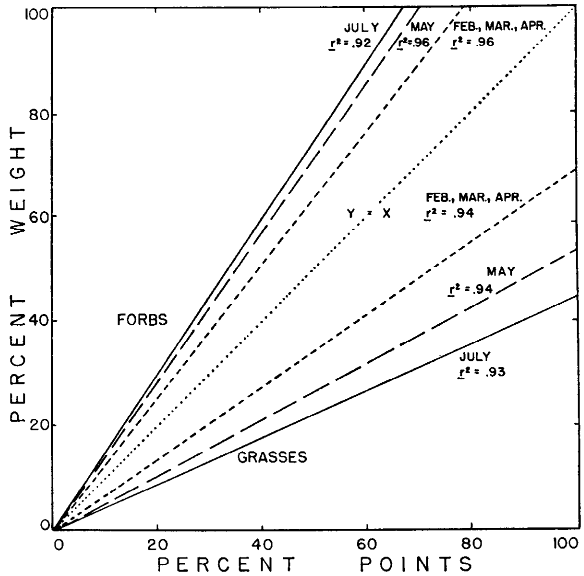

FIGURE 2. Regression of percent weight on percent points for grasses and forbs at five periods during the growing season.

The equations for all grasses and forbs were developed from individual species data in each sample rather than on the sums of grasses and forbs in the samples. N would have been 200 in the latter calculations. If equations were developed with sums, false confidence is obtained because sampling errors tend to be canceling and variance reduced in summation of percentages.

Sets of 50 points were considered a sample in contrast to the usually reported 100 to 400 points. Relatively small standard errors indicate that compositing of material and subsampling can be used to reduce sample size if knowledge of field variation is not essential.

The range in slope from 0.17 for little quaking grass (*Briza minor* L.) to 1.99 for bur clover is caused by difference in plant structure. Little quaking grass has a large open inflorescence with fine branches that weigh less per point than the other species. Ripgut (*Bromus rigidus* Roth.) is a coarser plant than soft chess. In July, after many forb leaves had shattered, the stems of bur clover weighed more per point than those of filaree. Examples of slopes or weight:point ratios for other species are 0.32 for nitgrass (*Gastridium ventricosum* (Govan) Schinz and Thell.), 0.48 for galium (*Galium parisiense* L.), and 1.00 for turkey mullein (*Eremocarpus setigerus* Benth.).

Stage of Maturity

Until approximately the first of April, plants in the California annual type are short with little stem material. Stem elongation occurs and flower parts emerge as soon as temperatures rise. In the year the samples were taken, plants were short during the first three sampling periods, approaching maturity at the May sampling, and over a month past maturity in July. Within grasses and forbs, slopes of the prediction equations for February, March, and April were essentially the same (Figure 2). In May, forbs weighed more per point and grasses less than earlier in the season. The trend continued in July.

High predictive value of these equations is indicated by narrow confidence limits on the predicted percentage weights at the mean of percentage points (Table 4). At the extremes of low and high percentage points the predictive values are less. The confidence limits for the different lines overlap at point percentages below 6 to 13, indicating a minimum level where difference between months could be detected. Data in Table 4 apply to the regression lines in Figure 2.

Predicted percentage weights were less for grasses than the percentage points and the reverse was true for forbs (Table 4). That is, grasses weigh less per point than do forbs, or assuming constant density of plant material, there is greater cross-sectional area per point for

Table 4. Predicted percent weight ($\hat{Y}$), with confidence limits (C.L.) at the 95% level, for all grasses and forbs at five dates, (a) calculated at the mean percentage point composition ($\bar{x}\pm$ Standard error) and (b) confidence limits at the mean point composition ± three standard deviations.

