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Estimating Herbaceous Yield from Species Frequency

Abstract

Frequency sampling is a useful method for quantitatively classifying and monitoring vegetation composition. However, it does not provide herbage production data needed to calculate and monitor carrying capacity. Frequency-yield relationships were examined on 12 dry mountain meadow sites in central Idaho. Herbaceous yield and species frequency were sampled, and regression equations were developed to relate these two parameters. Significant regressions ($P < 0.10$) were achieved for 21 of 30 species with most r^2 values 0.70 or greater. Estimated total site yields were calculated from individual species' regressions. Estimated total yields and actual total yields did not differ ($P > 0.05$). Development of similar area-specific regression equations may enable land managers to obtain satisfactory yield estimates from frequency data. This may enable land managers to use the same sampling method for monitoring species composition and calculating carrying capacity from year to year.

Introduction

Herbaceous yield is a vegetation attribute widely used to quantitatively estimate species composition. However, composition estimates based on yield depend on when sites are sampled because of seasonal (Odum 1960) and yearly (Craddock and Forsling 1938, Harris 1954) climatic fluctuations. Therefore, the true effect of management practices is often masked by changes in weather. For these reasons frequency data have been proposed as an alternative means to monitor changes in species composition (USDA 1981).

Perennial plant frequency does not significantly fluctuate annually or seasonally since it is partially determined by density (Hyder *et al.* 1966). Frequency sampling is also more repeatable between observers because its measurement is less subject to personal bias. This reliability is attractive to land management agencies whose data are usually collected by an ever-changing field staff. However, a common criticism of frequency sampling is that it does not provide herbage production data needed to calculate and monitor carrying capacity. Species composition can be classified and monitored using frequency data (Smith 1982, Mosley *et al.* 1986), but presently land managers are unable to estimate a species' or site's yield from species frequency. This study was initiated to examine whether satisfactory yield estimates could be obtained from frequency data.

Study Area and Methods

Dry mountain meadows of central Idaho were selected as the vegetation type in which to test the hypothesis that herbaceous yield could be estimated from species frequency. Study sites were located on the Lowman Ranger District of the Boise National Forest, approximately 200 km northeast of Boise, Idaho. Meadows in this region provide most of the summer forage for domestic livestock grazing mountain rangeland; the grazing season typically extends from 1 July to 15 October. Study sites range in elevation from 1950 to 2045 m. According to U.S. Forest Service (USFS) records, annual precipitation on these sites varies from 510 to 1020 mm with approximately 70 percent occurring as snow. Precipitation was considered normal during the sampling season and year, but precipitation was not measured on each individual site.

Vegetation on 12 study sites was sampled for frequency and yield during a 30-day period in July and August of 1982. To sample variability inherent within dry mountain meadows, four sites were selected from each of three range condition classes—good, fair, and poor. Condition was determined from USFS range analysis and trend study records. Study sites ranged in production from 512 to 1547 kg/ha. Botanical nomenclature followed Hitchcock and Cronquist (1973).

A 30.5 x 30.5-m frequency macroplot was established on each site in a topographically

uniform area with homogenous vegetation structure. This macroplot consisted of five parallel 30.5-m transect lines spaced 7.6 m apart. Rooted frequency of occurrence was recorded by species within 10x10-cm quadrats placed at 1.5-m intervals along the five transects: therefore, 100 frequency quadrats were measured per site. Quadrat size and sampling intensity were determined in a previous study (Mosley *et al.* 1986).

Yield was sampled within a 30.5 x 30.5-m Permanent Site Analysis Transect (PSAT) macroplot superimposed on the 30.5-m² frequency macroplot. This PSAT macroplot consisted of three parallel 30.5-m transect lines spaced 15.25 m apart. At 3.05-m intervals along the three transects, vegetation within a 0.29-m² circular plot was clipped and weighed by species. This procedure provided 30 yield plots per site (USDA no date). Dry weight determinations were made using conversion tables (USDA 1981).

Simple linear regression was used to estimate yield (kg/ha) from frequency (%) for each species encountered on four or more sites. Linear and quadratic models were evaluated.

