Influence of Environmental Factors on Blackbird Damage to Sunflower

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Abstract

As part of a 3-year survey designed to estimate the extent of sunflower seed losses to blackbirds in North Dakota, South Dakota, and Minnesota, several habitat variables were recorded at each survey field in an effort to identify potential predictors of among-field and within-field variation in damage. Variables included the presence or absence of certain habitat types near the survey field, the size of the survey field, the distance between rows, and the average head size and plant height. We chose a subset of these potential predictors for each year by using a statistical method based on contingency tables; these three subsets were subsequently used in a log-linear modeling procedure to analyze the damage distribution within each year. The largest influence on damage levels—the presence of nearby marshes—was associated with increased losses. Other factors that had significant associations in at least 1 year were row spacing; presence or absence of adjacent plowed fields, pastures, and trees; and weed density in the survey field. The ecological relevance of these factors to blackbirds is discussed.

As reported in Part I, "Bird Damage to Sunflower in North Dakota, South Dakota, and Minnesota, 1979–1981," blackbird damage to cultivated sunflower is unevenly distributed among fields. Thus, although most farms suffer little or no damage, the economic impact on others is severe. Several factors might be responsible for the large among-field variation in damage, such as the adjacency of certain other habitats or the particular agricultural practices in use. Meanley (1971) suggested that blackbird damage to ripening rice in the southeastern United States could be related to adjacent woody cover, and that grasses and sedges found in some rice fields could attract blackbirds. Dolbeer (1980) states that high weed populations could attract blackbirds to ripening cornfields, and he noted that surveys of corn damage in Ohio showed that the level of depredations was associated with the proximity of the field to blackbird roosts. Although blackbirds do not generally use trees and shelterbelts as roosting sites during the damage season in North Dakota (Besser et al. 1979), such habitat is heavily used for resting and loafing throughout the day and potentially attracts feeding birds.

If sunflower seed losses are also related to habitat factors, then losses might be reduced through cessation of planting in identified high-risk areas, changes in cultural practices, or more effective use of control methods (e.g., chemical repellents or scare devices) when high-risk areas are cultivated. This concept was the impetus behind the decision to collect ancillary habitat information in conjunction with the damage survey described in Part I. In addition, we measured several field and plant characteristics to explore factors that might be related to variation in damage among or within fields.

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Table 1. *Independent variables used to assess damage distribution among fields.*

Variable	Categories 1	2	3
Field size (ha)	<20.2	20.2–40.5	>40.5
Distance between rows (cm)	<76.2	>76.2	—
Sunflower type[a]	oil	non-oil	—
Adjacent habitats			
standing crops	absent	present	—
plowed fields	absent	present	—
stubble fields	absent	present	—
pasture	absent	present	—
trees	absent	present	—
urban[a]	absent	present	—
Presence of marsh[a]	absent	present	—
Distance to marsh (km)[b]	<0.81	>0.81	—
Average head size (cm^2)	<220	220–300	>300
Average plant height (cm)	<117	117–137	>137
Average weed density	<1.2	1.2–1.6	>1.6

[a]Recorded in 1979 and 1980 only.
[b]Replaced "presence of marsh" in 1981.

We present a data analysis that identifies potential relations. It is important to realize that in such an analysis, direct cause and effect relations cannot be established. We have attempted to identify factors that are worthy of further investigation in experiments designed specifically to test hypotheses suggested by this analysis.

Methods

The methods used in field selection, plot selection, and bird damage assessment for the 3-year survey are described in detail in Part I. In addition, the surveyors recorded the following for each sampled field: Weed density in each plot was visually examined and rated as 1 = low (<5% coverage), 2 = medium (5–50% coverage), or 3 = high (>50% coverage). The height of the fifth head in each plot was measured. Adjacency of six habitat types to each field (Table 1) was recorded as present or absent. Also noted were the presence or absence of nearby marshes, the size of the field, type of sunflower (oil or confectionary), and the distance between rows.

