Determination of Peak Standing Crop Biomass of Herbaceous Shoots by the Harvest Method

CHARLES R. MALONE[1]

Department of Zoology, Rutgers—The State University, New Brunswick, New Jersey 08903

ABSTRACT: The peak standing crop biomass of herbaceous shoots, a measure of net primary shoot production, was determined in three first-year old fields by two methods: (1) sampling the peak community standing crop at one moment and (2) summing the peaks of the individual species over the entire growing season. The methods gave similar estimates of peak standing crop in the two old fields where the major producers reached peaks at comparable times. In the third old field, a large discrepancy existed between the two estimates as a result of the diverse times at which the major producers reached peak standing crops. It was valid to use an estimate of net primary shoot production based on the community peak standing crop only when the dominant species had similar phenologies. Whenever this occurred, such an estimate had a smaller statistical error associated with its mean than an estimate derived from the sum of individual species peaks.

INTRODUCTION

The short-term harvest method as described by Odum (1960) currently is one of the most widely used methods of estimating net primary shoot production in herbaceous vegetation. The basic premise of this method is that the peak standing crop biomass of vegetation is representative of community net primary production.

For maximal accuracy with the short-term harvest method Odum considers it necessary to determine the peak standing crop of each important producer separately rather than determining the peak standing crop for the community at one moment as a whole. This consideration is set forth as a basic procedural step in the method and is derived from the assumption that since vegetation is dynamic all the dominant species might not reach a peak standing crop simultaneously. The implication that net primary production would be underestimated should the peak of an important producer be missed was demonstrated by Wiegert and Evans (1964).

Some workers conform to Odum's procedures and determine the peak standing crop separately for each major producer (*e.g.*, Golley and Gentry, 1966; Bliss, 1966), whereas others utilize the community standing crop at its peak as indicative of net primary production (*e.g.*, Ovington *et al.*, 1963; Hadley and Buccos, 1967). Regardless of the approach, criteria usually are not given for the preference of one method over the other and the comparative virtues of the two apparently are unknown.

The purpose of the analysis presented here is to demonstrate that estimates of net primary shoot production obtained either by (1)

[1] Present address: Radiation Ecology Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830.

sampling the peak community standing crop at one moment or by (2) summing the peaks of individual species over the growing season can be useful under different ecological circumstances. The work was restricted to shoot production since it is difficult to sample root production accurately on a species basis. Such comparisons for roots must await the development of suitable methodology.

METHODS

Estimates of net primary shoot production were made in three first-year old field ecosystems of different floristic composition by sampling the community standing crop at its peak and also by summing the peak standing crops of individual species over the growing season. Both methods of estimating the peak standing crop could be compared since they were used simultaneously with the same sampling program in each old field.

The three one-year old fields studied were located on the piedmont of central New Jersey. FIELD 1 adjoined Hutcheson Memorial Forest near East Millstone, New Jersey, was 10 hectares in area, and in 1965 had been cultivated in soybeans. FIELDS 2 and 3 were in the Stony Brook-Millstone Watershed near Pennington, New Jersey, and each contained three hectares. Both were cultivated in corn until 1964, when they were sown with a cover crop of perennial ryegrass (*Lolium perenne*). In December, 1965, FIELDS 2 and 3 were deeply plowed and abandoned. Portions of them are being utilized in a study discussed elsewhere (Malone *et al.*, 1967).

Net primary shoot production was determined for all three fields during the 1966 growing season by harvesting the green shoots at two-week intervals from 4 June through 10 September. The vegetation was sampled on square $0.25m^2$ quadrats located with a table of random numbers. Fifteen of these were clipped on each sampling date in FIELD 1; ten were harvested in FIELDS 2 and 3. Shoots were clipped at ground level, bagged, returned to the laboratory, and sorted into several groups. Each important and frequently encountered producer was placed in a separate group and the infrequent species were grouped as a composite. The vegetation was oven-dried at 90 C for 24 hours and biomass determinations were made on a pan balance sensitive to 0.1 g.