Estimated total site yields were calculated by summing estimated individual species' yields. Only significant regression equations ($P < 0.10$) were used to estimate individual species' yields from frequency. Yields of species with a non-significant regression and of species sampled on less than four sites were estimated with that species' average yield over all sites on which it was sampled. Estimated total site yields were compared to actual total site yields with a paired t-test and regression analysis.

Results

The ranges of species' yield and frequency values sampled are shown in Table 1. Zero values are present because of the different quadrat size and placement used for sampling yield and frequency. For a site to be included in a species' regression, at least one non-zero value must have been recorded for either yield or frequency. Utilizing these data simple linear regressions between yield and frequency were significant ($P < 0.10$) for 21 of the 30 species (Table 2). Coefficients of determination were 0.70 or greater for 13 of these 21 species. Quadratic regressions also significantly related yield and frequency for 21 of the 30 species included in the analysis (Table 3), and

TABLE 1. Ranges of species' yield (kg/ha) and frequency values (%) for all sites.

Species	No. of sites	Range of Values	
		Yield	Frequency
Graminoids			
<i>Agropyron dasystachyum</i>	6	4- 81	2-43
<i>Agropyron caninum</i>	4	26- 80	6-21
<i>Carex</i> spp.	12	67-332	19-72
<i>Danthonia intermedia</i>	12	2-148	1-86
<i>Deschampsia cespitosa</i>	6	36-340	12-89
<i>Festuca idahoensis</i>	7	1-303	0-68
<i>Juncus</i> spp.	5	13-152	4-25
<i>Koeleria cristata</i>	6	3- 72	0-24
<i>Muhlenbergia filiformis</i>	6	0- 9	1-12
<i>Stipa occidentalis</i>	6	0- 87	1-13
Forbs			
<i>Achillea millefolium</i>	9	39-266	32-84
<i>Agoseris glauca</i>	6	9-159	0-32
<i>Antennaria corymbosa</i>	11	1- 19	0-20
Annual forbs	8	0- 26	1-69
<i>Arabis</i> spp.	4	0- 7	0- 3
<i>Arenaria congesta</i>	4	0- 36	1-27
<i>Aster</i> spp.	12	15-297	4-42
<i>Calochortus nuttalli</i>	8	3- 44	0-17
<i>Camassia quamash</i>	6	2-109	0-43
<i>Cirsium vulgare</i>	6	4-149	1-20
<i>Delphinium nuttallianum</i>	7	2- 36	0- 6
<i>Gentiana calycosa</i>	5	0- 86	1-11
<i>Orthocarpus luteus</i>	10	0- 40	0-12
<i>Polygonum bistoides</i>	4	3- 28	0- 5
<i>Potentilla gracilis</i>	4	2- 53	2-17
<i>Ranunculus alismaefolius</i>	4	0-123	1-39
<i>Senecio integerrimus</i>	8	2-265	1-29
<i>Taraxacum officinale</i>	4	10- 44	3-18
<i>Trifolium longipes</i>	11	3- 98	2-89
<i>Wyethia helianthoides</i>	7	0-142	0- 5

coefficients of determination were also 0.70 or greater for 13 of these species. Yield and frequency were not related in these models for eight species (Tables 2 and 3). It is not clear why these vegetation parameters were unrelated for these species.

Estimated total site yields did not differ ($P > 0.05$) from actual total site yields. This was true when either linear or quadratic models were used to estimate yield. The relationship between estimated and actual total site yield was linear (Figure 1). Our models tended to overestimate yield at the lower range of production (< 800 kg/ha) and underestimate actual yield at the higher levels of production.

Conclusions

Estimating herbaceous yield from species frequency appears promising. This study employed

TABLE 2. Coefficients of determination and linear regression equations relating yield (kg/ha) to frequency (x).