Data Analysis

Two types of analyses were performed. We first examined the relation between the predictor variables listed previously and the level of damage experienced in a field. Most often, analyses of data sets similar to ours attempt to relate a set of predictor variables to some biological response by use of stepwise regression, multiple regression, or multivariate (i.e., principal components) techniques (Able 1973; Converse and Morzuch 1981). However, the possibility for violation of one or more of the assumptions necessary for valid use of regression techniques (e.g., homogeneous error terms and mutual independence among the predictor variables) is well established. Johnson (1981) discussed the potential for misuse of multivariate analyses of such data sets. In addition, variables are often discrete or categorical rather than continuous, which makes the aforementioned methods of analysis even less appropriate.

In view of these considerations and the fact that we chose to categorize all variables involved in this analysis, the methods of analysis proposed by Grizzle et al. (1969) were used. The following brief description of the methodology is from Glahn and Otis (1986):

> This approach is similar to multiple regression analysis except log–linear model approximates are used for categorical data. The FUNCAT routine in the Statistical Analysis System package (Helwig and Council 1979) was used to perform the calculations after screening a large set of independent variables to derive a small subset of variables that satisfied these criteria:

(1) each variable in the subset appeared to be associated with the incidence of damage, (2) the variables could be considered mutually independent (i.e., not intercorrelated), and (3) the subset had a sufficiently small number of variables to satisfy the data requirements of the Grizzle et al. (1969) modeling procedure. Although 2-way chi-square tests of association were initially used for selecting the subset, a more objective method (Higgins and Koch 1977) was employed to supplement and verify subsets selected. This method is a stepwise approach that uses different types of chi-square tests and methods of combining variables to best fit the model.

Because percentage loss in a given field was estimated with relatively poor precision due to the small number of plots used in 1979 and 1980, damage was treated as a categorical variable in all years. We believed that it was important to account for any regional differences in average bird loss when defining the damage categories. That is, percentage loss was standardized according to the average loss in the region. The 1979 and 1980 surveys covered an extensive and diverse area, comprising four topographical regions following the classification scheme of Bluemle (1977). These four strata (Drift Plains, Missouri Coteau, Agassiz Plain, and the Great Plains) differ in breeding bird densities (Stewart and Kantrud 1972) and possibly in late-summer (i.e., damaging) bird densities, although the relation between breeding bird density and late-summer density is not clear. We looked at mean percentage damage in each of the strata in 1979 and 1980 and found that the Drift Plains stratum had significantly higher damage than the other three strata in both years. (We deleted fields in Stutsman County, North Dakota, from the 1980 calculations, because of the aberrant damage encountered as mentioned in Part I, and because the county is bisected by the Drift Plains–Missouri Coteau border). Because there were no significant differences among the three non-Drift Plains strata, they were pooled, forming two areas. The response Y, the percentage loss in the field, was categorized according to whether it was above or below the average loss for the area. In 1979, the average loss for the Drift Plains region was 1.1% and the average loss for the combined regions was 0.6%; in 1980, the corresponding losses were 1.7% and 0.5%. Only four counties were surveyed in 1981, and the response variable Y was categorized as being either $<1\%$ or $>1\%$. Because the fields sampled in 1981 were in a few small areas with traditionally high damage, the categorization of the response variable was the same for all areas.

Categories for the continuous independent variables (Table 1) were established on the basis of two criteria: (1) biological or economic relevance, and (2) a sufficiently balanced sample size, as determined by number of fields per category, to permit valid use of the statistical analyses to be performed. Although each year was analyzed separately, categories for all of the predictor variables were the same in all 3 years. The Appendix lists two-way cross-classifications of categorized damage versus each of the independent variables, for each of the years 1979–81.

A second analysis determined if damage distribution within a field was correlated with head size, head height, or weed density. Only the 1981 survey had a sufficient number of plots per field (50) for this type of analysis, and only fields with $Y > 0\%$ were used. To test the null hypothesis of no relation between head size and head damage, we obtained simple correlation coefficients between these variables for the approximately 250 heads sampled per field. Similarly, we correlated head height and head damage for the 50 heads in each field for which height was recorded (one per plot). Absolute areas of damage (cm^2) rather than percent damage was used for these correlations. A one-way analysis of variance (ANOVA) was used to examine the effect of weed density on percent plot damage. The skewed frequency distribution of weed densities within fields (usually very few "medium" or "high" categories) precluded performing an analysis for each field. Therefore fields were grouped into low ($<1\%$), medium (1–5%), or high ($>5\%$) damage categories, and a one-way ANOVA was performed for each group.

