13.4.5. A Technique for Estimating Seed Production of Common Moist-soil Plants

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Seeds of native herbaceous vegetation adapted to germination in hydric soils (i.e., moist-soil plants) provide waterfowl with nutritional resources including essential amino acids, vitamins, and minerals that occur only in small amounts or are absent in other foods. These elements are essential for waterfowl to successfully complete aspects of the annual cycle such as molt and reproduction. Moist-soil vegetation also has the advantages of consistent production of foods across years with varying water availability, low management costs, high tolerance to diverse environmental conditions, and low deterioration rates of seeds after flooding.

The amount of seed produced differs among plant species and varies annually depending on environmental conditions and management practices. Further, many moist-soil impoundments contain diverse vegetation, and seed production by a particular plant species usually is not uniform across an entire unit. Consequently, estimating total seed production within an impoundment is extremely difficult.

The chemical composition of seeds also varies among plant species. For example, beggartick seeds contain high amounts of protein but only an intermediate amount of minerals. In contrast, barnyardgrass is a good source of minerals but is low in protein. Because of these differences, it is necessary to know the amount of seed produced by each plant species if the nutritional resources provided in an impoundment are to be estimated.

The following technique for estimating seed production takes into account the variation resulting from different environmental conditions and management practices as well as differences in the amount of seed produced by various plant species. The technique was developed to provide resource managers with the ability to make quick and reliable estimates of seed production. Although on-site information must be collected, the amount of field time required is small (i.e., about 1 min per sample); sampling normally is accomplished on an area within a few days. Estimates of seed production derived with this technique are used, in combination with other available information, to determine the potential number of waterfowl use-days available and to evaluate the effects of various management strategies on a particular site.

Technique for Estimating Seed Production

To estimate seed production reliably, the method must account for variation in the average amount of seed produced by different moist-soil species. For example, the amount of seed produced by a single barnyardgrass plant outweighs the seed produced by an average panic grass plant. Such differences prevent the use of a generic method to determine seed production because many species normally occur in a sampling unit.

My technique consists of a series of regression equations designed specifically for single plant species or groups of two plant species closely related with regard to seed head structure and plant height (Table 1). Each equation was developed from data collected on wetland areas in the Upper Mississippi alluvial and Rio Grande valleys. The regression equations should be applicable throughout the range of each species because the physical growth form of each species (i.e., seed head geometry) remains constant. As a result, differences in seed production occur because of changes in plant density, seed head size, and plant height, but not because of the general shape of the seed head. This argument is supported by the fact that the weight of seed samples collected in the Rio Grande and Upper Mississippi valleys could be estimated with the same equation.

Estimating seed production requires collecting the appropriate information for each plant species and applying the correct equations. The equations provide estimates in units of grams per 0.0625 m^2; however, estimates can readily be converted to pounds per acre by using a conversion factor of 142.74 (i.e., grams per 0.0625-$m^2 \times 142.74$ = pounds per acre). Computer software developed for this technique also converts grams per square meter to pounds per acre.

Collection of Field Data

Measurements Required

Plant species
Seed heads (number)
Average seed head height (cm)
Average seed head diameter (cm)
Average plant height (m)

Equipment Required

Meter stick
Square sampling frame (Fig. 1)
Clipboard with paper and pencil (or field computer)

Method of Sampling

1. Place sampling frame in position. Include only those plants that are rooted within the sampling frame.

Table 1. *Regression equations for estimating seed production of eleven common moist-soil plants.*

Measurement[a] group	Plant species	Regression equation[bc] (weight in grams per 0.0625 m^2)	Coefficient of determination (R^2)
Grass			
	Barnyardgrass[d]	$(HT \times 3.67855) + (0.000696 \times VOL)$[e]	0.89
	Crabgrass	$(0.02798 \times HEADS)$	0.88
	Foxtail[f]	$(0.03289 \times VOL)$[g]	0.93
	Fall panicum	$(0.36369 \times HT) + (0.01107 \times HEADS)$	0.93
	Rice cutgrass	$(0.2814 \times HEADS)$	0.92
	Sprangletop	$(1.4432 \times HT) + (0.00027 \times VOL)$[e]	0.92
Sedge			
	Annual sedge	$(2.00187 \times HT) + (0.01456 \times HEADS)$	0.79
	Chufa	$(0.00208 \times VOL)$[h]	0.86
	Redroot flatsedge	$(3.08247 \times HEADS) + (2.38866 \times HD) - (3.40976 \times HL)$	0.89
Smartweed			
	Ladysthumb/water smartweed	$(0.10673 \times HEADS)$	0.96
	Water pepper	$(0.484328 \times HT) + (0.0033 \times VOL)$[g]	0.96