Species	r ²	Equation
Graminoids		
<i>Agropyron dasystachyum</i>	.74**	Y = 2.59 + 1.38x
<i>Agropyron caninum</i>	—	not significant
<i>Carex</i> spp.	.31*	Y = 44.84 + 2.16x
<i>Danthonia intermedia</i>	.92**	Y = 14.21 + 1.74x
<i>Deschampsia cespitosa</i>	.83**	Y = 4.71 + 4.15x
<i>Festuca idahoensis</i>	.91**	Y = -11.55 + 4.33x
<i>Juncus</i> spp.	.92**	Y = -7.21 + 6.65x
<i>Koeleria cristata</i>	.78**	Y = 3.32 + 2.79x
<i>Muhlenbergia filiformis</i>	—	not significant
<i>Stipa occidentalis</i>	—	not significant
Forbs		
<i>Achillea millefolium</i>	.56**	Y = -44.18 + 2.96x
<i>Agoseris glauca</i>	—	not significant
<i>Antennaria corymbosa</i>	.62**	Y = 2.42 + 0.70x
Annual forbs	.97**	Y = -1.15 + 0.39x
<i>Arabis</i> spp.	—	not significant
<i>Arenaria congesta</i>	.97**	Y = -2.74 + 1.41x
<i>Aster</i> spp.	.49**	Y = -0.35 + 4.87x
<i>Calochortus nuttalli</i>	.48*	Y = 3.86 + 1.58x
<i>Camassia quamash</i>	.94**	Y = 1.39 + 2.29x
<i>Cirsium vulgare</i>	—	not significant
<i>Delphinium nuttallianum</i>	.81**	Y = -2.56 + 5.43x
<i>Gentiana calycosa</i>	.74*	Y = 4.44 + 6.74x
<i>Orthocarpus luteus</i>	.46**	Y = 8.73 + 3.07x
<i>Polygonum bistordies</i>	.84*	Y = 3.43 + 4.02x
<i>Potentilla gracilis</i>	—	not significant
<i>Ranunculus alismaefolius</i>	—	not significant
<i>Senecio integerrimus</i>	.70**	Y = 13.13 + 8.58x
<i>Taraxacum officinale</i>	—	not significant
<i>Trifolium longipes</i>	.52**	Y = 11.43 + 0.60x
<i>Wyethia helianthoides</i>	.53*	Y = 9.79 + 19.79x

*Significant at P < 0.10

**Significant at P < 0.05

TABLE 3. Coefficients of determination and quadratic regression equations relating yield (kg/ha) to frequency (x).

Species	r ²	Equation
Graminoids		
<i>Agropyron dasystachyum</i>	.90**	Y = 6.03 + 0.04x ²
<i>Agropyron caninum</i>	—	not significant
<i>Carex</i> spp.	.34**	Y = 81.60 + 0.02x ²
<i>Danthonia intermedia</i>	.69**	Y = 35.19 + 0.02x ²
<i>Deschampsia cespitosa</i>	.69**	Y = 93.84 + 0.04x ²
<i>Festuca idahoensis</i>	.94**	Y = 20.17 + 0.06x ²
<i>Juncus</i> spp.	.87**	Y = 27.31 + 0.22x ²
<i>Koeleria cristata</i>	.72**	Y = 11.28 + 0.11x ²
<i>Muhlenbergia filiformis</i>	—	not significant
<i>Stipa occidentalis</i>	—	not significant
Forbs		
<i>Achillea millefolium</i>	.64**	Y = 27.69 + 0.03x ²
<i>Agoseris glauca</i>	—	not significant
<i>Antennaria corymbosa</i>	.47**	Y = 4.33 + 0.03x ²
Annual forbs	.93**	Y = 1.44 + 0.01x ²
<i>Arabis</i> spp.	—	not significant
<i>Arenaria congesta</i>	.99**	Y = -0.10 + 0.05x ²
<i>Aster</i> spp.	.39**	Y = 46.19 + 0.09x ²
<i>Calochortus nuttalli</i>	.45*	Y = 7.73 + 0.08x ²
<i>Camassia quamash</i>	.98**	Y = 8.55 + 0.05x ²
<i>Cirsium vulgare</i>	—	not significant
<i>Delphinium nuttallianum</i>	.96**	Y = 1.95 + 0.92x ²
<i>Gentiana calycosa</i>	—	not significant
<i>Orthocarpus luteus</i>	.33*	Y = 12.39 + 0.21x ²
<i>Polygonum bistordies</i>	.89*	Y = 4.66 + 0.77x ²
<i>Potentilla gracilis</i>	.82*	Y = 8.20 + 0.15x ²
<i>Ranunculus alismaefolius</i>	—	not significant
<i>Senecio integerrimus</i>	.54**	Y = 51.76 + 0.25x ²
<i>Taraxacum officinale</i>	—	not significant
<i>Trifolium longipes</i>	.50**	Y = 17.31 + 0.01x ²
<i>Wyethia helianthoides</i>	.65**	Y = 19.00 + 4.32x ²