Data are reported as the mean grams dry weight/m^2 to the nearest gram. For the estimate of peak standing crop, a standard error and its percentage of the mean were determined for both the raw data and data normalized by square-root transformations. Statistical methods were taken from Bliss (1967), Greig-Smith (1964), and Southwood (1966). These will be more fully discussed in the following section.

RESULTS AND DISCUSSION

Tables 1A-B, 2A-B, and 3A-B give the values of net primary shoot production for FIELDS 1, 2, and 3, respectively, as determined by the two methods of estimating the peak standing crop biomass. The discussion of these data will be restricted to a comparison and evaluation of the methods and no consideration will be given to a comparison of inter-field production.

In FIELD 1 there was considerable discrepancy between the estimate of production based on the community value (Table 1A) and on the sum of individual species peaks (Table 1B). The values have an almost twofold difference in magnitude and provide a good demonstration of Odum's assumption that a community estimate of peak standing crop will fail to account for all the seasonal production. Because the important producers reached peak standing crops at various times during the growing season, the community in FIELD 1, when considered as a whole at any one moment, never reached a distinct peak. Instead, the standing crop biomass was maintained at a plateau throughout the season.

In contrast to the results in FIELD 1, the two estimates of net production in both FIELDS 2 and 3 were similar. In either of these two fields, however, the community estimate was slightly lower than the estimate obtained by summing the species peaks. The absence of a

TABLE 1 A-B.— Net primary shoot production for FIELD 1 during the 1966 growing season. The number of replicate samples was 15. The standard error and its percentage of the means are given for the estimate of net production by either method

A. Based on the community standing crop biomass at one moment

Harvest date	$\overline{X}$ g dry wt/m²
4 Jun.	30
18 Jun.	122
2 Jul.	219* ± 24.9 (11%)
16 Jul.	187
30 Jul.	210
13 Aug.	208
27 Aug.	215
10 Sep.	147

* peak standing crop

B. Based on the sum of the peak standing crop biomass of individual species

Species	$\overline{X}$ peak biomass g dry wt/m²	Date peak reached
Ambrosia artemisiifolia	123	30 Jul.
Chenopodium album	69	16 Jul.
Ipomoea pandurata	83	2 Jul.
Raphanus raphanistrum	90	2 Jul.
Setaria glauca	6	27 Aug.
Digitaria sanguinalis	8	30 Jul.
18 infrequent species	19	30 Jul.
SUM	398 ± 112.3 (28%)	

large discrepancy in FIELDS 2 and 3 between the two methods resulted from the dominant producers' having reached a peak standing crop at a comparable time. Consequently, the community biomass exhibited a precise peak rather than maintaining a constant standing crop over a prolonged period of time, as in FIELD 1.

The extent of the discrepancy between an estimate of production based on a community value and one based on the sum of species peaks obviously depends upon the phenology of the producers, phenology considered here as the uniformity or diversity in time with which the dominant producers reach their peak standing crop. Unless the phenology of each dominant producer is known to be similar, considerable error is risked in not determining the peak standing crop of individual species. However, if the dominants have similar phenologies, it appears valid to use the community peak standing crop as indicative of net primary production. This apparently never is considered and demonstrated by those who use the short-term harvest method based on a community estimate of peak standing crop.

Another important consideration in determining the peak standing crop is the comparative statistical errors of the mean estimates obtained by the two methods. In my study standard errors were deter-

TABLE 2 A-B.—Net primary shoot production for FIELD 2 during the 1966 growing season. The number of replicate samples was 10. The standard error and its percentage of the means are given for the estimate of net production by either method

A. Based on the community standing crop biomass at one moment

Harvest date	$\overline{X}$ g dry wt/m²
16 Jun.	23
30 Jun.	61
14 Jul.	90
27 Jul.	198
11 Aug.	217* ± 16.9 (7%)
30 Aug.	177
8 Sep.	128

* peak standing crop

B. Based on the sum of the peak standing crop biomass of individual species

Species	$\overline{X}$ peak biomass g dry wt/m²	Date peak reached
Ambrosia artemisiifolia	167	11 Aug.
Lolium perenne	68	27 Jul.
Amaranthus hybridus	4	27 Jul.
Portulaca oleracea	4	25 Aug.
Digitaria sanguinalis	7	25 Aug.
Mollugo verticillata	6	25 Aug.
14 infrequent species	11	27 Jul.
SUM	267 ± 43.5 (16%)	

mined according to Bliss (1967). In all three fields the percent error of the mean always was much greater when net production was estimated as the sum of the peak standing crops of the individual species. (To assess the magnitude of the differences, compare the percent error of the mean estimate in the A-Table with that in the B-Table for each field.)

