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A METHOD FOR APPRAISING BLACKBIRD DAMAGE TO CORN

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Abstract: The appraisal method described was developed from 1961 to 1965 at the Sand Lake National Wildlife Refuge, South Dakota. In 1962, 600 undamaged corn ears were collected at random, dried, and sorted by half-inch lengths into 15 size classes, and the kernels of each half-inch section were shelled off and weighed. The average cumulative weight of the kernels on each half-inch section for each size class was listed in a table that allowed an estimate of the dry weight lost to be read off from the length of the ear and the length of the damaged section. After adjustment by a standard percentage (by which any 1 year's crop was heavier or lighter than the 1962 crop), the data showed a uniform relationship between length and weight. Regression equations derived for each size class (R^2 at least 0.90 in all but one case) permitted a more accurate table to be generated mathematically.

Total weight of corn lost to blackbirds each year was estimated by sampling two plots (each a 100-ft section of a corn row) per field on about 15 percent of the fields in the 94-square-mile study area. Damage on each plot was measured after the bird damage season simply by counting the number of damaged and undamaged ears and measuring the length of the damaged ears and the length of damage they had sustained. The chief advantage of this appraisal is the small amount of time it requires. Plots are examined only once, only damaged ears are measured, and damage is recorded directly from the length–weight table as weight of marketable corn lost per ear.

Corn and other ripening grains are often extensively damaged by large flocks of blackbirds, but suitable methods for assessing the losses have generally been lacking. Most investigators have relied on estimates by landowners, who sometimes may be biased by their desire to call attention to their problems. Only a few workers have attempted to estimate grain losses quantitatively. Neff and Meanley (1957) tried evaluating blackbird damage to rice but found most methods impractical. More intensive studies by Cardinell and Hayne (1945) and Hayne (1946) showed the relationship between the proportion of ears of corn opened by red-winged blackbirds (*Agelaius phoeniceus*) and the amount of grain taken in Michigan cornfields, but we found that their method of estimation had low reliability when more than 75 percent of the ears in a field were damaged, a situation often encountered in cornfields adjacent to marshes. With their method, the total yield of a field must be known in order to compute loss.

In 1960, personnel of the Denver Wildlife Research Center began a long-term research program on methods of controlling blackbird damage to ripening field corn on a 94-section area at the Sand Lake National Wildlife Refuge, Brown County, South Dakota (De Grazio 1964). A necessary part of the program was the development of a reliable quantitative method of determining the amounts of corn lost to birds each year. Because our study area was large and required fairly extensive sampling, a simple and rapid method was necessary. By measuring and weighing undamaged ears, we were able to establish clear length–weight relationships and prepare a table converting length of damage on an ear to weight of corn lost. With this table and a suitable sampling design, we needed only to measure the length of sample ears to estimate the bushels per acre of marketable corn lost to birds in the study area.

We gratefully acknowledge the assistance given in gathering field data by K. H. Larsen, R. R. West, P. P. Woronecki, and E. W. Schafer of the Denver Wildlife Research Center; by summer employees D. L. Gilbert, E. E. Best, V. Riddle, and R. Sonstegard; and by Refuge personnel L. J. Schoonover and T. Wahl. T. J. DeCino, A. Zajanc, J. A. Neff, and other members of the Denver Wildlife Research Center aided in planning field phases of the study; D. W. Hayne contributed importantly to the experimental design; and Ann H. Jones critically reviewed the manuscript.

SAMPLING DESIGN

The rectangular study area contained most of the Refuge marshes and the most heavily damaged cornfields in the county. During the study, an average of 321 fields totaling about 8,500 acres was planted to corn annually. The varieties grown were from 11 national and local seed corn companies; they were essentially similar in maturation rate and physical characteristics.

Cornfields were aerially mapped each year in early July when the plants were 2 or 3 ft high and easily distinguishable from other crops. An observer accompanying the pilot plotted cornfields on aerial photos (8 inches per mile). Each field on the photo was measured with a plastic grid to determine acreage and plotted on a map of the study area (4 inches per mile).