The alpha level for all tests of significance was set at 0.05.

Results

Damage Distribution Among Fields

Because of sample size limitations, it was determined that no more than three independent variables could be used in the FUNCAT procedure and still produce reliable results. The variables selected by the Higgins and Koch (1977) procedure and their corresponding χ^2/df and termination statistic values are given in Table 2.

The results of modeling bird damage in a field as a function of each of the sets of independent variables are given in Table 3. Each of the final models produced by the FUNCAT analysis has a small residual chi-square ($P > 0.05$), indicating that the model provides a good fit; that is, the combination of factors in the model explains a significant amount of the overall variation in percentage damage. However, not all of the individual terms within the models are significant. Only the significant

Table 2. *Description of variables used as predictors in the FUNCAT procedure, as selected by the Higgins and Koch (1977) procedure.*

Year and step	Variable	df	χ^2/df	Termination statistic A	Termination statistic B
1979					
1	Presence of marsh	1	32.4	—	—
2	Distance between rows	3	11.1	7.8 (P = 0.02)	2.7 (P = 0.1)
3	Plowed fields	7	5.5	10.4 (P = 0.03)	1.4 (P = 0.16)
1980					
1	Presence of marsh	1	32.7	—	—
2	Pasture	3	12.5	6.6 (P = 0.04)	2.11 (P = 0.03)
3	Standing crops	7	7.3	9.8 (P = 0.04)	1.9 (P = 0.05)
1981					
1	Weed density	2	2.9	—	—
2	Standing crops	5	3.0	9.8 (P = 0.02)	0.9 (P = 0.39)
3	Trees	11	2.5	13.6 (P = 0.03)	1.9 (P = 0.06)

terms and their estimated coefficients (Table 4) are discussed.

In 1979, the presence of a marsh near the field was strongly associated with increased damage in the field, as indicated by the relatively large, positive coefficient for this variable (Table 4). Wider row spacing also was associated with higher damage. The interaction of presence of marsh with plowed fields had a negative coefficient, indicating that when both factors were absent, damage was increased. More specifically, close examination of the data revealed that when a marsh was absent, the presence of plowed fields was associated with reduced damage; if a marsh was present, plowed fields were not related to the response.

In 1980, the presence of marsh was again strongly related to higher damage levels. The presence of adjacent pasture areas was associated with reduced field damage, but did not represent as strong an influence on damage as marsh presence did, since the estimated coefficient is less than half of that for marsh.

Table 3. *Chi-square values for effects in final FUNCAT models.*

Year	Effect	df	χ^2	P
1979	Presence of marsh	1	15.62	0.01
	Distance between rows	1	7.50	0.01
	Plowed fields	1	3.26	0.07
	Presence of marsh × plowed fields	1	4.74	0.03
	Residual	3	2.79	0.43
1980	Presence of marsh	1	31.24	0.01
	Pasture	1	4.05	0.04
	Residual	1	2.14	0.14
1981	Standing crops	1	1.77	0.18
	Trees	1	3.13	0.08
	Weed density	2	3.13	0.21
	Standing crops × weed density	2	5.45	0.07
	Trees × weed density	2	6.42	0.04
	Residual	2	2.07	0.36

Table 4. *Estimated coefficients of significant effects in final FUNCAT models.*

Year	Effect	df	Estimate	SD	χ^2	P
1979	Presence of marsh	1	0.376	0.095	15.62	0.01
	Distance between rows	1	0.278	0.101	7.50	0.01
	Presence of marsh × plowed fields	1	−0.207	0.095	4.74	0.03
1980	Presence of marsh	1	0.686	0.124	31.24	0.01
	Pasture	1	−0.261	0.130	4.05	0.04
1981	Standing crops × weed density	2	0.684	0.300	5.21	0.02
			−0.535	0.285	3.52	0.06
	Trees × weed density	2	−0.535	0.295	3.29	0.07
			0.768	0.304	6.37	0.01