[a] Refer to Fig. 3 for directions on measuring seed heads.
[b] HT = plant height (m); HEADS = number of seed heads in sample frame; HL = height of representative seed head (cm); HD = diameter of representative seed head (cm); VOL = volume (cm^3).
[c] Conversion factor to pounds per acre is: grams per 0.0625 $m^2 \times 142.74$.
[d] *Echinochloa crusgalli* and *E. muricata*.
[e] VOL (based on geometry of cone) calculated as: $(HEADS) \times (\pi r^2 h/3)$; $\pi = 3.1416$, r = HD/2, h = HL.
[f] *Setaria* spp.
[g] VOL (based on geometry of cylinder) calculated as: $(HEADS) \times (\pi r^2 h)$; $\pi = 3.1416$, r = HD/2, h = HL.
[h] VOL (based on geometry of half sphere) calculated as: $(HEADS) \times (1.33\pi r^3/2)$; $\pi = 3.1416$, r = HD/2.

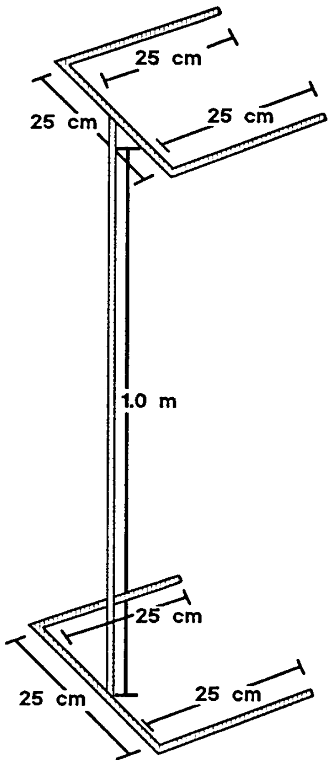

Fig. 1. Sampling frame design.

2. Record plant species present within sample frame on data form (Fig. 2).
3. For each plant species, record the number of seed heads within the sample frame. All seed heads occurring within an imaginary column formed by the sample frame should be counted.
4. For each plant species, select a single representative plant and measure
   a. the straightened height of the entire plant (from the ground to the top of the tallest plant structure) in meters,
   b. the number of seed heads within the sample frame,
   c. the height of the seed head in centimeters (measure along the rachis [i.e., main stem of flower] from the lowest rachilla [i.e., secondary stem of flower] to the top of the straightened seed head [Fig. 3].), and
   d. the diameter (a horizontal plane) of the seed head in centimeters (measure along the lowest seed-producing rachilla [Fig 3].).

Although average values calculated by measuring every plant within the sample frame would be more accurate, the time required to collect a sample would increase greatly. In contrast, obtaining measurements from a single representative plant allows a larger number of samples to be collected per unit time. This method also permits sampling across a greater portion of the unit, which provides results that are more representative of seed production in an entire unit.

Suggested Sampling Schemes

There are two basic approaches to estimating seed production within an impoundment. Both methods should supply similar results in most instances. The choice of method will depend largely on physical attributes of the impoundment and management strategies that determine the diversity and distribution of vegetation.

First approach: Sample across entire unit. The most direct procedure of estimating seed production is to collect samples across an entire unit using the centric systematic area sample design (Fig. 4). This method is recommended when vegetation types are distributed randomly across the entire impoundment (e.g., rice cutgrass and smartweed occur together across the entire

Plot Number	Plant species	Height (m)	Seed heads (no.)	Seed head height (cm)	Seed head diameter (cm)
1					
2					
3					
4					
5					
6					

Fig. 2. Sample data form for collecting information necessary to estimate seed production.