An analysis of variance for the first 3 years of sampling showed that bird damage varied more between fields than within them. In 1960, four plots (each consisting of a 200-ft section of a single corn row) were surveyed in each of 20 fields, but we found that reducing the number and length of the plots and increasing the number of fields sampled provided more reliable data per unit of time expended. The 1963 design, two 100-ft plots per field, was selected as the most suitable one. With this design, we needed to sample only about 15 percent of the fields in the study area to estimate total losses within 45 percent of the mean ($P < 0.10$). This degree of accuracy was adequate for our purposes.

All test fields were selected by random number. To select plots, the length and width of a field as measured from aerial photos were converted to yards; since corn rows in Brown County are planted 40 inches apart, the total number of rows in the field could be accurately estimated. Random numbers were used to select the two rows that were to contain plots and the number of yards to the point where each plot began. The most accessible corner of the field served as the starting point.

Damage to corn was not appraised until late September, several weeks after all kernels had dented. After this time, only a negligible amount of bird damage occurred. The number of damaged and undamaged ears and the amount of loss on the damaged ears were recorded for each plot. Loss was obtained by stripping the husks from the damaged ears and measuring the total length of the cob that had borne developed kernels and the length of the damaged portion to the nearest ½ inch. Ears with less than a ¼ inch of damage were recorded as having "trace" damage and were not measured. When ears were damaged unevenly, the length of damage was estimated; for example, if there were 3 inches of damage on one side of an ear and none on the other, the ear was recorded as having 1½ inches of damage. Other types of damage, such as that from insects and disease, were negligible and could readily be distinguished from bird damage.

EMPIRICAL LENGTH–WEIGHT TABLE

The first length–weight table was made in 1962. Six hundred dented, undamaged ears of corn were collected at random on the study area, put in mesh bags, and allowed to dry to the moisture level present in stored corn (12–13 percent). They were then sorted by ½-inch lengths into 15 classes between 4 and 11 inches. No ears fell outside these limits; 87 percent were 6 to 9 inches long. Random samples were taken of each ½-inch size class; 20 ears were used for the 6- to 9-inch classes, and 10 or 5 for the less common classes. The kernels were shelled from each ½-inch section of each sample ear and weighed to the nearest 0.1 g. The weights for each ½-inch section from ears of each class were averaged and listed to form the empirical length–weight table (Table 1).

With the table, it was possible to measure the length of an ear and the length of the damaged portion and simply read off the estimated amount of corn lost. For example, an 8-inch ear with ½-inch of damage lost 2.5 g of corn, and one with 1-inch of damage lost 7.6 g. "Trace" damage was calculated as half the average weight of the tip ½-inch section of all size classes, or 1.1 g.

A second length–weight table was made in 1963. To determine whether the regular relationship evident in the 1962 table held from year to year, we compared 25 ears in the 6-, 7-, 8-, and 9-inch classes from 1963 with the 80 ears in the same size classes from 1962. The 1963 ears were heavier than the 1962 ears by about 23 percent. When the figures for average weight in the 1962 table were increased by this factor, they differed only slightly from the average weights of the 1963 samples; the mean deviation was 1.7 percent, with a range of –1.6 percent to +2.4 percent. Because of this

Table 1. 1962 empirical length-weight table, giving average cumulative weight in grams of ½-inch sections of corn ears 4 to 11 inches long. (Figures are from fully dried corn and are not corrected for shrinkage of field-measured ears during final drying.)