The estimate of each individual species had a relatively large error due to the nonrandom distribution common to most herbaceous species, and, whenever all the species peaks were summed, the errors became additive, resulting in a large error of the sum. On the other hand, whenever all the species within a quadrat were composited to determine community biomass, the biomass was more randomly distributed, resulting in a smaller statistical error of the estimated mean.

It thus appears that even though from a phenological standpoint the peak standing crop is best determined as the sum of individual species peaks, this method results in an estimate with a larger statistical error than if the community peak is used as the net production. Since the suspected reason for the greater error is because of a deviation from a normal distribution, the error should be reduced if the data are normalized by numerical transformations (Greig-Smith, 1964). To test this assumption it was first necessary to de-

TABLE 3 A-B.—Net primary shoot production for FIELD 3 during the 1966 growing season. The number of replicate samples was 10. The standard error and its percentage of the means are given for the estimate of net production by either method

A. Based on the community standing crop biomass at one moment

Harvest date	$\overline{X}$ g dry wt/m²
16 Jun.	24
30 Jun.	77
14 Jul.	109
27 Jul.	148
11 Aug.	154* ± 11.7 (7%)
30 Aug.	123
8 Sep.	86

* peak standing crop

B. Based on the sum of the peak standing crop biomass of individual species

Species	$\overline{X}$ peak biomass g dry wt/m²	Date peak reached
Ambrosia artemisiifolia	67	11 Aug.
Lolium perenne	33	27 Jul.
Chenopodium album	27	27 Jul.
Amaranthus hybridus	17	27 Jul.
Portulaca oleracea	18	11 Aug.
Digitaria sanguinalis	4	25 Aug.
21 infrequent species	28	11 Aug.
SUM	194 ± 73.8 (38%)	

termine if the data actually deviated from a normal distribution. This was accomplished by testing each set of observations with an index of dispersion (Southwood, 1966). In almost every case the distribution of the data deviated from normal. The selection of the proper transformation to normalize the data was made by use of a power law (Southwood, 1966) which indicated that a square-root transformation was needed. As suggested by Greig-Smith (1964), the transformation chosen was $\sqrt{N + 0.5}$. Plotting the transformed values on probability paper confirmed that the transformations were successful in normalizing the data.

Transformed means, standard errors, and percent errors of the means for the estimates of peak standing crop by the two methods for all three fields are given in Table 4. These data demonstrate that the transformations resulted in reducing the percent error of all estimates of net production as compared to the raw data, usually by as much as 75%. However, even with these manipulations the estimates based on peaks of individual species still had large errors compared to the estimates based on the community peak standing crop. Therefore, it seems that the peak standing crop estimated on a community basis would be the most appropriate method whenever minimum statistical error of a mean is needed.

The data analyzed here suggest that peak standing crop biomass should be determined by the sum of individual species peaks, as proposed by Odum (1960), unless it is known that the dominant producers within the community have similar phenologies and reach a peak standing crop biomass at comparable times. When this is the case it is valid to estimate net primary production based on the community peak standing crop. Such a determination of the peak might indeed be more useful for comparisons with other communities since it will have a smaller statistical error associated with its mean.

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TABLE 4.—Statistics of the estimates of net primary shoot production in the three fields after the raw data were normalized by the transformation $\sqrt{N + 0.5}$

Field	Peak community standing crop			Sum of peaks of individual species		
	($\bar{X}$)	(Sx)	(% error)	($\bar{X}$)	(Sx)	(% error)
1	14.56	0.892	6	19.85	3.176	16
2	14.73	0.589	4	15.79	1.714	11
3	12.41	0.496	4	13.48	2.426	18

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