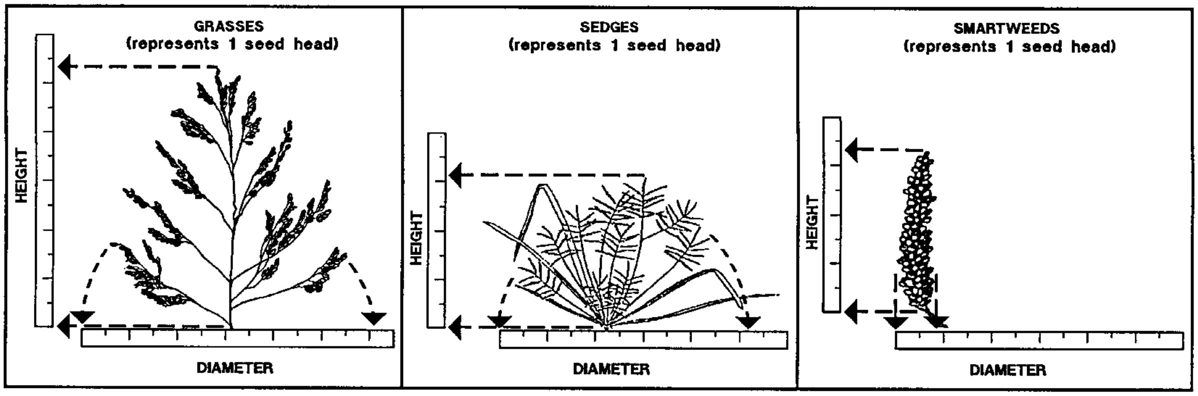

Fig. 3. Method of measuring dimensions of three seed head types.

impoundment; Fig. 5a). Divide an entire unit into blocks of equal dimension and establish a 0.0625-m^2 sample frame at the center of each block. In the field, this is accomplished by walking down the center of a row of such blocks and sampling at the measured interval. The precise number of samples necessary to provide a reliable estimate depends on the uniformity of each plant species within the impoundment and the desired accuracy of the estimate. The dimensions of the blocks are adjustable, but collect a minimum of one sample for every 2 acres of habitat. For example, a block size of 2 acres (i.e., 295 feet per side) results in 25 samples collected in a 50-acre moist-soil unit.

At each sampling station, measure and record each plant species of interest and the associated variables (i.e., plant height, number of seed heads, seed head height, and seed head diameter)

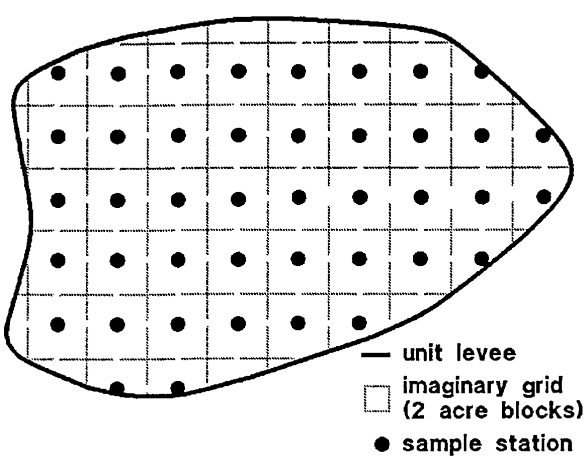

Fig. 4. Centric area sample method (unit = 84 acres)

necessary for estimating seed production of that species. If the same plant species occurs at two distinct heights (e.g., 0.4 m and 1.2 m), determine a seed estimate for plants at each height. If a plant species for which an estimate is desired does not occur within the sample frame, the plant species should still be recorded and variables assigned a value of zero. For example, if barnyardgrass seed production is to be estimated and the sample frame is randomly placed in an area where no barnyardgrass occurs, record a zero for plant height, number of seed heads, seed head height, and seed head diameter. This represents a valid sample and must be included in calculating the average seed production of barnyardgrass in the unit.

Collect samples across the entire unit to ensure that a reliable estimate is calculated. Exercise care to sample only those areas that are capable of producing moist-soil vegetation. Borrow areas or areas of high elevation that do not produce moist-soil vegetation should not be sampled.