Length of Corn on Ear (inches)	Length of Damage (inches)																					
	½	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11
4	1.8	6.4	13.1	21.1	29.7	38.3	46.2	53.5														
4½	2.4	7.7	15.0	23.3	32.2	40.9	50.1	59.2	67.4													
5	2.5	7.9	15.3	23.9	33.1	42.8	53.0	63.2	72.7	81.4												
5½	2.7	8.6	16.6	25.6	35.3	45.1	55.1	65.2	75.2	84.7	92.5											
6	2.8	8.7	16.4	24.9	34.4	44.1	54.3	64.7	75.1	85.4	95.7	104.6										
6½	2.8	8.8	16.3	24.8	33.9	43.6	53.6	64.2	74.8	85.5	96.2	106.3	115.6									
7	2.8	8.5	16.3	25.2	34.5	44.8	55.2	66.0	76.8	87.6	98.1	108.4	118.5	128.6								
7½	2.7	8.0	15.5	24.6	34.2	44.2	55.0	65.7	76.2	87.4	98.3	109.4	120.2	130.9	140.9							
8	2.5	7.6	14.5	23.4	32.8	43.0	53.9	64.7	75.8	88.5	100.1	111.8	123.5	134.4	145.4	156.2						
8½	1.9	7.0	14.1	22.5	32.2	42.4	53.2	65.0	76.3	88.0	99.8	112.0	123.2	136.0	148.1	159.3	170.5					
9	2.1	7.0	14.4	22.9	32.3	43.1	54.5	66.3	78.6	91.1	104.0	117.3	130.2	143.2	155.8	168.4	180.0	191.2				
9½	2.3	7.8	15.9	24.6	34.9	46.5	58.1	70.4	83.4	97.0	110.7	124.5	138.9	153.3	167.6	181.7	195.4	208.3	220.3			
10	1.9	7.6	15.1	24.1	34.2	44.7	56.3	68.4	81.2	94.4	108.2	122.4	136.9	151.2	165.9	180.0	194.3	208.5	221.8	234.4		
10½	2.0	6.3	13.0	21.7	31.1	41.7	53.0	64.7	77.1	90.3	103.0	116.1	129.4	142.9	156.4	169.9	183.4	197.0	211.3	226.1	243.4	
11	1.8	6.4	13.2	21.8	32.6	44.3	56.6	70.0	83.4	97.3	112.3	128.0	143.9	160.1	176.3	192.3	207.7	223.0	238.2	252.8	265.6	279.2

Table 2. Regression equations and coefficients of determination showing the relationship between length (X) and weight (Y) of ears of corn.

Ear Class (inches)	Regression Equation	R^2
4	$\hat{Y} = -8.31 + 15.36X$	0.92
4½	$\hat{Y} = -8.79 + 16.79X$	0.83
5	$\hat{Y} = -10.41 + 18.18X$	0.92
5½	$\hat{Y} = -10.00 + 18.68X$	0.93
6	$\hat{Y} = -6.79 + 15.28X + 0.59X^2$	0.97
6½	$\hat{Y} = -6.19 + 14.66X + 0.66X^2$	0.93
7	$\hat{Y} = -8.25 + 16.55X + 0.46X^2$	0.97
7½	$\hat{Y} = -8.85 + 16.95X + 0.49X^2$	0.97
8	$\hat{Y} = -9.67 + 16.39X + 0.59X^2$	0.95
8½	$\hat{Y} = -10.47 + 16.39X + 0.62X^2$	0.90
9	$\hat{Y} = -11.80 + 17.27X + 0.64X^2$	0.98
9½	$\hat{Y} = -13.27 + 18.95X + 0.65X^2$	0.96
10	$\hat{Y} = -12.51 + 17.82X + 0.74X^2$	0.97
10½	$\hat{Y} = -12.72 + 17.04X + 0.69X^2$	0.98
11	$\hat{Y} = -17.53 + 19.94X + 0.71X^2$	0.97

constant relationship, the time-consuming process of constructing a new length–weight table was not repeated in 1964 and 1965, and only 50 ears in a single size class (7 inches) were weighed each year for the purpose of adjusting the weight figures in Table 1. Ears weighed 4.5 percent less in 1964 than in 1962, and 12.4 percent more in 1965.

In 1964 we realized that dented ears collected in the field shrank more than a negligible amount when they were further dried to 12–13 percent moisture content. To assess this factor, 60 ears of 12 size classes in 1964 and 50 8-inch ears in 1965 were measured in the field in late September and then remeasured after drying. For the 2 years, they lost an average of 8.9 percent in total length (range 5.5–12.7 percent for different size classes). Since the corn measured for bird damage was still on the stalk, direct use of Table 1 would have resulted in an average 13.1 percent overestimation of the weight lost, and it was therefore necessary to reduce losses calculated from the table each year by this amount to obtain actual losses.

The number of bushels of corn per acre lost to blackbirds in the study area each year was estimated by dividing the total grams lost per plot (corrected for shrinkage) by 194.2. This factor was obtained by dividing the plot size in acres (1/130.8 acres, for plots 100 ft long by 40 inches wide) by the fraction that 1 g is of the number of grams in a bushel of shelled corn (1/25,401.6). The potential yield per acre each year was calculated similarly by multiplying the year's figures for the average number of ears per plot by the average weight in grams of undamaged ears and dividing this product by 194.2.

