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Abstract: The relative importance of various foods occurring in the diet of blue-winged teal (*Anas discors*), pintail (*A. acuta*), and gadwall (*A. strepera*) breeding in south-central North Dakota and lesser scaup (*Aythya affinis*) breeding in the vicinity of Great Slave Lake, Northwest Territories, are compared by the aggregate volume and aggregate percent methods. Advantages of the aggregate percent method are discussed in relation to the information presented.

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Recent investigations of the foods consumed by breeding and immature ducks inhabiting prairie and subarctic wetlands of North America have emphasized the value of using the esophageal contents rather than the gizzard for this purpose (Perret 1962; Bartonek and Hickey 1969*a*, 1969*b*; Dirschl 1969; Sugden 1969; Bartonek and Murdy 1970; Swanson and Bartonek 1970; Swanson and Nelson 1970; Krapu 1972; Swanson and Sargeant 1972). This change was implemented primarily through improved sampling procedures which provided birds containing substantial amounts of food in their esophagi. The trend toward utilizing the esophagus of waterfowl somewhat paralleled an earlier and similar change that occurred in food habit studies of upland game birds (Martin et al. 1946; Martin et al. 1951). The purpose of this paper is to reevaluate two existing methods of presenting either volumetric or weight data in light of the current use of the esophagus as a source of information. The data that form the basis for these comparisons were gathered to support feeding ecology studies of blue-winged teals, pintails, and gadwalls in south-central North Dakota and lesser scaups in the Northwest Territories.

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METHODS

The esophageal contents of 72 blue-winged teals, 14 pintails, 13 gadwalls, and 61 lesser scaups collected while actively feeding were measured by volumetric displacement, using methods similar to those described by Swanson and Bartonek (1970). Feeding behavior was observed for a minimum of 10 minutes prior to sampling to insure that the esophagus contained an adequate amount of food for analysis. Volumetric measurements of individual food items are expressed as the mean of volumetric percentages (aggregate percentage), and percentages of the total volume (aggregate volume) as defined by Larimore (1957) and Martin et al. (1946). The terms defined by Martin et al. (1946) are used in

this paper to avoid adding confusion to the literature by adopting new terms.

The measurements used in this paper can be defined on the basis of J food items and I birds where Y_{ij} equals the volume of the jth food item in the ith bird ($i = 1, \ldots, I$; $j = 1, \ldots, J$). On this basis, percentage of the total volume (aggregate volume) equals the total volume of the jth food item in the sample of all birds divided by the total volume of all food items in the sample. The average of volumetric percentages (aggregate percentage) equals the proportion of the jth food item in the ith bird averaged over all birds in the sample. The aggregate volume method gives equal weight to each unit of food consumed by *any* bird while the aggregate percent method gives equal weight in the analysis to each bird. The two methods give comparable results only when each bird in the sample contains the same total quantity of food. Distortion may arise when one or a few birds contain much more food than the others in the sample.

The frequency of occurrence (percent occurrence) is obtained by dividing the number of birds that consume a particular food item by the number of birds in the sample and is presented in the tables to aid in the evaluation of the two methods of presenting data.

Several authors have discussed methods of presenting food analysis data; among them are: McAtee (1912); Steven (1933); Martin et al. (1946); Hartley (1948); Martin et al. (1951); Bartonek (1968); and Korschgen (1969) for birds and Larimore (1957) and Windell (1968) for fish. In commenting on the two methods of presenting data, Larimore (1957) stated, "The reason for calculating the volume of each kind of food by both average of volume percentages and percentage of total volume is that these two calculations give very different expressions of volume." He further stated, "Although the above differences have been discussed in other food studies (...), a complete food analysis employing both methods has not been published to illustrate erroneous conceptions inherent in references to volume as a percentage without defining its derivation or meaning."