Estimate the weight of seed produced by each plant species in a sample with the appropriate regression equation (Table 1), or with the software developed for this purpose. Determine the average seed produced by each species in an impoundment by calculating the mean seed weight of all samples collected (if the species is absent from a sample, a zero is recorded and used in the computation of the mean) and multiplying the mean seed weight (grams per 0.0625m^2) by the total area of the unit. Determine total seed production by summing the average seed produced by each plant species sampled. Following collection of at least five samples, the accuracy of the estimate also can be

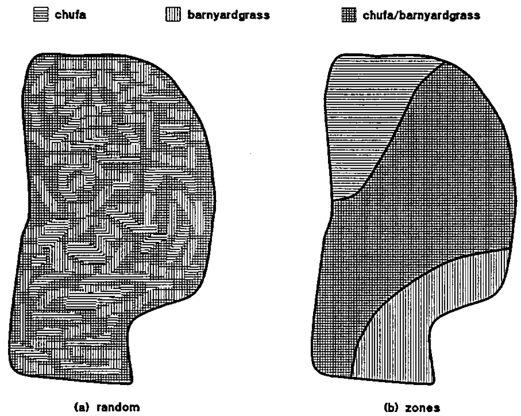

Fig. 5. Two general types of vegetation distribution.

determined. If higher accuracy is desired, collect additional samples by reducing the block size the appropriate amount or by randomly collecting additional samples.

Second approach: Sample within vegetation zones of a unit. This method is recommended for use in impoundments when species or groups of plants occur in distinct and nonoverlapping zones within a unit (e.g., smartweeds only occur at low elevations and barnyardgrass only occurs at higher elevations within the same unit; Fig. 5b). The same general methodology previously outlined for sampling an entire unit applies to this sampling scheme, except that

1. the centric area sampling method is applied separately to each vegetation zone within an impoundment,
2. seed production of an individual plant species over the entire unit is determined by multiplying the average seed production (based only on the samples collected within that zone) by the acreage of the zone sampled,
3. total seed production within a zone is calculated by summing the seed production estimates of each plant species occurring within that zone, and
4. total seed production across the entire impoundment is calculated by summing the seed production estimates of all zones composing the unit. If this sampling scheme is used, a cover map delineating vegetation zones is useful for calculating the acreage of zones sampled.

When to Collect Field Data

Samples must be collected when vegetation has matured and seed heads are fully formed because the regression equation for each plant species is based on seed head dimensions and plant height. Timing of sampling varies across latitudes because of differences in growing season length and maturation times of plant species. Information can be collected before the after-ripening of seeds (i.e., seed heads completely formed but seeds not mature) because seed head dimensions will not change appreciably. Information also can be collected following seed drop because seed head dimensions can be determined based on the geometry of the remaining flower parts (i.e., rachis and rachilla). This allows a greater time span for collecting information. If timed correctly, estimates for most moist-soil plants can be determined during the same sampling period.

Under certain conditions, two crops of moist-soil seeds can be produced within the same unit in a single year. Often, the second crop will be composed of plant species different from those composing the first crop. If this occurs, estimating total seed production requires sampling both first- and second-crop vegetation, even if the species composition of the second seed crop is similar to the first crop. Estimates based on the first crop cannot be applied to the second crop because seed head dimensions will be different.

Determining Required Sample Size

The number of samples necessary to estimate seed production will depend on the level of accuracy desired. Although as few as three samples will provide a mean value of seed production and an estimate of the variability within the unit, this type of estimate normally is unreliable. The most important factors influencing accuracy include the degree of uniformity in plant distribution and the species of plant sampled.

Plant distribution affects accuracy if the density of a plant species varies widely within the area sampled. Potential factors influencing changes in plant density include differential hydrology, use of spot mechanical treatments, and changes in soil type. Often, these factors can be controlled by selecting the appropriate sampling scheme. In addition, seed production by perennials that propagate by tubers tends to be more variable and, therefore, a larger number of samples may be required.

Following collection of at least five samples in a unit, the standard deviation (SD) can be calculated with the equation SD = $(s^2)^{1/2}$. The sample variance (s^2) is estimated with the formula $s^2 = (\sum_{i=1}^{n} x_i - \bar{x})^2 / n-1$, where x_i = seed estimate of sample i, $\bar{x}$ = average seed weight of all samples, and n = number of samples collected. The standard deviation indicates the degree of variation in seed weight and is, therefore, a measure of precision (see example)—the larger the SD, the lower the precision of the estimate.