Two interactions involving weed density were important in 1981. Each interaction has 2 df, so two coefficient estimates are needed for complete description. Thus, although the overall interaction term of standing crops × weed density is not significant, it is included in Table 4 because it has a significant probability level ($P = 0.02$) associated with one of the degrees of freedom. This comparison indicates that at low weed density the absence of adjacent standing crops was related to much reduced damage, whereas at high weed density there was less difference in damage distribution between fields with and without adjacent crops. For the interaction of trees × weed density, the nonsignificant ($P = 0.07$) degree of freedom indicates no difference in the effect of trees for fields having low and high weed densities. The significant ($P = 0.01$) degree of freedom indicates a difference in the effect of trees for fields having medium and high densities of weeds. More specifically, tree presence was associated with increased damage in fields containing medium weed density, but trees were not related to damage in fields with high weed density.

Damage Distribution Within Fields

Of the 199 fields sampled in 1981, 181 fields had some damage ($Y > 0\%$). More than half of the estimated correlation coefficients calculated for these fields were not significantly different from zero. Eighty coefficients were significantly positive, but averaged only 0.26, and the remaining two coefficients were significantly negative. Thus, these data provide little support for the hypothesis that larger heads within a field tend to experience greater loss. In the analysis of head height and head damage, 181 correlation coefficients were again obtained; 18 were significantly positive, 159 nonsignificant, and 4 significantly negative. This result provides little evidence of a relation, since one would expect nine fields (5% of 181) to be significant at the $P = 0.05$ level by chance alone under the null hypothesis of no relation. In the analysis of variance for the effect of weed density on percent plot damage, only the groups of fields with low overall damage showed a significant difference among weed categories ($F = 3.71$; $P = 0.025$). However, the difference between plots with low weed density (mean damage = 0.7%) and high weed density (mean damage = 0.1%) in these fields was not large, and thus significance was mostly due to the large ($N = 5{,}075$) number of observations in the analysis. Thus, we found no general tendency for damage distribution within a field to be related to corresponding weed densities.

Discussion

The most salient result of the analysis of field-to-field variation in bird damage was the influence of marshy areas—the most important predictor variable in the 1979 and 1980 models. The odds of receiving greater than average damage were 2.1 and 3.9 times greater in those fields with an adjacent marsh in 1979 and 1980, respectively. red-winged blackbirds and yellow-headed blackbirds—by far the most important depredating species—preferentially use marshes for nesting, roosting, and daytime loafing. Marshes are especially important as roosting habitat in late summer, when nesting territories are abandoned and birds begin to congregate in large numbers before their eventual southward migration, and when sunflower seeds are most attractive to feeding blackbirds (Cummings 1982). Dolbeer (1980) reported that blackbirds in Ohio will travel as far as 32 km from major roosts to feed on corn, but that cornfields closest to the marsh suffer the greatest damage. This probably reflects foraging strategy that results in the greatest energy intake per unit of energy expenditure, which is especially important in late summer because the birds are molting and storing body fat in preparation for migration (Weins and Dyer 1975). Although the marshes we recorded were potholes generally less than 1 ha, the same phenomenon observed by Dolbeer for major roosts seems to apply here. Even a small pothole with tall emergent vegetation may attract hundreds of loafing birds. The glacial action that created these numerous potholes, scattered through much of the northeastern Great Plains, practically assures that croplands will come in contact with large numbers of roosting blackbirds.

The presence of marshes near fields was not an important influence on damage in 1981, but this seemingly inconsistent result must be interpreted in light of the 1981 survey design. In that year, the survey was conducted in only four counties, each of which had suffered high damage in the previous 2 years. Each of these counties includes areas of extensive marshland; for example, one of the counties (Bottineau) surveyed in North Dakota contains the J. Clark Salyer National Wildlife Refuge, which has 12,000 ha of marshland. The late-summer roosting population of blackbirds at this refuge reached an estimated 450,000 birds in 1981 (C. E. Knittle, personal communication). Extensive marshland also existed in the other three counties surveyed that year. Thus, the huge blackbird concentrations in these counties resulted in a damage distribution that was unaffected by the proximity of individual fields to marshes. Seemingly there was such an abundance of roosting habitat in the large marshes that additional potholes around fields had less attraction.