RESULTS

Data presented in the following tables demonstrate how the diet of a few birds can dominate a sample if the aggregate volume method is used, thereby creating a misleading impression of the relative importance of food items in the diet. Presenting food habits information in this manner becomes a problem when a few individuals gorge themselves on a food item that rarely occurs in the diet. Use of the aggregate percent method greatly reduces the importance of these infrequently consumed foods.

During the spring of 1969, 2 (18 percent) of the 11 blue-winged teals included in Table 1 consumed wheat (*Triticum aestivum*). Because of the large volume consumed by a few birds, wheat comprised 56.7 percent by the aggregate volume method compared to 16.1 percent by the aggregate percent method. Distortion of the data was less apparent in 1970 and 1971 because the larger sample sizes reduced the influence of infrequently consumed foods. Statistics presented in the 3-year summary (Table 1), however, indicate that volumetric percentages still varied between the two methods. The data for teal also suggest that crustaceans (primarily fairy shrimp), which are comparatively soft foods and, therefore, more readily digested than other foods, are underestimated by the aggregate volume method and that insects and gastropods are measured fairly equally by the two methods. A single bird observed to

Table 1. A comparison of the aggregate volume and aggregate percent methods of presenting food items found in the esophagi of breeding blue-winged teals, male pintails, and postlaying female gadwalls collected during April–June of 1969–72 in south-central North Dakota.

Species	Date	Sample size	Food items	Aggregate volume	Aggregate percent	Percent occurrence
Blue-winged teal	1969	11	Gastropoda	33.9	44.4	64
			Crustacea	1.5	10.1	73
			Insecta	4.1	16.1	73
			Misc. seeds	2.1	11.1	45
			Wheat	56.7	16.1	18
			Misc.	1.7	2.2	9
	1970	37	Gastropoda	32.8	38.4	78
			Crustacea	6.2	6.2	49
			Insecta	40.6	38.3	95
			Misc. seeds	7.8	9.2	73
			Wheat	5.4	1.3	3
			Misc.	7.2	6.6	32
	1971	24	Gastropoda	36.5	24.6	58
			Crustacea	17.1	40.0	83
			Insecta	28.2	27.4	75
			Misc. seeds	3.4	2.6	46
			Wheat	12.8	3.3	8
			Misc.	2.0	2.1	42
	Total 1969–71	72	Gastropoda	34.4	35.8	69
			Crustacea	8.7	18.8	64
			Insecta	26.5	27.3	85
			Misc. seeds	4.8	7.6	60
			Wheat	22.0	6.9	7
			Misc.	3.6	3.6	32
Pintail	1969–71	14	Animal	8.0	30.0	93
			Sea blite seeds	46.0	13.5	14
			Misc. seeds	46.0	56.5	93
Gadwall	1971–72	13	Crustacea	70.8	36.4	54
			Insecta	3.1	9.7	77
			Vegetation (excluding seeds)	26.0	46.2	85
			Seeds	0.1	7.7	39

feed intensely on clam shrimp and fairy shrimp for a period of 2 hours (presumably enough to fill its esophagus) contained an esophagus only approximately one quarter filled. This illustrates how rapidly soft crustaceans are processed in the digestive tract.

Use of the aggregate volume method for determining the relative importance of various foods in the male pintails' diet led to a distortion similar to that among blue-winged teals. In this case the seeds of sea blite (*Suaeda depressa*) filled the esophagi of two male pintails, causing this food item to constitute nearly half of the aggregate volume. When weighted by the aggregate percentage method, this food item comprised only 13.5 percent of the diet, placing the importance of sea blite seeds in better perspective.

Two female gadwalls consumed a large volume of fairy shrimp because of the high availability of this species and, as a result,

Table 2. A comparison of the aggregate volume and aggregate percent methods of presenting data based on food items found in the esophagi of lesser scaups collected during the summer of 1969 in the vicinity of Great Slave Lake, NWT.