	(a)	(b)	
	$\hat{Y}\pm$C.L.	±C.L.	$\bar{X}\pm$S.E.
GRASSES			
Feb.	18±0.25	4.31	26±2.1
March	15±0.14	3.78	22±2.3
April	11±0.16	2.91	17±1.8
May	11±0.12	2.48	20±2.2
July	8±0.08	1.88	17±1.9
FORBS			
Feb.	33±0.31	5.63	26±2.3
March	36±0.29	5.27	28±2.3
April	32±0.08	2.30	25±2.0
May	30±0.30	5.28	21±1.9
July	23±0.32	6.15	15±1.7

forbs than for grasses. These differences were maintained through the growing season and became accentuated because more forb leaves shattered than grass leaves.

The comparisons thus far made were on a basis of point sampling of clipped material with the binocular microscope. Percentage foliage cover of grasses, on a basis of field point sampling, was lowest in March and highest in July (Table 5). Heights of the field hits were measured with the apparatus described by Heady and Rader (1958). Average height and average weight per square foot gradually increased until April, reached a peak in May after a short rapid growth period, and declined as the dry season progressed, agreeing with earlier findings (Ratliff and Heady, 1962).

Ratios of percentage weights to percentage points decreased more for grasses in the field than was shown in the laboratory sampling, although the two trends are similar. Percentage cover of grasses increased but percentage weight decreased, thus accounting for the lower ratios. Forbs showed an increase in weight per point in the field over results in the laboratory. As relative forb cover decreased relative weight increased.

As all plants grew taller, the weight per hit increased but at a lesser rate than the height, so the ratio of weight to height decreased. Grasses showed this relationship more than forbs. Even though grasses were always taller than the forbs, the latter were always heavier per point and became increasingly heavier with growth. Observations agree with the data in suggesting that stems and fruiting parts of the forbs increased in coarseness more than the same parts of grasses. Evidently the effect of shading on the forbs by grasses did not cause the forbs to lengthen and develop thin stems.

Decrease in weight and height from May to July was due to normal shattering of leaves and inflorescences and to the actions of small animals. The enclosures were ungrazed by livestock. Decrease in the ratio of weight to height in grasses and an increase in forbs from May to July is because of more weight loss in shattering of grasses than of forbs. This is probably because of the more complete shattering of inflorescences in the grasses.

These data suggest that each hit has a certain weight value that is different for grasses and forbs. The values change through the growing season, especially during the periods of rapid growth and shattering after plant maturity. For equations to be most useful in predicting percent weight from percent points they should be developed from data on plants at the same stage of maturity to which they are to be applied.

Table 5. Relative changes in mean cover, height, and weight of grasses and forbs through a growing season.

Date	Field hits (%)[b]	Height (ft)	Weight (g/ft²)	Weight (%)	Field[a] Weight: Points (%:%)	Field[a] Weight: Height (g/ft²: ft)	Lab Weight: Points (%:%)
GRASSES							
Feb.	35	.080	3.62	39	1.00	1.00	1.00
March	32	.101	4.29	36	1.01	0.94	0.99
April	34	.136	4.53	33	0.87	0.74	0.99
May	35	.415	11.75	32	0.82	0.63	0.80
July	42	.292	6.10	27	0.58	0.46	0.66
FORBS							
Feb.	65	.050	5.55	61	1.00	1.00	1.00
March	68	.076	7.74	64	1.00	0.92	1.00
April	66	.108	9.17	67	1.08	0.76	1.01
May	65	.310	25.22	68	1.12	0.73	1.12
July	58	.188	16.61	73	1.34	0.80	1.18

[a] All ratios are adjusted to those of February equalling 1.00.
[b] Percentage field hits are based on 1600 points at each date.

Species Composition

As indicated earlier, the four enclosures had different species composition at the time of sampling (Table 1). Averaged over all dates, ratios of percentage weight to percentage points increase for both forbs and grasses as the proportion of grass in the stand increased (Figure 3). The lowest weight per point occurred on the filaree plot and the highest on the resident annual plot. Forbs on the forb plots had thinner plant parts and less weight per point on the average than forbs on the grass plots. Conversely, grasses on the grass plots had more weight per point than grasses on the forb plots. These differences were not consistently significant above approximately 20 percent composition, below which no significant differences were found.