The number of samples necessary to achieve a specified level of precision (95% confidence interval) can be calculated with the formula $n = 4s^2/L^2$, where s^2 = sample variance and L = allowable error (± pounds per acre). The sample variance (s^2) can be estimated from previous experience or calculated based on preliminary sampling. Because seed production varies among plant species and units, sample variance should be determined independently for individual plant species and units. Numerous environmental factors influence seed production on a particular site. Therefore, sample variance should be calculated annually for each site. A subjective decision must be made concerning how large an error (L) can be tolerated. This decision should be based on how the seed production estimate is to be used. For example, an L of ± 100 pounds per acre would be acceptable for determining the number of waterfowl use-days available. In other cases, a larger error might be acceptable. As the allowable error increases, the number of samples required decreases.

Estimating Seed Production

Although the technique is simple to use, several important factors must be considered to obtain accurate estimates of seed weight. The following example illustrates the process of making these decisions. In addition, the process of computing estimates using the regression equations demonstrates the correct manner of using field data to arrive at valid estimates.

1. *Unit considerations*—unit size is 10 acres. Vegetation consists of barnyardgrass distributed uniformly across the entire unit.
2. *Sampling strategy*—use a centric area sampling method with a maximum recommended block size of 2 acres to establish the location of five sample areas uniformly across the unit.
3. *Data collection*—at each plot, select a representative barnyardgrass plant within the sample frame and record the necessary information (Table 2).
4. *Estimate seed production*—for each sample, use the appropriate equation to determine the estimated seed weight. In this example, only the barnyardgrass equation is required (Table 3).
5. *Maximum allowable error*—in this example, an L of ± 100 pounds per acre is used for barnyardgrass. The standard deviation is then calculated to determine the precision of the estimate. If the standard deviation is less than the allowable error, no additional samples must be collected. However, if the standard deviation is greater than the allowable error, the estimated number of additional samples that must be collected is calculated.

- Allowable error = L = ± 100 pounds per acre
- Number of samples collected = n = 5
- Weight of individual samples (pounds per acre) = x_i = 982; 1,119; 871; 1,124; 1,237
- Average weight of samples (pounds per acre) = $\bar{x}$

  = 982 + 1,119 + 871 + 1,124 + 1,237 / 5
  = 5,333 / 5
  = 1,066.6 or 1,067
- Variance = $s^2 = \Sigma(x_i - \bar{x})^2/n-1$

  = $(982 - 1{,}067)^2 + (1{,}119 - 1{,}067)^2 + (871 - 1{,}067)^2 + (1{,}124 - 1{,}067)^2 + (1{,}237 - 1{,}067)^2 / 5 - 1$
  = $(-85)^2 + (52)^2 + (-196)^2 + (57)^2 + (170)^2 / 4$
  = 7,225 + 2,704 + 38,416 + 3,249 + 28,900 / 4
  = 80,494 / 4
  = 20,123.5 or 20,124 pounds per acre
- Standard deviation = $s = (s^2)^{1/2}$

  = $20{,}124^{1/2}$
  = 141.8 or 142 pounds per acre

Based on these computations, an estimated average weight of 1,067 ± 142 pounds per acre (i.e., 925–1,209 pounds per acre) of barnyardgrass seed was produced. However, the standard deviation (142 pounds per acre) is greater than the allowable error (100 pounds per acre), indicating that additional samples must be collected to obtain an average seed weight value that is within the acceptable limits of error.

Table 2. *Sample data sheet for estimating seed production.*

Plot	Plant species	Height (m)	Seed heads (number)	Seed head height (cm)	Seed head diameter (cm)
			Initial samples		
1	Barnyardgrass	1.1	12	16	9
2	Barnyardgrass	1.1	13	16	10
3	Barnyardgrass	1.1	11	16	8
4	Barnyardgrass	1.1	14	15	10
5	Barnyardgrass	1.2	9	18	12
			Additional samples		
6	Barnyardgrass	1.1	12	16	10
7	Barnyardgrass	0.9	15	17	9
8	Barnyardgrass	0.9	14	17	10

Table 3. *Estimating seed weight of individual samples.*

Plant species	Regression equation[a]	Plot	Estimated weight (grams per 0.0625-m^2)	Estimated weight (pounds per acre)
		Initial samples		
Barnyardgrass	(HT × 3.67855) + (0.000696 × VOL)	1	6.88[b]	982 [c]
		2	7.84	1,119
		3	6.10	871
		4	7.88	1,124
		5	8.67	1,237
		Additional samples		
		6	7.55	1,077
		7	7.08	1,010
		8	7.65	1,092