GENERATED LENGTH–WEIGHT TABLE

Examination of the data used in constructing the 1962 and 1963 tables revealed a consistent association within each size class between the length of the section of an ear from which corn was removed and the weight of the corn removed. The strength of this association and the mathematical relationship representing it were evaluated for the 15 ½-inch size classes by linear correlation and by linear and curvilinear regression. A least-squares procedure was used to determine the best-fitting polynomial for each size class, and analysis of variance was used to test the deviations due to regression through the fourth-degree curve. When regressions appeared similar on scatter diagrams, covariance analysis was used to test differences between their regression coefficients and between their means both within and between years. Confidence limits for predicted mean values were computed for all regressions ($P < 0.05$).

The coefficients of determination (R^2) for length versus weight in each size class

Table 3. Mathematically generated length-weight table, giving cumulative weight in grams of ½-inch sections of corn ears 4 to 11 inches long. (Figures for ½ inch of damage have been left out because they were negative; those from Table 1 should be used instead.)

Length of Corn on Ear (inches)		Length of Damage (inches) on the Stalk																				
		1	1½	2	2½, 3	3½	4	4½	5	5½	6	6½	7	7½	8, 8½	9	9½	10	10½	11	11½	12
		Length of Damage (inches) Dried																				
On the Stalk	Dried	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11
4½	4	7.1	14.7	22.4	30.1	37.8	45.5	53.1														
5	4½	8.0	16.4	24.8	33.2	41.6	50.0	58.4	66.8													
5½	5	7.8	16.9	26.0	35.0	44.1	53.2	62.3	71.4	80.5												
6	5½	8.7	18.0	27.4	36.7	46.0	55.4	64.7	74.1	83.4	92.7											
6½	6	9.1	17.5	26.1	35.1	44.4	53.9	63.8	73.9	84.4	95.1	106.1										
7	6½	9.1	17.3	25.8	34.6	43.7	53.2	63.0	73.1	83.6	94.4	105.5	117.0									
7½	7	8.8	17.6	26.7	36.0	45.5	55.3	65.3	75.5	86.0	96.7	107.6	118.8	130.1								
8, 8½	7½	8.2	17.1	26.3	35.7	45.3	55.2	65.4	75.7	86.4	97.2	108.3	119.7	131.3	143.1							
9	8	7.3	16.2	25.5	35.0	44.8	54.9	65.3	76.0	87.0	98.3	109.9	121.8	134.0	146.4	159.2						
9½	8½	6.5	15.5	24.8	34.4	44.3	54.5	65.0	75.8	87.0	98.4	110.2	122.3	134.6	147.3	160.3	173.6					
10	9	6.1	15.5	25.3	35.4	45.8	56.5	67.5	78.9	90.6	102.5	114.9	127.5	140.5	153.7	167.3	181.2	195.5				
10½	9½	6.3	16.6	27.2	38.2	49.4	61.0	72.9	85.2	97.7	110.6	123.8	137.4	151.2	165.4	179.9	194.8	209.9	225.4			
11	10	6.1	15.9	26.1	36.7	47.6	58.9	70.6	82.7	95.1	107.9	121.1	134.6	148.5	162.8	177.4	192.4	207.8	203.6	239.7		
11½	10½	5.0	14.4	24.1	34.2	44.6	55.4	66.5	77.9	89.7	101.9	114.4	127.2	140.4	153.9	167.8	181.9	196.5	211.4	226.7	242.3	
12	11	3.1	14.0	25.2	36.8	48.7	61.0	73.6	86.6	99.9	113.6	127.7	142.1	156.8	172.0	187.4	203.3	219.4	236.0	252.9	270.1	287.7

ranged from 0.83 for 4½-inch ears to 0.98 for 9- and 10½-inch ears and were 0.90 or above for all but one class (Table 2). These high coefficients indicated that the technique of measuring the length of an ear was a reliable method of estimating corn weight. The analysis of variance showed that a linear equation ($Y = A + BX$) fit best for the 4- through 5½-inch classes and that a quadratic ($Y \doteq A + BX + CX^2$) fit best for the other classes. The equations that best represented the relationship between length (X) and weight (Y) for the different size classes are given in Table 2.