Change in plant form may be the result of more lower leaves dying in relatively pure grass stands. Therefore, the proportion of stems in the total herbage and the average weight per point would be greater than in mixed stands. Such an explanation fits the relationships of grasses in the plots but not the forbs. Forbs may react differently by growing taller with thinner stems. Whatever the cause, weight to point ratios change with differences in composition, but these changes are of less magnitude than those associated with stage of maturity and species.

Summary

Regression analyses show that percentage botanical composition by weight can be estimated from composition determined with the laboratory point method. This conclusion is based on point sampling with a binocular microscope of clipped herbage and hand separation of the same material.

Satisfactory results were obtained by analysis of the percentage data, on a linear basis through the origin, without transformation of the variates.

Individual grass species exhibited percentage weight to percentage point ratios at maturity from 0.17 to 0.79 and forbs from

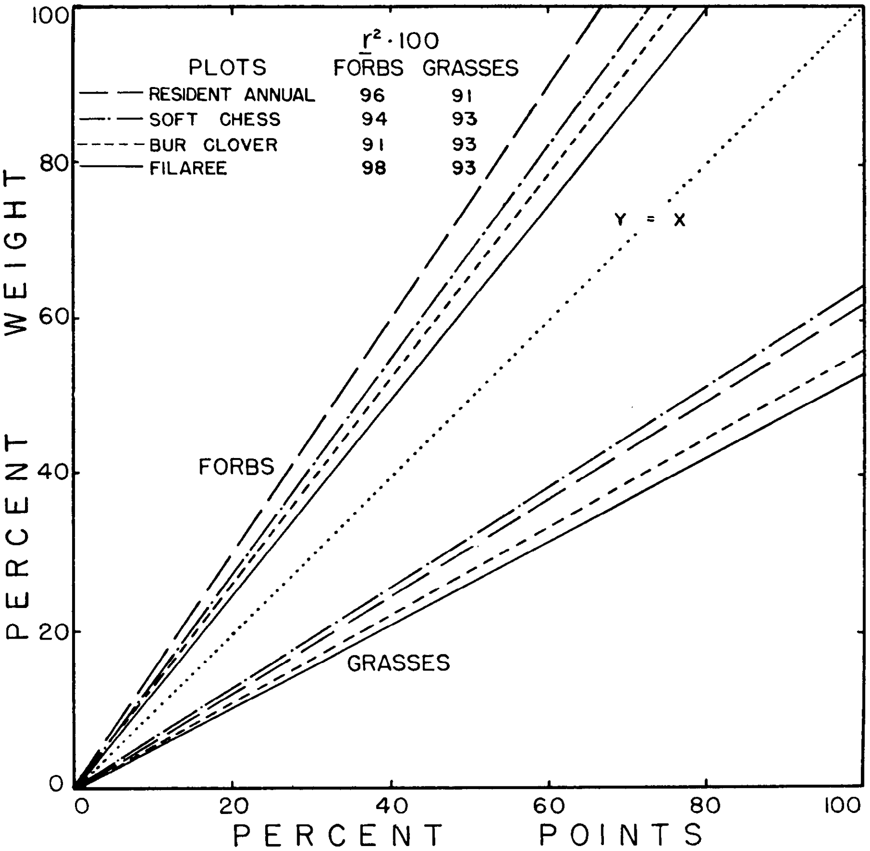

FIGURE 3. Change in ratio of percent weight to percent points for forbs and grasses from plots of different species composition.

1.00 to 1.99. Prediction equations for all grasses combined and all forbs combined were similar to the equations for the dominant species of each group at each sampling period.

Ratios of weight to points changed during the growing season because of changing thickness of plant parts, shattering, and varying proportions of plant parts. With maturity, forbs became heavier and grasses lighter per point, whether measured in the field or laboratory. In the field grasses increased while forbs decreased in herbage cover and grasses increased in height more than forbs. Weight to height ratios decreased in both forbs and grasses but more so in the grasses.

Regression of percent weight on percent points varied with species composition, although not as much as among species and through the growing season. Percentage weight composition can be estimated satisfactorily from laboratory point analysis, if differences among species, seasons of growth, and botanical composition are taken into account.

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