[a] HT = plant height (m); HEADS = number of seed heads in sample frame; HL = height of representative seed head (cm); HD = diameter of representative seed head (cm); VOL = volume (based on geometry of cone) calculated as: (HEADS) × (πr^2h/3); π = 3.1416, r = HD/2, h = HL.
[b] Weight (grams per 0.0625-m^2) = (HT × 3.67855) + (0.000696 × VOL) = (1.1 × 3.67855) + (0.000696 × 4081.6) = 4.0464 + 2.8408 = 6.88
VOL = (HEADS) × (πr^2h/3); π = 3.1416, r = 9/2 = 4.5, r^2 = 20.3, h = 16 = (12) × (3.1416 × 20.3 × 16/3) = (12) × (340.131) = 4081.6
[c] Conversion from grams per 0.0625-m^2 to pounds per acre: 6.88 × 142.74 = 982.

Total number of samples required = $4s^2/L^2$
= $(4 \times 20{,}124) / (100)^2$
= 80,496 / 10,000
= 8

Additional samples required = total samples required – samples collected
= 8 – 5
= 3

Based on these calculations, three additional samples must be collected.

6. *Additional samples*—collect additional samples at random locations (Tables 3 and 4). Following collection of data, the average seed weight and standard deviation of samples must be recalculated using the equations in Step 5. If the accompanying software is used, these calculations are performed automatically. In this example, the revised estimate of average seed weight ($\bar{x}$) is 1,064 pounds per acre, and the standard deviation (s) is 110 pounds per acre.
7. *Estimating total seed production*—after collecting a sufficient number of samples of each species to obtain an average seed estimate with a standard deviation less than the maximum allowable error, estimate total seed production. An estimate of seed produced by each species is determined by computing the average seed weight of that species in all samples collected and multiplying this value by the area sampled. Total seed production is estimated by summing seed produced by each species. In this example only barnyardgrass was sampled. Therefore, total seed produced is equivalent to barnyardgrass seed produced.

Barnyardgrass seed produced = average seed weight $\times$ area sampled
= 1,064 ($\pm$ 110) pounds per acre $\times$ 10 acres
= 10,640 $\pm$ 1,100 pounds in unit.

Computer Software

Computer software is available for performing the mathematical computations necessary to estimate seed weight. The program is written in Turbo Pascal and can be operated on computers with a minimum of 256K memory. The program computes the estimated seed weight of individual plant species collected at each sample location and displays this information following entry of each sample. In addition, a summary screen displays estimates of average and total seed produced in an impoundment as well as the standard deviation of the estimate. This information is automatically stored in a file that can be printed or saved on a disk. A copy of the program is available upon request. Instructions pertaining to the use of the program are obtained by accessing the README file on the program diskette.

Suggested Reading

Fredrickson, L. H., and T. S. Taylor. 1982. Management of seasonally flooded impoundments for wildlife. U.S. Fish and Wildlife Service Resource Publication 148, Washington, D.C. 29 pp.

Reinecke, K. J., R. M. Kaminski, D. J. Moorehead, J. D. Hodges, and J. R. Nassar. 1989. Mississippi alluvial valley. Pages 203–247 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, editors. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock.

Appendix. Common and Scientific Names of Plants Named in Text.

Annual sedge	*Cyperus iria*
Barnyardgrass	*Echinochloa crusgalli*
Barnyardgrass	*Echinochloa muricata*
Beggarticks	*Bidens* spp.
Chufa	*Cyperus esculentus*
Crabgrass	*Digitaria* spp.
Fall panicum	*Panicum dichotomiflorum*
Foxtail	*Setaria* spp.
Ladysthumb smartweed	*Polygonum lapathifolium*
Redroot flatsedge	*Cyperus erythrorhizos*
Rice cutgrass	*Leersia oryzoides*
Sprangletop	*Leptochloa filiformis*
Water pepper	*Polygonum hydropiper*
Water smartweed	*Polygonum coccineum*

Note: Use of trade names does not imply U.S. Government endorsement of commercial products.

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