From these regressions it was possible to generate Table 3, which is similar to the empirically derived Table 1 but more mathematically accurate. The only place in which the generated figures are less suitable than the empirical ones is in the column for ½ inch of damage. As sometimes happens with regression equations, the low values of X resulted in negative values of Y, the estimated variable. To avoid the obvious absurdity of negative damage, we have left this column out of Table 3, and recommend that the empirical figures for ½ inch of damage from Table 1 be used instead.

Table 3 can be used, as was Table 1, to quickly and easily read off the weight of corn lost from simple length measurements of ears. The figures will, of course, still have to be adjusted for the percentage by which the current year's crop is heavier or lighter than the figures in the table. To correct Table 3 so that it can be used to convert length of ears on the stalk to dry weight of marketable corn lost, we have added a column for length on the stalk (8.9 percent larger than dry weight) instead of decreasing the weight figures by 13.1 percent as we had done with Table 1. In this way, ears can be measured in the field, as in our usual procedure, but could also be measured dry, after harvest, if this should prove a desirable sampling technique.

Investigators wishing to use Table 3 for areas greatly different from Brown County may want to take a rather large sample of ears in several size classes the first year to assure themselves that the figures in the table and the factor for shrinkage hold true for their area. After that, to calculate the weight difference of the year's crop, smaller samples in a single size class should be adequate.

DISCUSSION

Linehan (1967) has discussed some of the difficulties involved in sampling corn for blackbird damage. The problem has two facets. One is to recognize the variables that may influence the degree of damage, such as the maturity of the corn or the distance from roosts or flightlines. These variables must be taken into account when the sampling design is set up. The other is to measure the damage—predicting the amount of corn lost in a field by measuring the damaged kernels on a few sample ears. The sampling design in this case must take into account the uniformity of the corn population and the reliability of the measuring criteria used. In addition, the measuring process chosen must not be unduly time-consuming for the type of test being conducted.

We allowed for any differences in damage due to the maturity of the corn or other seasonal factors by measuring the total damage after the damage season was over. All cornfields in the study area were within 3 miles of major roosts or flightlines; differences in damage due to the exact location of the study plots were neutralized by random selection of both plots and fields. In our preliminary studies, we found that blackbirds fed indiscriminately on different-

sized ears. Although Cardinell and Hayne (1945:14) noted that blackbirds preferred large ears, we found that other variables such as stage of maturity, amount of husk, presence of some ears with exposed kernels, and angle of ears on the stalk, all combined to outweigh any preference they may have had for ear size. Indiscriminate feeding was confirmed in 1962 by comparing 2,675 damaged ears with 600 randomly picked undamaged ears; the two groups had almost identical distribution in size classes.

Examination of corn grown in the study area revealed that the various varieties produced ears of about the same weight, width, and depth of kernel, and that the major factor influencing yield was simply the ear's length. In constructing the empirical length–weight tables, we divided ears by length into ½-inch classes to take this into account, but we did not anticipate the remarkably uniform relationship we found. This regular pattern enabled us to generate Table 3, which turned out to provide considerably more accuracy than our sampling design had called for.

One of the chief advantages of our survey method was the small amount of time it required. Sampling about 15 percent of the fields in the study area reduced the number of plots needed to about 80. Each plot was inspected only once and, although all ears were counted, only damaged ones were measured. Sampling a plot took one person about 30 minutes when damage was moderate, although it could take as long as 1 hour for two people (one to measure and one to record) when damage was extremely heavy. Time was also saved by the use of aerial surveys to map the area. Flying time was about 6 hours; a survey of the same area by car in 1960 required about 10 man-days. The most time-consuming part of the technique was construction of the length–weight tables, but the strong correlation between length and weight meant that a new table was not required each year and that only enough ears had to be collected to furnish a correction factor for the basic table.

Table 3 may have wide application for measuring corn damage, especially in the Midwest, since the technique is reliable for standard varieties of field corn, is suitable for assessing large acreages and all degrees of damage, and expresses results in actual weight of marketable corn per acre. Other investigators with a smaller study area, a more uniform damage situation, or more manpower may be able to take better samples and thus take greater advantage of the tables' accuracy than we could. The table could also be used, with a little modification, for computing yields. The principle of constructing a length–weight table may have even wider application, since it is probable that even unusual hybrid corn, such as is sometimes grown at experiment stations, would show the strong correlation between length and weight that permits the use of such a table.

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