In 1979, sunflower fields with wider row spacing were associated with higher damage. Fields with wider spacing tend to have slightly larger heads. The mean head size for fields in the smaller row spacing class (263.1 cm^2) was less ($P = 0.05$) than the mean for fields in the larger class (273.3 cm^2), although average head size was not chosen as a predictor variable in the among-field analysis. Moreover, the correlations between head size and damage reported earlier for 1981 fields suggested a relatively weak and inconsistent relation. Parfitt (1984) also reported inconsistent results with respect to head size and damage in his experiment with sunflower and feeding blackbirds and sparrows. Thus, we cannot explain the significance of row spacing to increased damage in 1979.

The interaction of marsh and adjacent plowed fields was also important in 1979. These two variables, considered individually, had opposing influences on field damage: marsh was associated with increased damage, and plowed fields were associated with lower damage levels (the main effect of plowed fields, although not significant, had a negative coefficient in the final FUNCAT model of -0.172, $P = 0.07$). When a marsh was present, its effect apparently cancelled out the relatively weak effect of plowed fields. However, when only fields without a nearby marsh were considered, the presence of plowed fields was associated with significantly reduced damage. Fall plowing indicates areas of intensive agricultural development, where blackbird habitat is limited. When the absence of marshes is combined with the presence of plowed fields, the lack of suitable habitat reduces blackbird numbers in the area enough to cause significantly reduced damage.

The decreased level of damage to fields with adjacent pastureland in 1980 could indicate that pastures provide benefits to birds (e.g., food or cover), which tend to draw them out of sunflower fields. However, closer inspection of the geographic distribution of pastures reveals that this result may be at least partly due to an artifact of the data. Although the sample sizes were different, we found that almost all survey fields (8 out of 9) in dry western North Dakota (southwest of the Missouri River) had adjacent pastures, whereas less than a third of the fields (22 out of 81) had adjacent pasture in the relatively wet eastern edge of the State. Such dry areas, like heavily farmed areas, offer little suitable blackbird habitat.

In 1981, the presence of adjacent trees was associated with an increase in damage in fields with medium weed density, yet trees seemingly had no influence on damage in fields with either low or high weed densities. It is logical to expect that trees would have a positive influence on damage in general, given their attractiveness to birds as loafing sites, and therefore we cannot explain why this phenomenon appeared only in 1981 in fields with medium weed density.

Although the odds of sustaining greater damage in a field with adjacent crops was the same regardless of weed density, in fields without adjacent crops these odds were much less for fields of low weed density compared with fields of medium or high weed density. Apparently, the absence of adjacent crops and weeds in the sample field combined to make the field relatively unattractive to birds.

For 1981, the analysis of within-field variation in damage showed that, once birds had selected a field in which to feed, damage was not greatly influenced by variation in plant and weed characteristics in the field. However, there occasionally was some tendency for larger heads to receive greater damage. This may be due to an unknown nutritional advantage of larger heads. In addition, blackbirds usually damage heads by perching on the top rim of the head (heads are usually oriented so that the plane of the disc is perpendicular to the ground) and reaching down to feed on the outermost rows of seeds. Such a feat is probably easier when the head is larger, providing a more stable perch. Finally, it may also be more economical (in an energetic sense) for a bird to feed longer on a larger head than to fly between several smaller ones to consume the same amount of seed.

We were generally satisfied with the usefulness of the statistical approach for identifying and quantifying the associations of habitat factors with the level of bird damage among fields. This approach did not require us to make unreasonable assumptions concerning the statistical properties of our data. The method also provided a logical and objective way to identify a small subset of independent variables that potentially were related to the response. The problem of variable selection when a large number of independent variables are measured is usually a troublesome one and we were satisfied with the performance of the selection method used. Finally, it was helpful to have the output from the FUNCAT procedure in a format that is familiar to anyone with experience in using traditional ANOVA techniques.