Sample size	Food items	Aggregate volume	Aggregate percent	Percent occurrence
23 adults	Hirudinea	6	3	26
	Crustacea	66	45	82
	Insecta	18	26	74
	Hydracarina	tr[a]	tr	9
	Gastropoda	3	14	52
	Pelecypoda	7	12	57
	Misc. seeds & veg.	tr	tr	17
38 juveniles	Crustacea	75	45	74
	Insecta	23	50	92
	Hydracarina	tr	4	8
	Gastropoda	tr	1	16
	Pelecypoda	tr	tr	8
	Misc. seeds & veg.	tr	tr	8

[a] tr = values less than 1 percent.

caused crustaceans to dominate the diet of 13-postlaying birds when the aggregate volume method of analyses was used. Weighting the data for this group of birds by the aggregate percentage method changed the proportion of crustaceans in the diet from 70.8 to 36.4 percent.

The proportions of crustaceans and insects in the diet of mature and juvenile lesser scaups also differed when calculated by the two methods described (Table 2). Crustaceans (predominantly amphipods) accounted for 75 percent of the diet of 38 juveniles by the aggregate volume method. Their proportion, however, dropped to 45 percent when these data were weighted by the aggregate percentage method, and, as a result, insects were the dominant food consumed.

DISCUSSION

A major factor to consider in evaluating the merits of the two methods is the significance of "fullness" of the esophagus. In discussing the function of the esophagus, Farner (1960) points out that, in addition to its basic function of serving as a passageway for food from the pharynx to the stomach, it provides an important storage function which may be effected simply by a temporary expansion or by the existence of a more specialized and permanently enlarged section, the crop.

Certain factors unrelated to the rate of ingestion can influence the fullness of an esophagus. Hard and soft foods are processed at different rates and, as a result, accumulate in varying quantities in the esophagus (Swanson and Bartonek 1970). In discussing methods of presenting information on food consumption, Windell (1968) pointed out that data may be distorted by differential rates of digestion or by occasional occurrence of an exceptionally bulky food item. "Fullness," therefore, does not appear to be indicative of overall intake if considered in terms of the proportion of different foods that are consumed over a a longer period of time.

Food habits information derived by the aggregate volume method is also distorted if esophagus size varies widely among animals in the sample. For example, failure to weight or segregate immature birds by various age classes leads to data biased toward the diet of older individuals having the

largest storage capacity and tends to mask the importance of foods consumed by the younger birds having smaller storage capacities. The volume of grit within the gizzard provides an indication of the relative storage capacity of the upper digestive tract and, therefore, the relative volume of food able to be processed. Among three species of pochards (*Aythya* spp.), the volume of grit in the gizzards of the older Class III and flying juveniles ranged between 2.4 and 4.7 times greater than that of Class I ducklings and from 1.2 to 1.4 times greater than that of Class II ducklings (Bartonek 1969).

In some instances, a certain food may be abnormally abundant and available, and birds may gorge themselves on it. In addition to the examples cited in this study, the authors have noted ducks feeding on piles of spilled grain and have seen esophagi of field-feeding ducks packed with several ounces of grain. A similar situation exists when insects emerge in the evening and concentrate on the water surface (Swanson and Sargeant 1972). A total of 701 chironomids have been recorded in a single esophagus under these conditions. Thus, a few birds can greatly distort the overall results unless the data are weighted by the aggregate percentage method.

As the number of birds in the sample increases, the effect of the "fullness" factor is less pronounced; however, even data from large collections are usually segregated into smaller discrete groups for detailed analysis. Weighting data in the manner described insures that each bird is represented equally in a sample.

It should be recognized that studies of the feeding ecology of birds serve different purposes (Steven 1933) and, as a result, alternate methods of presenting data may be desired. For our purpose, which is to document foods utilized by breeding birds, where feeding intensity is observed prior to sampling and the birds generally contain an esophagus well filled with foods that vary in digestibility, the weighted (aggregate percent) method as described appears to provide the least biased results. The value of this procedure is further improved when combined with other methods such as frequency of occurrence.

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