*Significant at P < 0.10

**Significant at P < 0.05

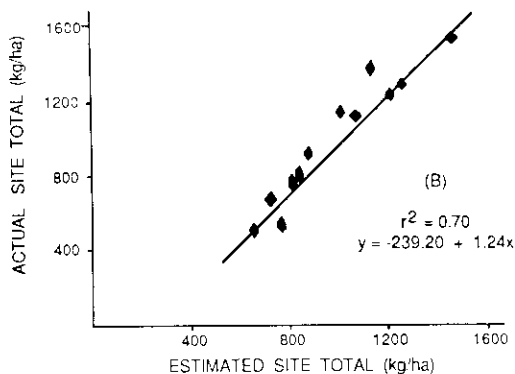
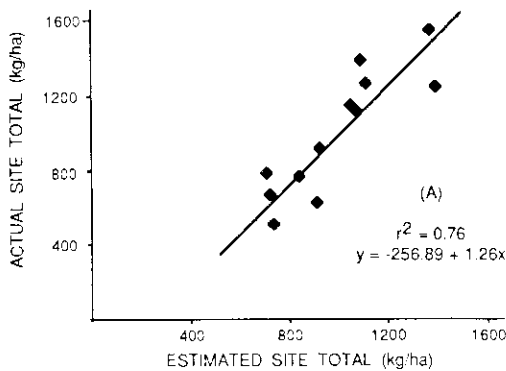


Figure 1. Relationship between estimated and actual total yields for 12 dry mountain meadow sites. Estimated site totals are the sum of individual species' estimates derived using linear (A) and quadratic (B) regression equations.

linear regression to develop significant ($P < 0.10$) equations for 21 species in dry mountain meadows of central Idaho. If yield and frequency were determined within the exact same quadrats, frequency-yield relationships should correlate even more closely. Both linear and quadratic equations were calculated; linear and quadratic models appeared equally appropriate. Selecting the better model depends upon which particular species are of special interest. Regression equations for individual species were used to estimate total yields for 12 mountain meadow sites.

Estimated total yields did not differ ($P > 0.05$) from actual total yields.

Estimating yield from frequency data may have utility for monitoring key management species. Formulating regression equations for all species in many vegetation types may be time-prohibitive for most management applications. However, equations for one or two species per type could be developed relatively easily and inexpensively. Such yield information could be used to help set initial stocking levels. Managers should remember that it is impossible to precisely estimate carrying capacity from a single forage inventory because a site's herbaceous production varies with the amount and pattern of precipitation. Proper carrying capacity can best be determined by subsequently monitoring yield and species composition under the initial stocking level and making necessary adjustments in stocking rate.

A potential problem exists when relating frequency to yield. This is because frequency percentages are bounded variables whereas yield is an unbounded variable (Greig-Smith 1983). This potential problem reemphasizes the need to sample frequency with a proper quadrat size, one that provides intermediate frequency values which do not approach the bounded limits (Hyder *et al.* 1965). In addition to quadrat size, rooted frequency is also affected by the plant sizes, distributions, and densities present in a given community (Kershaw 1973). Relationships between species frequency and yield are thus specific to individual geographic areas and vegetation types. Therefore, different areas and different vegetation types would need their own regression equations. Equations presented here are specific for central Idaho's dry mountain meadows.

Finally, although species frequency is not largely influenced by temporal fluctuations in precipitation, herbaceous yield is greatly affected. Regression studies usually sample such variation by repeating measurements on the same site in different years. The effects of fluctuating precipitation levels can also be incorporated into regression equations by sampling several sites that differ widely in annual precipitation, provided that all of the sites are within the same community type. This study sampled dry mountain meadows receiving 510 to 1020 mm annual precipitation, varying from 512 to 1547 kg/ha herbaceous production.

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