There are, however, some disadvantages in the procedure. First, the data requirements are substantial; for example, with about 1,000 observations, at most three independent factors could be simultaneously investigated, and each of these, as well as the response, could have at most three levels. Second, there is the need to categorize any continuous variables, which introduces a certain amount of arbitrariness and loss of information into the procedure. This shortcoming can largely be overcome by defining categories in biologically and economically meaningful ways, as well as by using different categorizations to ensure that the results are not sensitive to such definitions. We recommend this statistical procedure to researchers attempting to analyze data from large surveys in which the response of interest may be measured relatively poorly for each sampling unit and a large number of ecological variables have been measured in an attempt to identify potential relations. Although such analyses cannot confirm causal relations, they can serve to suggest hypotheses of interest that may be appropriate for subsequent experimentation.

Future research on the influence of environmental variables on blackbird damage to sunflower should concentrate on more precisely quantifying the effects of a few of the variables identified in our analysis. Such information should be obtainable by designing the study with only these variables in mind, so that an increased and balanced amount of information is collected on each variable and combination of variables. Although it may not be possible to conduct a truly controlled experiment (i.e., environmental variables cannot be randomly assigned to sunflower fields), it may be desirable to use standard linear models for analyzing the data. In any such study we would recommend that size of and distance to the nearest marsh or roost be measured and included in the analysis, perhaps as a covariate, so that the effects of other environmental factors could be adjusted for this important variable. Finally, we recommend that sampling intensity for estimated field loss be at least as high as that used in 1981, and that absolute yield—not percentage—loss be considered as the response of interest because of its independence from variation among fields in the total amount of seed available.

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Appendix

Two-way cross-classifications of damage versus measured field characteristics and adjacent habitats. Refer to Table 1 for category definitions of independent variables and to the text for definitions of low (=1) and high (=2) percent loss.

1979

Damage	Field size 1	2	3
1	313	232	196
2	79	68	44

Damage	Distance between rows 1	2
1	288	353
2	51	114

Damage	Sunflower type 1	2
1	704	31
2	183	7

Damage	Standing crops 1	2
1	259	440
2	62	112

Damage	Plowed fields 1	2
1	281	418
2	87	87

Damage	Stubble fields 1	2
1	434	265
2	120	54

Damage	Pasture 1	2
1	490	209
2	116	58

Damage	Trees 1	2
1	591	108
2	146	28

Damage	Urban 1	2
1	676	23
2	164	10

Damage	Marsh 1	2
1	423	270
2	65	110

Damage	Average head size 1	2	3
1	216	263	262
2	61	70	60

Damage	Average plant height 1	2	3
1	129	207	387
2	14	53	118

Damage	Average weed density 1	2	3
1	352	137	234
2	73	33	81

1980

Damage	Field size 1	2	3
1	197	138	96
2	58	27	29

Damage	Distance between rows 1	2
1	256	175
2	76	38

Damage	Sunflower type 1	2
1	396	34
2	100	14

Damage	Standing crops 1	2
1	214	215
2	65	48

Damage	Plowed fields 1	2
1	60	369
2	15	96

Damage	Stubble fields 1	2
1	154	275
2	28	84

Damage	Pasture 1	2
1	263	165
2	73	39

Damage	Trees 1	2
1	185	243
2	37	77

Damage	Urban 1	2
1	413	14
2	108	4

Damage	Marsh 1	2
1	301	107
2	49	60

Damage	Average head size 1	2	3
1	177	160	94
2	35	47	32

Damage	Average plant height 1	2	3
1	252	120	59
2	56	42	16

Damage	Average weed density 1	2	3
1	169	100	162
2	42	20	52

1981

Damage	Field size 1	2	3
1	41	33	47
2	27	27	24

Damage	Distance between rows 1	2
1	101	20
2	64	14

Damage	Standing crops 1	2
1	42	79
2	32	46

Damage	Plowed fields 1	2
1	21	100
2	17	61

Damage	Stubble fields	
	1	2
1	37	84
2	22	56

Damage	Average head size		
	1	2	3
1	32	59	30
2	25	32	21

Damage	Pasture	
	1	2
1	66	55
2	43	35

Damage	Average plant height		
	1	2	3
1	36	39	46
2	19	28	31

Damage	Trees	
	1	2
1	44	77
2	20	58

Damage	Average weed density		
	1	2	3
1	42	37	42
2	15	27	36

Damage	Distance to marsh	
	1	2
1	58	63
2	43	35